Rieppi, Storfjorden, Troms

Wind analysis and production estimate for Rieppi wind farm

Report number: KVT/DEW/2012/R061

Report number	Date
KVT/DEW/2012/R061	15.06.2012
Report Title	Availability
Rieppi, Storfjorden, Troms	Limited to client
	Revision number
Wind analysis and production estimate for Rieppi wind farm	1
Client	Number of pages
Troms Kraft Produksjon AS	24 + Appendices
Client Reference	Status
Steinar Helland	Final

Summary

The wind conditions for the Rieppi wind farm are derived from onsite measurements. The average measured wind speed at 49.1m a.g.l. is 7.1±0.2m/s.
The derived mean wind shear $\alpha_{30\text{-}49m}$ is 0.10. This leads to the estimated long term wind speed at 80m a.g.l. at the mast location of 7.4±0.4m/s. These wind conditions are horizontally extrapolated to the designated wind park area using WAsP.

The results are utilized to design three wind park layouts based upon different types of turbines, and estimate their energy production:

Turbine Type	IEC Class	Number [turbines]	Installed Capacity [MW]	Net AEP [GWh/year]	Eq. Full Load Hours [hours/year]
Vestas V112 3.0MW	II	26	78.0	220	2821
Siemens SWT 113 2.3MW	II	26	59.8	200	3346
Nordex N117 LS 2.4MW	III	23	55.2	179	3236

Revision history

Rev. number	Date	Number of copies	Comment	Distribution
1	15.06.2012		Report	

	Name	Date	Signature
Prepared by	David Weir	15.06.2012	David Weir
Reviewed by	Finn Nyhammer	15.06.2012	Finn K. Nyhammer
Approved by	Lars Tallhaug	15.06.2012	Lars Tallhaug

Content

1 Introduction

This report provides an analysis of the wind conditions in Skibotndalen and gives a production estimate for the Rieppi wind farm along Lake Rihpojarvi as planned by Troms Kraft. The findings in this report are based on a measurement campaign which has been continuously ongoing for more than seven years. This comprises wind measurements from two masts located in Skibotndalen as indicated in Figure 1.1.

The design of the measurement campaign, together with the collected parameters is described in chapter 2. Chapter 3 explains the methodology of the data treatment and analysis, the results of which are depicted in chapter 4. An energy yield estimate based on these findings is given in chapter 5 for three different park layouts. The uncertainties connected to the results are estimated in chapter 6.

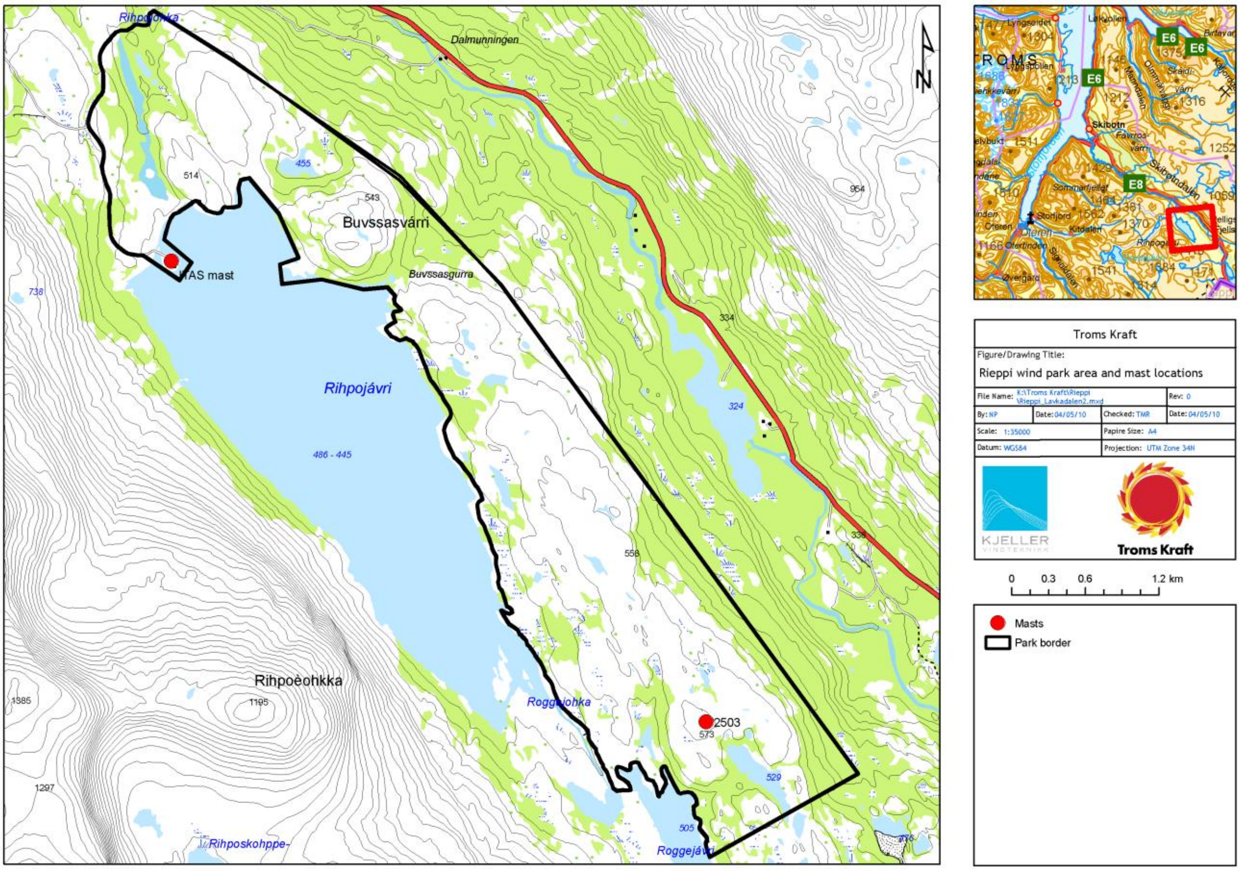


Figure 1.1: Map of the Rieppi wind park area

2 Description of measurement data

2.1 ITAS site

On 09.10.2003 the measurements with a 10 meter high mast were started at the ITAS site. The mast is equipped with an ultra-sonic anemometer, tracing 10-minute averages of the wind speed, direction, gustiness and temperature. An additional cup anemometer and a wind vane were installed to give backup information for these measurements at a later stage.

Due to the limited height of the mast, these measurements are unsuited for a determination of the wind conditions at the hub height of a possible wind turbine. They are, however, well suited for a validation of the measurements from the other site and the results derived from them.

2.2 Site 2503 Rieppi

On 27.09.2004 the measurements with a 50 meter high mast at the position 69.18665253 N, 21.31955831 Ø began. Its construction is shown in Figure 2.1. The station is called 2503 Rieppi and records data to this day. An overview of the equipment mounted on the mast is given in Table 2.1.

Table 2.1: Sensors of 2503 Rieppi

Sensor	Parameter	Height [m.a.g.l.]	Boom dir [°mag]	Comments
NRG#40	Wind speed	49.1	217	
NRG#40	Wind speed	30.0	222	
NRG#40	Wind speed	10.4	222	
Risø P2546A	Wind speed	49.1	37	Main anemometer
NRG HAE icefree3	Wind speed	42.4	219	
NRG HVE icefree3	Wind dir	42.1	39	
NRG#200	Wind dir	9.7	40	Main wind vane
NRG110S	Air temp	2.0		

The complete instrumentation overview of the site is given in Appendix A. The schematic drawing of the mast can be found in Appendix B.

Structures in the vicinity of the anemometers will influence the wind speed measurements. The largest disturbances in the measured wind speed occur when the anemometer is located downstream from the mast center, i.e. when the wind stream is perturbed by the reference anemometer, body of the lattice mast, and/or lightening rod. When this occurs the anemometer is said to be in the mast shadow. The dominant wind direction at 2503 Rieppi is expected to be parallel to the valley floor. The mast is constructed accordingly, i.e. the top boom (see Figure 2.1) is oriented perpendicular to the prevailing wind direction.

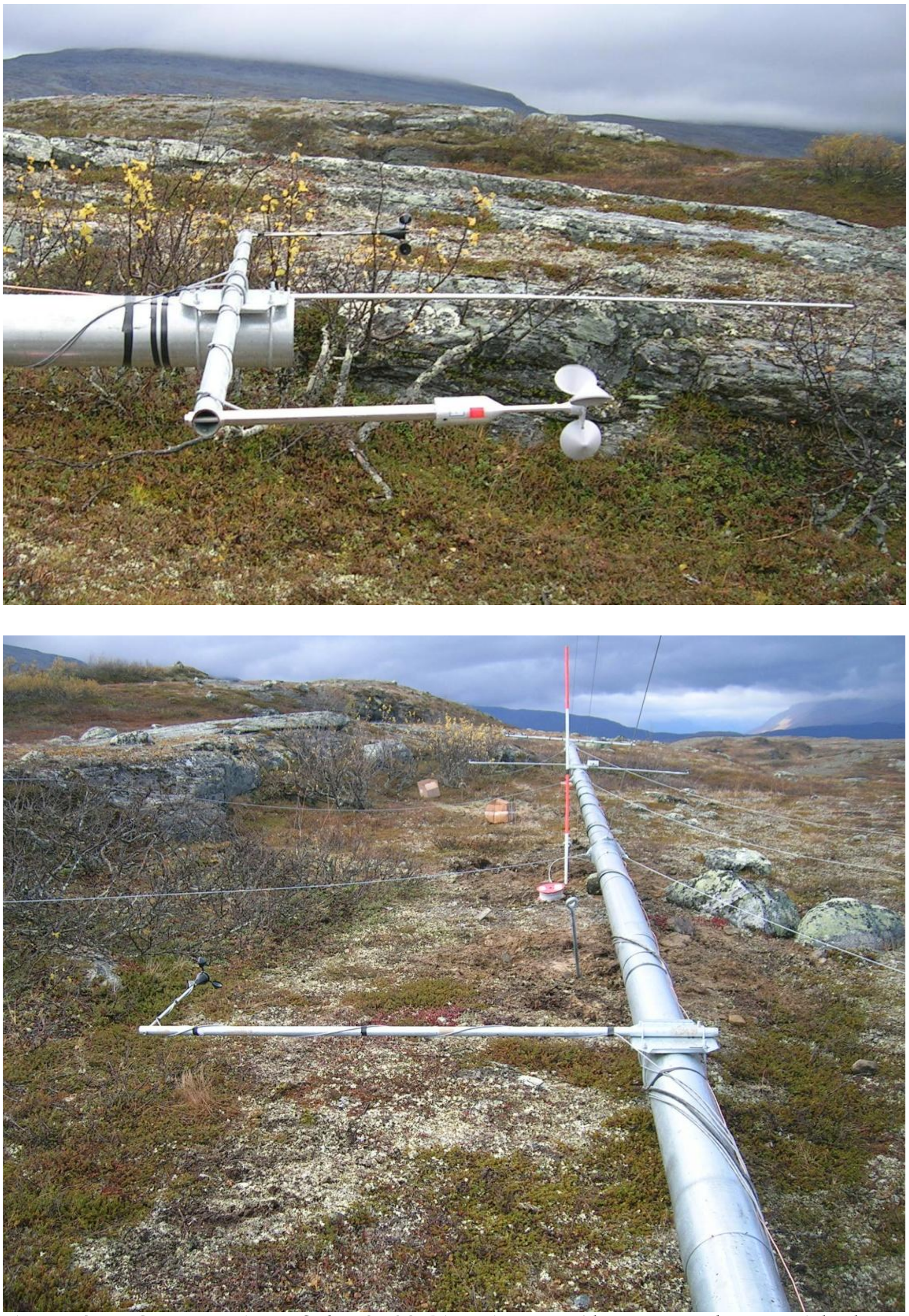


Figure 2.1: Construction of the 2503 Rieppi mast. Above: Top boom with the two anemometers Risø P2546A (front) and NRG#40 (background.). Below: Middle part of the mast with a NRG#40 anemometer

The Risø P2546A cup anemometer on top of the mast is the main wind speed sensor of 2503 Rieppi. It measures the horizontal component of the wind at a distance of 1.4 meters from the center of the mast. Its boom is facing towards north-east (tilted by 37° to magnetic north) so that it can capture the dominating wind along the valley without being in the mast shadow. A schematic drawing of the top boom is shown in Appendix B. The other anemometers are used for the purpose of quality control and backup, as well as the calculations of the vertical wind profile. A set of heated sensors is specially used for the treatment of ice affected measurements of the main sensors. The main wind vane NRG#200 is mounted at 9.7 on a boom which is also facing towards north-east. Its distance to the mast is 1.0 meters. The air temperature measured by the NRG110S at 2.0m a.g.l. is used as one input parameter for the analysis of icing events on the anemometers.

All parameters are sampled at 0.5 Hz with a NRG Symphonie logger. The values which are logged consist of 10-minute averaged wind speed, wind direction and temperature. The standard deviation, the maximum and the minimum of the speed and direction in each 10-min interval is also recorded.

2.3 An attempt for reference data

Data from the meso-scale WRF model (Weather, Research and Forecast model) is available to long-term correct wind measurements. The WRF model data has a temporal resolution of 1 hour and a spatial horizontal resolution of 5x5 km. The closest WRF reference point can therefore not be more than $\sqrt{2} * 2.5km = 3.5km$ away from 2503 Rieppi. Its data is available from year 2000 onwards. The closest WRF model point to the measurement site 2503 Rieppi is located at N69.19° E20.61°, and its wind data from a height of 58m a.g.l. is displayed in section 2.4 (blue line).

2.4 Data overview

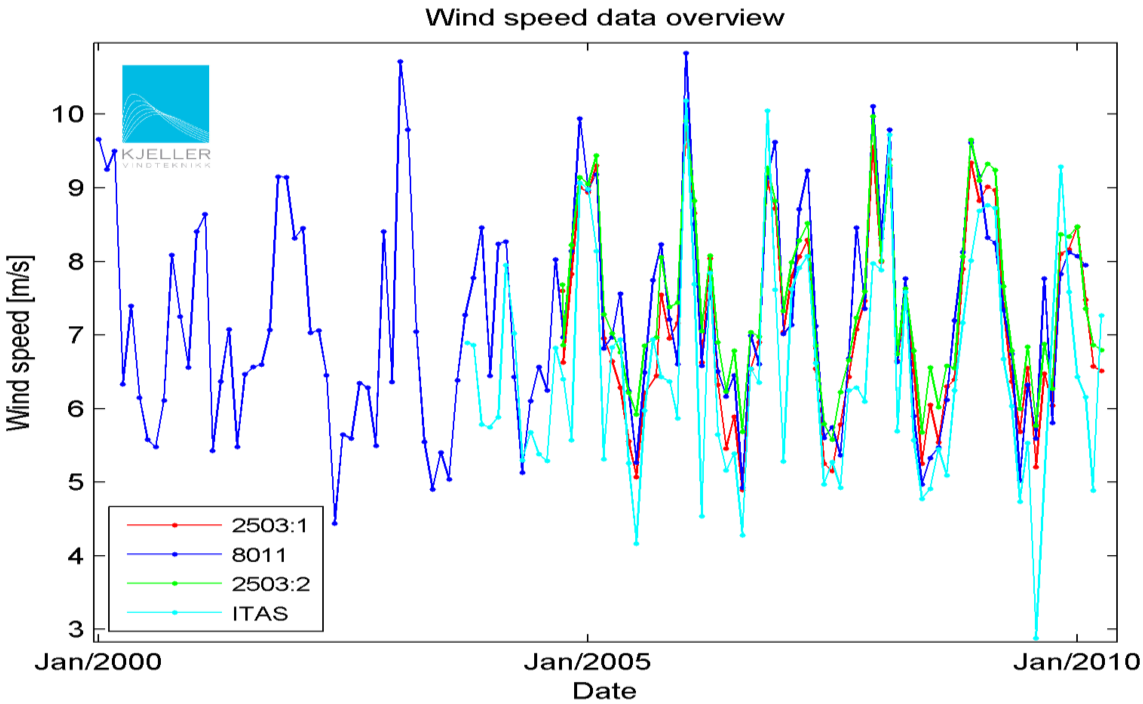


Figure 2.2: Monthly average of the available wind speed data. Red line: Risø P2546A on 2503 at 49.1meters height. Blue line: WRF reference point 8011 at 58meters height. Green line: NRG HAE ice-free3 at 42.1meters height. Cyan line: Ultra-sonic sensor on ITAS mast

3 Methodology

3.1 WRF model

The general trends of the measured data (2503) are in good agreement with the modeled reference data from WRF (8011), cf. Figure 2.2. The overall hourly correlation of the modeled wind speed to the main anemometer at 2503 Rieppi, however, is only 0.62. This exceptionally poor correlation is likely to be caused by the singular location of the measurement site inside the valley. As other WRF model points in the vicinity of 2503 Rieppi did not yield a better correlation, the WRF model could not be used to lower the data uncertainties by a long-term correction of the measurements.

A check of the correlation of the measurements with a new 4 km x 4 km run of WRF in June 2012 showed a similarly poor correlation with the measurements of 0.67 and a long-term correction with this data was similarly deemed to give more uncertainty in the long-term wind speed than using the measurements alone, given the exceptionally long period of measurement.

3.2 Treatment of ice affected measurements

Cup anemometers and direction sensors can accumulate ice under certain conditions, such as ambient temperatures near or below the freezing point combined with high air humidity, super-cooled cloud or fog droplets, as well as freezing rain, or sleet. The ice can slow down the anemometer or halt it completely, making the measurements unsuited for predicting the average wind speed. An ice filter routine has been implemented in the analysis in order to filter out measurements influenced by icing.

One way of identifying icing periods is to compare measurements from the main anemometer with ones taken by the heated backup anemometer. If the main anemometer measures wind speeds which are unusually low compared to the heated anemometer, the measurement is likely to be ice affected. Hence, the routine removes measurements, when the ratio of the 10-minute averaged value from the heated anemometer to the main anemometer is larger than two times its standard deviation.

In addition, an ice period is identified when 5 or more consecutive measurements from a wind vane are identical and the temperature is below 3 degree Celsius. Such a period, and the 3 hours of data preceding and following it, is removed because anemometer slow down can occur when the wind vane is frozen in.

For critical ice periods on the main sensors, measurements from the heated backup anemometer and wind vane can be facilitated. Due to differences in construction, they do not necessarily give identical values, even for perfectly normal measurement periods. Their measurements do, however, follow a certain relationship. Therefore, a linear mapping function between data from the heated NRG HVE icefree3 anemometer and the Risø P2546A was determined for times other than the ice influenced suspicious periods. This yields a simple but faithful means to map data from one anemometer to the other, when necessary.

In case the main wind vane halts, its values are corrupt. Moreover, data from the unheated Risø P2546A anemometer becomes suspicious. If however, the heated sensors show normal reading, their measurements are linearly mapped to the main sensors. If the readings from the heated wind vane appear suspicious as well, the period is defined as icing, and its measurements filtered from the data set.

Note that the filtering out of ice affected measurements can induce artifacts to the wind statistics, first and foremost the frequency distribution of wind speeds. This is due to the fact that the two anemometers have different characteristics (e.g. offset value, inertia) which are mixed together by the ice filter routine. Care must be taken in order not to carry possible artifacts on in the calculations. The frequency distribution, wind rose, wind shear and turbulence statistics are therefore produced from a data set in which measurements were only filtered out, but not restored. The mean wind speeds, however, is derived from a maximally restored data set.

From 01.11.2008 to 24.09.2009 the unheated wind vane of 2503 Rieppi was malfunctioning. This period is filled carefully using mapped data from the heated anemometer and the heated wind vane. This is done both in the dataset used for deriving the mean wind speed and in the data set used to determine the wind statistics.

The amount of icing encountered at site 2503 Rieppi is presented in section 4.1.

3.3 Wind shear estimate

The mean wind speed at a site varies with height. The vertical velocity profile is often expressed by the wind shear coefficient, α, described by the expression

$$V(z) = V_r \left(\frac{z}{z_r} \right)^{\alpha},$$

where z is the height above ground level, z_r is a reference height, V is the horizontal velocity and V_r is the velocity at the reference height. By rearranging the expression above we can express α through the wind speed measured at different heights at the mast. One can therefore use the wind profile measured by the anemometers mounted alongside the mast to estimate α. The value obtained for α is then used to extrapolate the average wind speed to heights other than the measuring height.

3.4 The horizontal extrapolation of measurements utilizing WAsP

The wind resource map has been calculated using the micro-scale model WAsP (Bowen and Mortensen (1996), WAsP manual (1993)). This model is a linear perturbation solver, hence it cannot fully describe non-linear phenomena such as flow separation and turbulence generation by complex terrain. The empirical ΔRIX-correction can be performed to examine and correct for the expected non-linear influence of the flow field. This method uses the RIX factor as a measure of the complexity of a location. RIX is short for Ruggedness Index, and is a measure of how large part of the surrounding area that has a steepness above a given threshold. In Berge et al. (2006) it was found that the best practice is to define the RIX number as the fraction of the terrain within an area of 2km with a slope exceeding 30% or 16.7°. The velocity correction at a location is made based on the difference, ΔRIX, from the RIX-value of the measurement location according to the formula:

$$U_{WAsP\Delta RIXcorr} = U_{WAsP} \cdot (1 - k \cdot \Delta RIX)$$

Based on earlier experiences using this equation, k=1 is found to fit measurements best in complex Norwegian terrain. Generally the uncertainty of the horizontal extrapolation is smallest if the ΔRIX level is small, and increasing with increasing ΔRIX level. The uncertainty is also increasing with increasing RIX level. If all RIX values are zero, the model is operating within the area where the linearization is valid. For high RIX values the model is operated outside its physical limits.

A ΔRIX correction was carried out in the calculation of the wind conditions at Rieppi 2503.

3.5 Roughness classification

The roughness classification is done manually based on background maps and photos from aircrafts. The classification used is:

Table 3.1: Overview of the roughness classification used in the area

Description	Roughness length [m]
Water	0.0002
Forest	0.6
Bare rock face	0.03

The roughness classification follows standard roughness values (Arya, 1988). One challenge at this site is that the the site is covered with snow for most of the year, meaning that the roughness field will be more homogeneous during these periods. This particularly applies to Rihpojávri which freezes over in the wintertime and takes on a similar roughness to the snow-covered surroundings. The designation of the lake as a water roughness for the creation of the wind atlas thus indtroduces more uncertainty in horizontal extrapolation than would otherwise be estimated for a site of only moderate complexity. Uncertainty is discussed in Chapter 6.

3.6 Wake modeling and production estimates utilizing WindPRO

The wake modeling and production estimates are carried out utilizing WindPRO 2.7. The methods used in the model are described in the WindPRO User Guide. The wake influence is calculated by the N. O. Jensen (Risø/EMD) wake model. Production estimates in WindPRO are carried out based on the velocity distribution as defined by the Weibull distribution.

4 Wind conditions

4.1 Wind conditions during period of measurements

The following analysis is based on data from the main anemometer (Risø P2546A at 49.1 m a.g.l.) and main wind vane (NRG#200 at 9.7 m a.g.l). Applying the ice filter as described in section 3.2, 89% of the monthly data could be made available for the analysis.

Table 4.1 shows the horizontal wind speed as measured by the main anemometer at 2503 Rieppi, averaged to months, years and the total measurement campaign. The absolute mean wind speed at 49.1 m a.g.l. in the period 01.01.2005 to 31.12.2011 is found to be 7.1m/s.

Table 4.1: Monthly, yearly and total average wind speed at 2503 Rieppi

	2004	2005	2006	2007	2008	2009	2010	2011	2012	Total
Month	U [m/s]	U [m/s]	U [m/s]	U [m/s]	U [m/s]	U [m/s]	U [m/s]	U [m/s]	U [m/s]	U [m/s]
Jan		9.0	9.8	7.0	8.0	8.8	8.6	7.5	8.7	8.4
Feb		9.3	8.7	7.8	9.4	9.0	7.4	9.3	8.3	8.7
Mar		7.0	6.6	8.1	6.7	9.0	8.3	8.1	8.1	7.7
Apr		6.7	8.1	8.3	7.5	7.4	6.3	7.2	5.0	7.3
May		6.3	6.3	6.5	6.5	6.4	6.2	5.8	7.0	6.3
Jun		5.6	5.5	5.3	5.2	5.7	6.7	5.4		5.6
Jul		5.1	5.9	5.2	6.0	6.6	5.7	5.7		5.7
Aug		6.2	4.9	5.8	5.5	5.2	5.7	6.0		5.6
Sep	7.7	6.4	6.5	6.4	6.3	6.5	5.8	7.3		6.6
Oct	6.6	7.6	6.9	7.1	6.4	6.0	7.3	7.3		6.9
Nov	7.8	7.0	9.1	7.5	7.9	8.1	6.6	6.9		7.6
Dec	9.0	7.2	8.7	9.6	9.3	8.2	7.9	7.8		8.5
Total	-	**7.0**	**7.3**	**7.0**	**7.2**	**7.4**	**6.9**	**7.0**	-	**7.1**

In the analysis for frequency distributions the an excerpt of exactly seven years of wind data, recorded in the period 01.01.2005 to 31.12.2011, was used to avoid seasonal biases. The data prior to and after this period has been left out in order to avoid any particular season from being statistically overrepresented. This applies specifically to the wind rose, the wind speed Weibull distribution, turbulence statistics and the wind shear.

The wind rose is shown in Figure 4.1. The wind rose shows that winds from sector 6 (150 degrees) prevail at 2503 Rieppi, dominating 35% of the time.

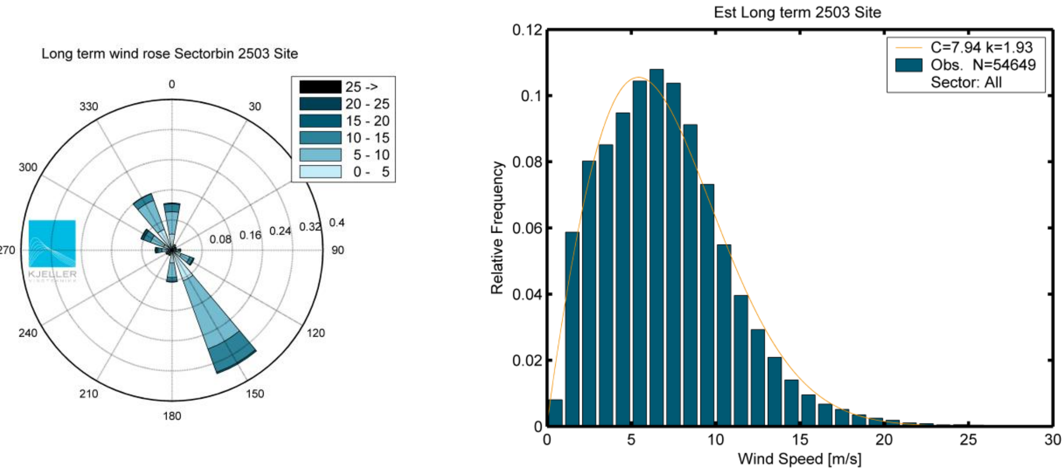


Figure 4.1: Wind rose and frequency distribution (Weibull approximated) based on an excerpt of precisely 5 years of data from 01.01.2005 to 31.12.2011.

The turbulence intensity as a function of wind speed is shown in Figure 4.3. The mean turbulence intensity at 15 m/s wind speed, TI_{15}, during the seven year period is 8.6%. At 15m/s the measured 90 percentile of the turbulence is 13.5%, which is just at the threshold of IEC class C turbine limitations.

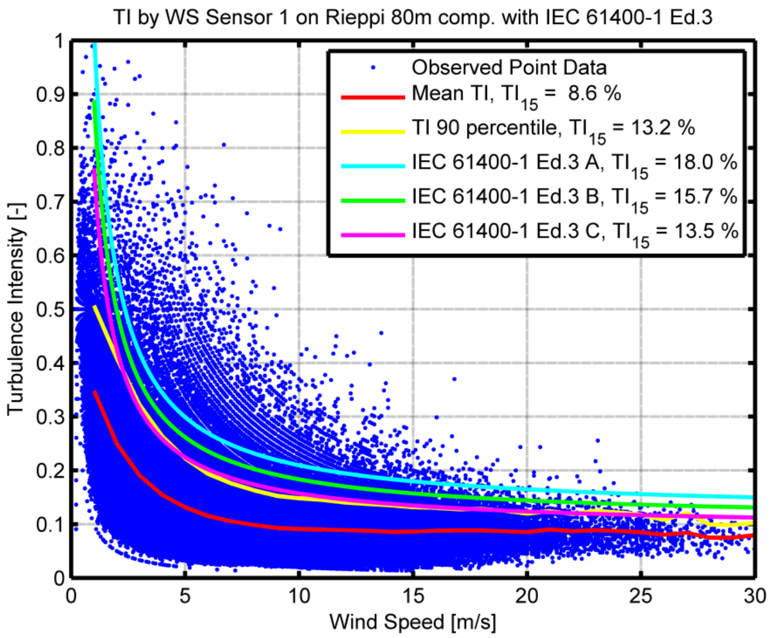


Figure 4.2: Turbulence intensity (TI) as function of wind speed based on seven years of data from 01.01.2005 to 31.12.2011.

The turbulence intensity varies with wind direction, as shown in Figure 4.3. One finds the minima in turbulence intensity at 150° and 330°, coinciding with the orientation of the valley floor. The maxima lie perpendicular to the dominant wind direction. They are likely caused by the surrounding topography.

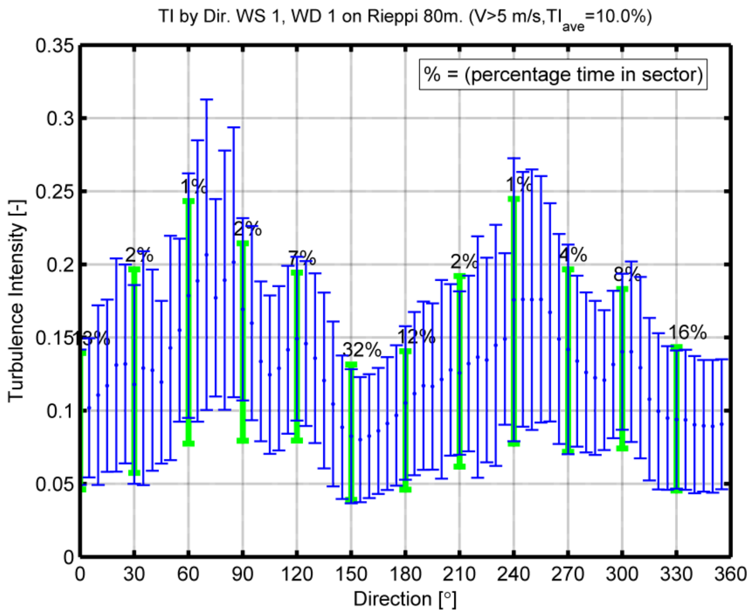


Figure 4.3: Turbulence intensity (TI) as function of direction based on five years of data from 01.01.2005 to 31.12.2011.

4.2 Wind shear

Concurrent wind speed measurements in two different heights can be used to estimate the wind shear coefficient α. The anemometers available at 2503 Rieppi vary in their properties (e.g. height, boom direction, ice protection). To calculate the wind shear coefficient α correctly it is important to choose two anemometers which are mounted at sufficiently different heights, have equal boom directions and a comparable response to wind fluctuations.

To comply with these demands, the pair of NRG#40 anemometers at 30.0m and 10.4m height on the mast were originally used in a 2010 report by Kjeller Vindteknikk (KVT/NPYY/2010/023). The wind shear was calculated according to the formula given in section 3.3. As is customary, wind speeds below 4.0m/s were filtered out in order to decrease the uncertainty. One wind shear coefficient is calculated for each of the twelve directional sectors, as an average of five whole years of data. The wind shear calculated between 10.4m and 49.1m, as well as between 30.0m and 49.1m, in order to ensure the quality of the used data. The results agreed with the used sensors in the main wind direction, but deviated considerably in 3 other sectors, as expected due to the mast influence.

In this updated analysis it was decided to base the wind shear from 50 – 80/84 m on the wind shear calculated from 30.0 – 49.1 m which gives a somewhat lower wind shear value of α=0.1 compare to the α=0.13 value which was used in the 2010 version of this report. This was after examination of the mast configuration with respect to the very dominant main wind directions, as well as evaluation of the terrain around the mast and experience with vertical behavior of wind shear in moderately complex terrain. This is discussed further in the uncertainty estimates in chapter 6.

The twelve wind shear coefficients are given in Table 4.2 for 30.0 – 49.1 m and visualized in Figure 4.4. The weighted mean wind shear at site 2503 Rieppi is found to be α=0.10 for 30.0 - 49.1 m, which meets one's expectation for the predominating type of terrain. The directional wind shear coefficients presented in Table 4.2 are used to extrapolate the wind speed to the various suggested hub heights. The calculated vales after extrapolation to 80 m a.g.l. are given in Table 4.3. Here, wind direction and shape factor are assumed to be independent of height, i.e. identical to the values in measuring height. The scale factor is extrapolated to 80m a.g.l., and the mean velocity is then calculated from the scale and shape factor. The same calculation was performed for 84m a.g.l. (the second relevant hub height).

Table 4.2: Wind shear coefficient by sector

Sector	1	2	3	4	5	6	7	8	9	10	11	12	Mean
Alpha	0.1	0.12	0.12	0.09	0.12	0.09	0.14	0.19	0.13	0.09	0.09	0.1	0.1

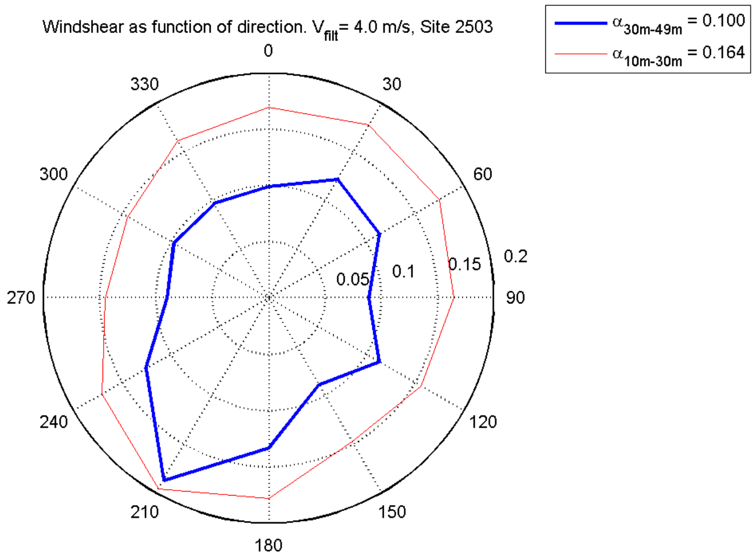


Figure 4.4: Wind shear by sector

Table 4.3: Wind conditions at 80m a.g.l.

Sector	Direction frequency [%]	Scale factor [m/s]	Shape factor [-]	Mean velocity [m/s]
1	12.5	8.1	2.01	7.18
2	1.6	4.9	1.39	4.48
3	1.3	4.7	1.36	4.35
4	2.3	7.7	1.28	7.13
5	6.3	7.8	1.6	7.02
6	34.9	8.7	2.5	7.72
7	8.5	7.5	1.95	6.64
8	1.5	5.6	1.58	5.06
9	1.8	8.8	1.42	8.04
10	4.4	11.2	1.78	9.95
11	8.8	9.7	1.92	8.57
12	16	7.5	2.21	6.65
Total	100	8.3	1.94	7.4

4.3 Wind resource map

Using both the vertical as well as the horizontal extrapolation of the measured data from 2503 Rieppi, the following wind resource map is calculated:

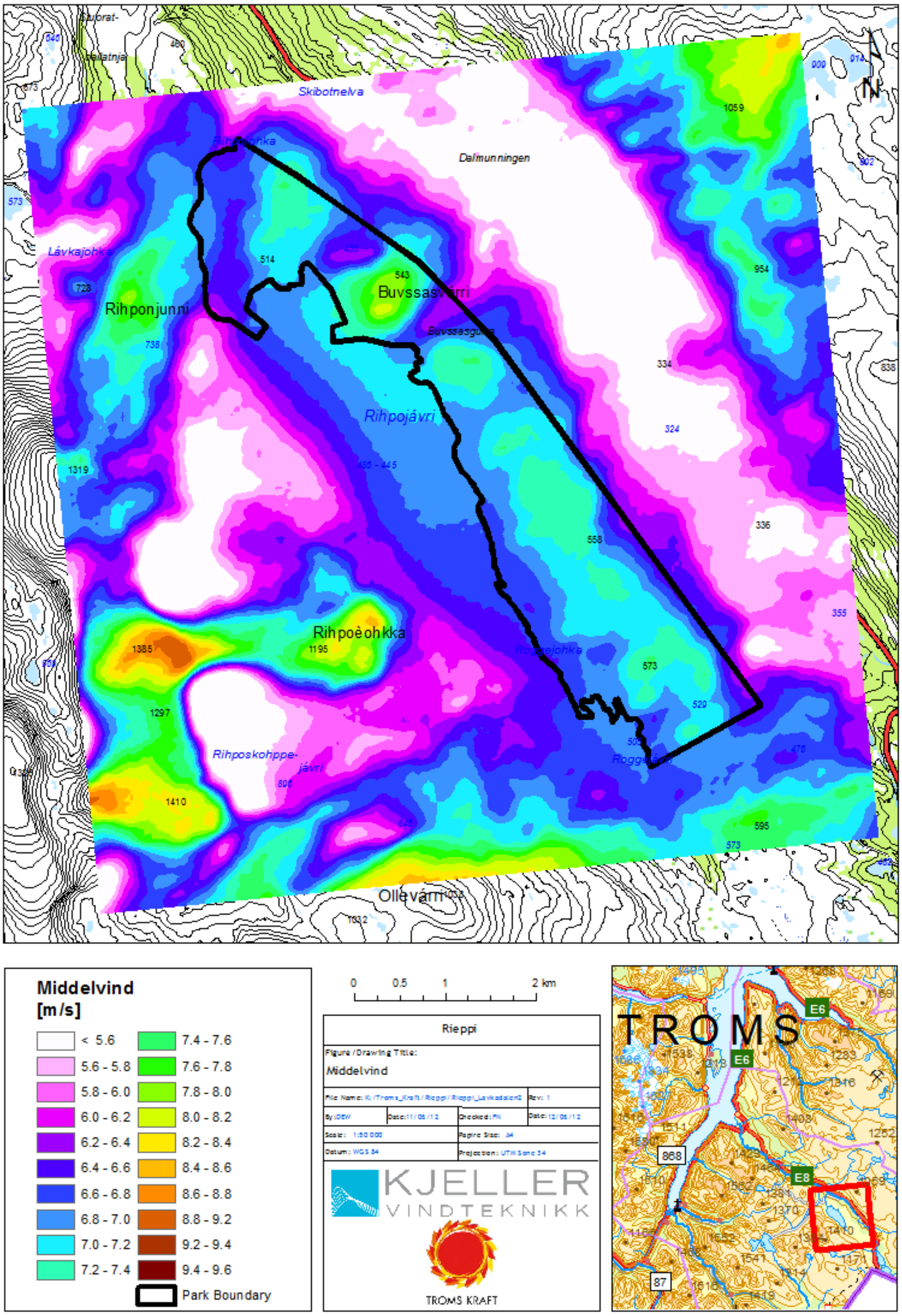


Figure 4.5: Wind resources at 80m a.g.l.

At the northern end of Lake Rihpojárvi the average wind speed is estimated to 6.8m/s at 80m a.g.l. This wind speed can be compared to measurements at the ITAS site. The data series recorded by this 10m high mast is more than 5 years long. It does have a poor coverage at times and contains certain irregularities. Nevertheless, one can perform a first order approximation of the mean wind speed at measuring height, which yields 6.6m/s. This would imply a very low wind shear at this location. Considering the fact that the main part of the wind comes from the direction of the lake, this is not unreasonable.

5 Energy yield estimate

This chapter presents three layouts for the Rieppi wind park, each based on one type of turbine. Due to the wind conditions at the site and wishes of Troms Kraft Produksjon AS, layouts using the Vestas V112 (3MW), the Siemens 101 (2.3MW) and the Nordex N90 LS (2.5MW) were developed. Note that this represents possible examples of turbine choices. Eventually, it is up to the turbine manufacturers to decide which turbines are best suited for the Rieppi wind farm.

The placement of these turbines is made subject to the following conditions:

- the mean wind speed at their respective hub heights
- the minimal distance between the turbines (7 rotor diameters along the main wind direction, 150º; 3 rotor diameters perpendicular to the main wind direction)
- the park border
- the height profile of the terrain
- a maximal possible efficiency and production estimate

Each layout is presented in form of a map of turbine locations, the energy yield and a loss analysis. Further details can be found in the WindPRO printouts in Appendix D.

5.1 Energy yield and losses

The WAsP/WindPRO model is used to calculate the variation of wind speed within the wind farm and to calculate the energy loss due to wake effects. When a turbine extracts power from the wind, a wake evolves downstream of the turbine. If another nearby turbine is operating within this wake, the power output for the downstream turbine will be reduced compared to the turbine operating in the free wind. The park efficiency is simulated for each of the layouts using WindPRO. Wake losses are calculated with the N.O.Jensen Risø/EMD wake model using the standard wake decay constant of 0.075.

Gross energy yield from model is the model output from WAsP/WindPRO. No losses are included. The other considered losses are:

Weibull adjustment: Production estimates in WindPRO are carried out based on the velocity distribution defined by the Weibull distribution from the analysis. The Weibull fitting can introduce errors to the analysis. Therefore the energy yield has also been calculated using a Matlab algorithm that uses table look-up on the power curve for the actual turbine directly from the time series of wind speed. The deviation between the Weibull output and the output from the real time series has been corrected for in the energy estimate.

Electrical efficiency can be calculated when the electrical system is defined. A complete calculation has not been within the scope in this report. The assumptions are based on typical values for wind farms.

Technical Availability has been assumed to be 95%. The conclusion of the study presented by Harman et al. (2008) showed that the average availability of European wind farms is 97%. The availability is given in time, and down time is likely to be overrepresented in winter time and periods of high wind. Experiences from production analyses in Kjeller Vindteknikk also show that not all down time incidents are being captured by either the availability warranty or other losses. We therefore chose to use 95% as an estimate of the production loss due to technical availability.

Icing and blade degradation can affect the energy production. Dirt, ice, insects, or salt on the blades will change the lift characteristics of the blades and therefore affect the energy output of the turbines. In this analysis the icing has been evaluated based on icing at the direction wane. This is a small instrument that is more easily influenced by icing than the turbines. At other sites where icing is analyzed more in detail, the estimated production loss due to icing has been at the order 1/2 of the icing on the instruments. With 5.4% icing on the unheated wind vane, the total loss due to icing and blade degradation is coarsely estimated to 2.2%. This is also in line with an active icing simulation from WRF. This icing map gives a value of 100 to 200 hours of active icing per year for the Rieppi area, which is 2.2% in the worst case.

High wind hysteresis losses is caused by the turbine cut in and cut out control system. The turbine will cut out when the wind speed exceeds the set values for maximum operating wind for the turbine and will not cut in again until the wind speed is lower than another set value. Normal cut out cut in settings on the mean wind are 25 m/s and 20 m/s respectively. The losses are calculated directly from the time series of wind speeds, yielding 1% production loss.

Low temperature losses occur when the ambient air temperature drops below the working range of the turbine. This lower limit of this range is typically -20ºC (-30ºC for special low temperature turbines). From the temperature measurements at Rieppi 2503 one finds that this threshold is undershot 1% of the time.

Substation maintenance is assumed to cause losses of 0.2%.

Modification of power curve can be necessary if the noise level at nearby houses exceeds national limits, or if other external factors affect the operation. This has not been considered here.

Wake effect from future projects can arise if a new wind farm is installed upstream of the actual wind farm. This has not been considered here.

5.2 26 turbines of type Vestas V112 (3MW)

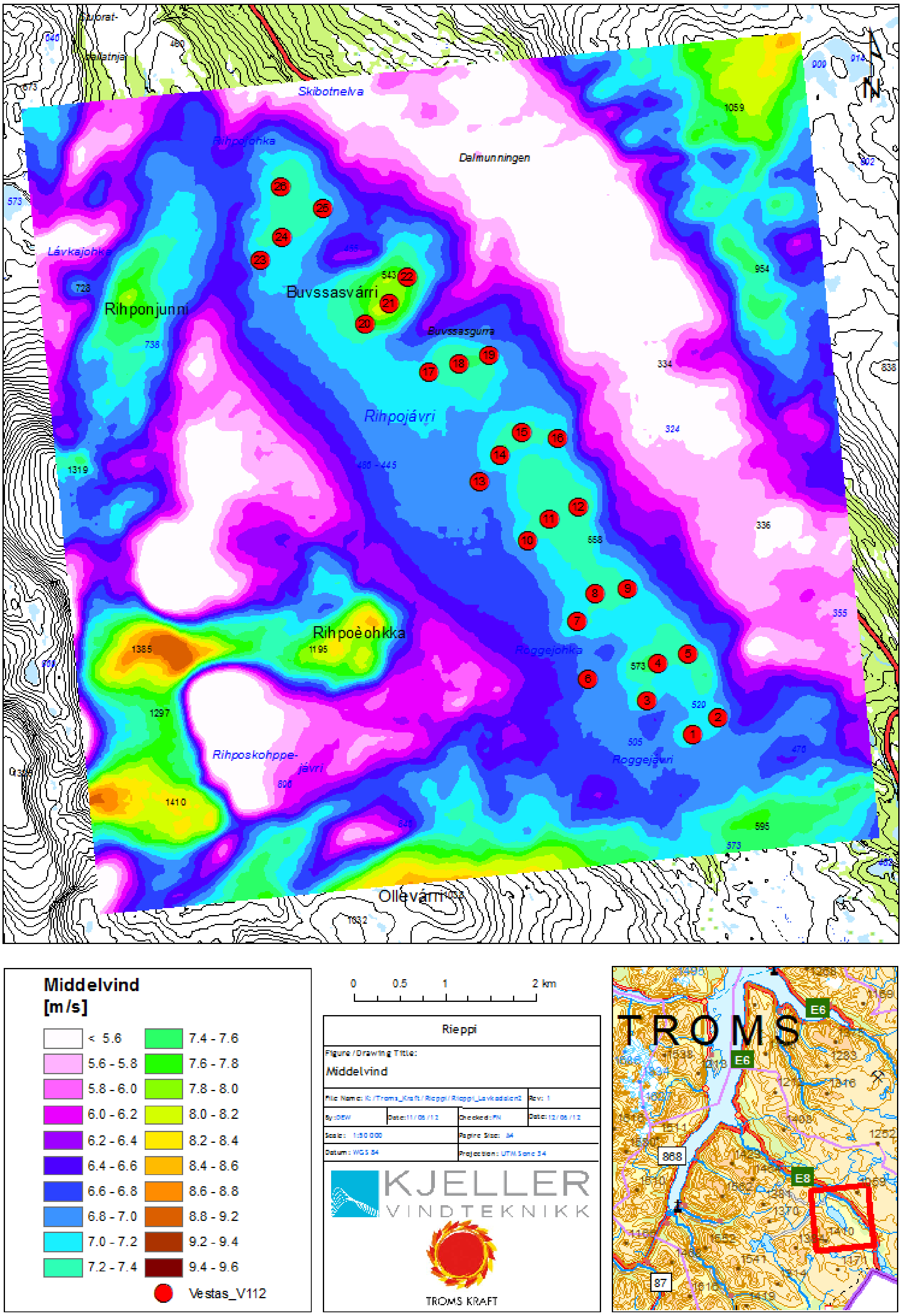


Figure 5.1: Wind resources at 84 m a.g.l. with the Layout for both Vestas V112 and Siemens SWT 2.3 113.

Table 5.1: Gross production, expected losses and net production for 6 Vestas V112 turbines.

Assumptions:		
Number of Turbines	26	
Rated power one turbine	3 MW	
Hub height	84 m	
Rated power Park	78.00 MW	
Gross annual energy yield	273.3 GWh/yr	
Losses:		
Wake effects	90.4 %	Calculated in WindPRO
Electrical efficiency	98.0 %	Assumption
Technical availability	95.0 %	Assumption
Non-accessibility losses	100.0 %	Not considered
Icing and blade degradation	97.8 %	Based on WRF icing map
Low temperature downtime	99.0 %	Calculated from measurements
High wind hysteresis	99.0 %	Calculated from measurements
Substation maintenance	99.8 %	Typical value
Modification on power curve	100.0 %	Not considered
Wake effects from future project	100.0 %	Not considered
Other losses	100.0 %	Not considered
Projected net energy yield P(50)	**220.1 GWh/yr**	**2821 hrs full load**

5.3 26 turbines of type Siemens SWT 2.3 113 (2.3MW)

Table 5.2: Gross production, expected losses and net production for 26 Siemens SWT 2.3 113 turbines.

Assumptions:		
Number of Turbines	26	
Rated power one turbine	2.3 MW	
Hub height	84 m	
Rated power Park	59.80 MW	
Gross annual energy yield	246.9 GWh/yr	
Losses:		
Wake effects	91.0 %	Calculated in WindPRO
Electrical efficiency	98.0 %	Assumption
Technical availability	95.0 %	Assumption
Non-accessibility losses	100.0 %	Not considered
Icing and blade degradation	97.8 %	Based on WRF icing map
Low temperature downtime	99.0 %	Calculated from measurements
High wind hysteresis	99.0 %	Calculated from measurements
Substation maintenance	99.8 %	Typical value
Modification on power curve	100.0 %	Not considered
Wake effects from future project	100.0 %	Not considered
Other losses	100.0 %	Not considered
Projected net energy yield P(50)	**200.1 GWh/yr**	**3346 hrs full load**

5.4 26 turbines of type Nordex N117 (2.4MW)

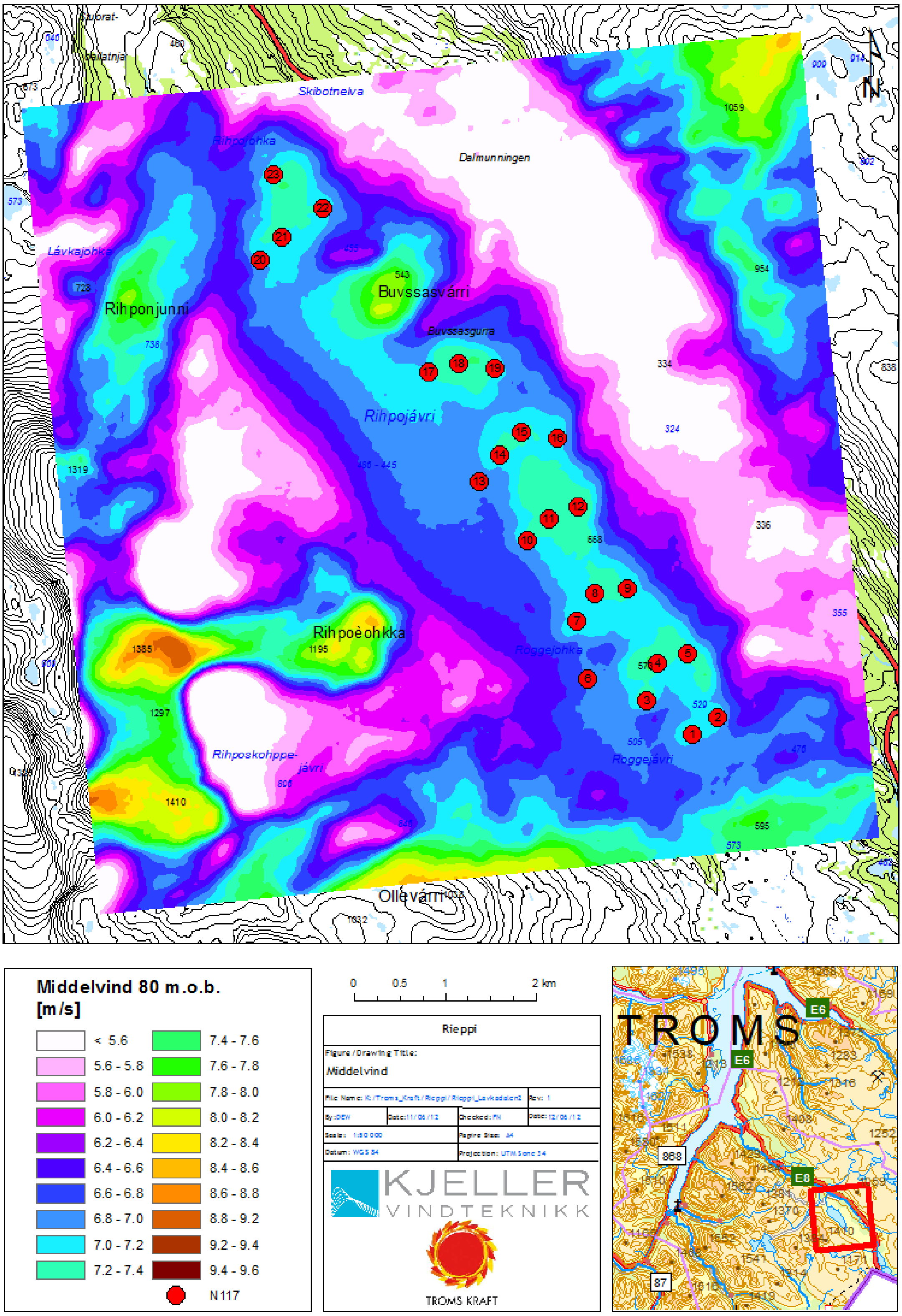


Figure 5.2: Wind resources at 80m a.g.l. with the layout for Nordex N117 turbines

For the Nordex N117 turbines the layout is adjusted to account for the larger rotor diameters, and three turbines are removed from the top of Buvssasvárri due to the higher winds at that location which exceed the mean wind speed for IEC class III.

Table 5.3: Gross production, expected losses and net production for 23 Nordex N117 class III turbines.

Assumptions:		
Number of Turbines	23	
Rated power one turbine	2.4 MW	
Hub height	84 m	
Rated power Park	55.20 MW	
Gross annual energy yield	219 GWh/yr	
Losses:		
Wake effects	91.5 %	Calculated in WindPRO
Electrical efficiency	98.0 %	Assumption
Technical availability	95.0 %	Assumption
Non-accessibility losses	100.0 %	Not considered
Icing and blade degradation	97.8 %	Based on WRF icing map
Low temperature downtime	99.0 %	Calculated from measurements
High wind hysteresis	99.0 %	Calculated from measurements
Substation maintenance	99.8 %	Typical value
Modification on power curve	100.0 %	Not considered
Wake effects from future project	100.0 %	Not considered
Other losses	100.0 %	Not considered
Projected net energy yield P(50)	**179 GWh/yr**	**3236 hrs full load**

6 Uncertainty estimates

The results given above are subject to different uncertainties. These are summarized in the uncertainty table in Appendix C. The following list provides some of the arguments for the chosen values:

- The energy sensitivity to the wind speed of 23.1% (Vestas V112), 23.3% (Siemens 101) and 26.0% (Nordex N90 LS) is calculated by decreasing the overall wind speed by 5% and then estimating the resulting energy production utilizing WindPRO again. This derivative of the park production as a function of mean annual wind speed yields information about the energy sensitivity.

- Anemometer calibration: 1% is generally used for Measnet members. At 2503 Rieppi calibrations are carried out at Svend Ole Hansen ApS and Deutscher Kalibrierdienst (DKD)
- Configuration: Generally, the largest tower influence is caused by the wake of the tower, but even above the tower the flow is influenced. The two top sensors are mounted on each end of a 1.4m long boom with the lightning rod in the middle. The uncertainty related to the configuration is estimated to 3%.
- The uncertainty of the main anemometer is 1%.
- The ice filter routine described in section 3.2 corrects all measurements when icing is detected. There is still expected to be periods of time when measurements are influenced by icing, yet not corrected (reduced velocity due to increased friction). This uncertainty is assumed to be 1.0%.
- The mean standard deviation of the mean wind over one year in Northern Europe is 6.0% of the expected long term wind (Wind Energy – The Facts, 2004). This is found in a European study of meteorological measurement stations.
- The uncertainty associated to the vertical extrapolation from measuring height to hub height is estimated by 3.5%. This takes into account the difference in mounting between the anemometers which were used to calculate the wind shear, as well as the dominant directions and the typical variability of wind shear for a site like Rieppi.
- It is difficult to give theoretical estimates of the uncertainty caused by the terrain, the roughness and the wind modeling. It depends on the size of the area and the complexity and variation within the area. In a paper by Berge et al. (2006) it was found that a maximum error in the prediction of other met masts of 6% in complex terrain, leading to a standard uncertainty of 5%. The uncertainty is increasing with distance to the met mast. At Rieppi the distances for the farthest turbine is 7km, with a usual complexity of terrain. 5.0% was used as an estimate for the standard uncertainty for horizontal extrapolation of the mean wind speed inside the park area.
- The uncertainty level of the wake modeling is estimated from the recommended lower limits of the wake decay constant, leading to an estimated standard uncertainty of 3.0% for all layouts.
- The uncertainty connected to the Weibull fit and the wind rose is estimated to 1.5%, because more than five years of measurements are available which makes these statistics very certain.

- The estimated production loss due to icing is 2.2%. The uncertainty related to this loss is assumed to be at the same order as the loss. The uncertainty due to icing and blade degeneration is assumed to be 2%.
- In this analysis it was chosen to set the uncertainty related to the power curve for the entire park to 3%, a common assumption.
- As a general value, the uncertainty on the electrical efficiency is set to 1.0%.

Assuming these sources of error as being independent from each other, the total uncertainty of the long term wind (10 year period) at the turbines can be estimated to 7.5%. This uncertainty in the wind recourses propagates to the energy production of each park layout proposed here. For the Vestas V112 layout it becomes 14.2% for a 10 years period, 13.1% for Siemens 101, and 14.2% for Nordex N117. More details of the uncertainty calculations, including P75 and

7 Summary

The wind conditions for the Rieppi wind farm are derived from onsite measurements. The average measured wind speed at 49.1m a.g.l. is 7.1±0.2m/s.
The derived mean wind shear $\alpha_{30\text{-}49m}$ is 0.10. This leads to the estimated long term wind speed at 80m a.g.l. at the mast location of 7.4±0.4m/s. These wind conditions are horizontally extrapolated to the designated wind park area using WAsP.

The results are utilized to design three wind park layouts based upon different types of turbines, and estimate their energy production:

Turbine Type	IEC Class	Number [turbines]	Installed Capacity [MW]	P50 [GWh/year]	Eq. Full Load Hours [hours/year]
Vestas V112 3.0MW	II	26	78.0	220.0	2821
Siemens SWT 113 2.3MW	II	26	59.8	200.1	3346
Nordex N117 LS 2.4MW	III	23	55.2	178.6	3236

8 References

Pirk, N., Ydersbond, Y. 2010, Rieppi, Storfjorden, Troms. KVT report KVT/NPYY/2010/R023

Arya, S. P. 1988. Introduction to mictometeorology. Academic Press, Inc. California.

Berge, E., Nyhammer, F.K., Tallhaug, L. and Jakobsen, Ø. 2006. An evaluation of the WAsP modell at a coastal mountainous site in Norway. Wind Energy; 9: 131-140, 2006.

Bowen, A. J. and Mortensen, N. G. 1996. Exploring the limits of WAsP the wind atlas analysis and application program. In Proceedings of EWEC-1996, Gøteborg, Sweden.

WAsP Manual, 1993. Wind Analysis and Application Program (WAsP). Vol 2: Users Guide. Risø National Laboratory, Roskilde, Denmark, ISBN 87-550-178.

Wind Energy – The Facts. An analysis of the Wind Energy in the EU-25. Side 53. Februar 2004.

Appendix A. Instrumentation overview mast 2503 Rieppi

Meteorological station - Instrumentation overview

1. Site number and name:	2503_Rieppi
2. Project name:	Rieppi
3. Client:	Troms Kraft Produksjon AS, Ronald Hardersen
4. Local contact:	Ivar Henriksen

5. Dates [day/month/year]:

Installed:	Valid from:	Valid to:	Dismounted:
27.09.2004	24.09.2009		

6. Position

Map projection	datum	Zone	leight abov sea level [m]	Northing	Easting	Uncertainty
UTM	EUref89	34	567	7675208	487328	+/- 5 m

7. Tower

Type	Height [m]	Anchoring method
NRG 50m Talltower	50m	Rock anchors

8. Sensors

Parameter	Type	Serial #	Calibration body	Logger channel	Height [m]	Boom dir [° mag]	Boom dir [° True north]
Wind speed	NRG#40	108420	S.O.H.	1	49,1	217	222
Wind speed	NRG#40	108423	S.O.H.	2	30,0	222	227
Wind speed	NRG#40	446	S.O.H.	3	10,4	222	227
Wind speed	Risø P2546A	5599	S.O.H.	4	49,1	37	42
Wind speed	NRG HAE icefree 3	1C902		5	42,4	219	224
Wind dir	NRG HVE icefree 3	31384		7	42,1	39	44*
Wind dir	NRG#200	1470		8	9,7	40	45
Air temp	NRG110S	4039		9	2,0	N	

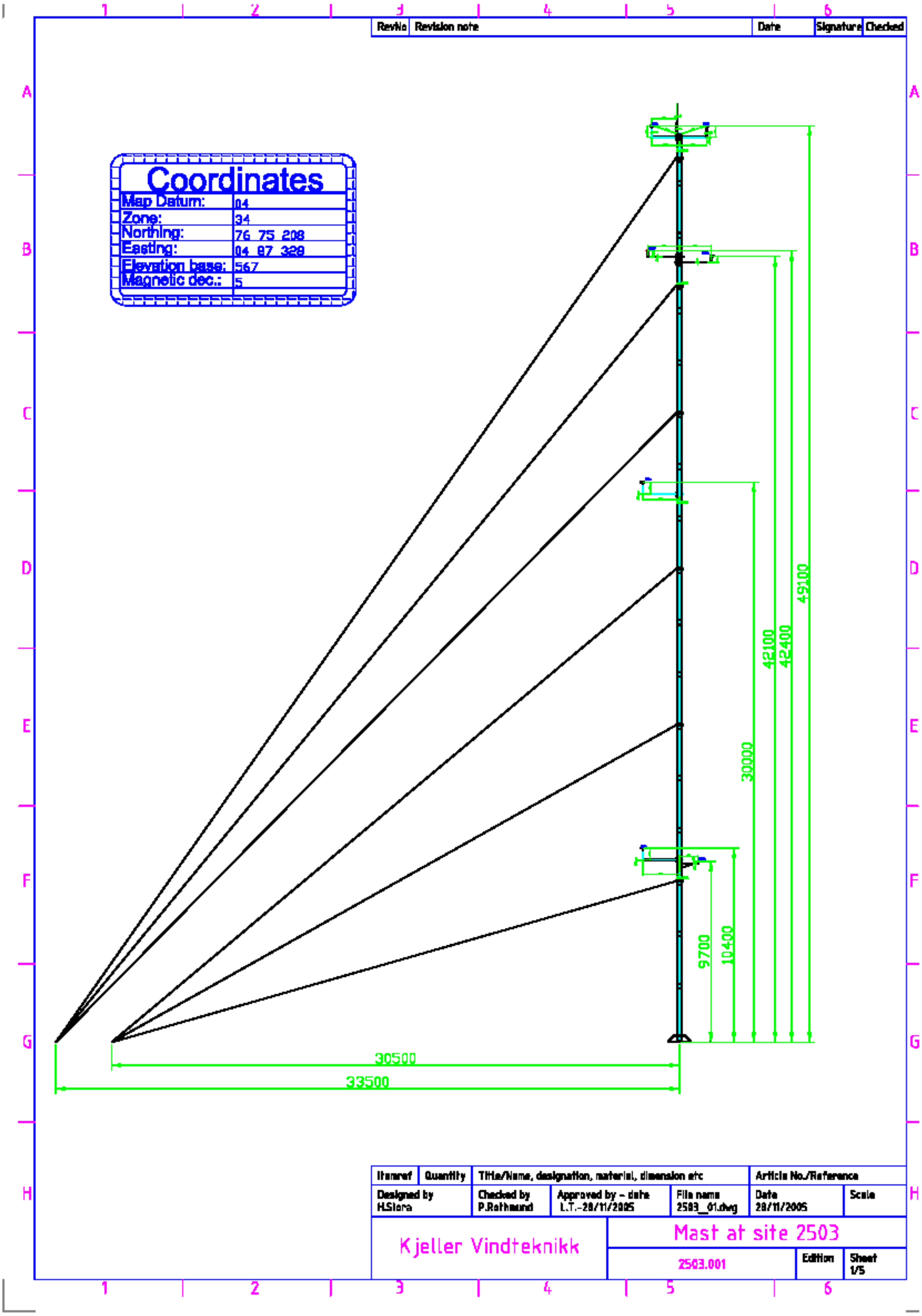
9. Data Acquisition System

Type	Serial	Phone #	Data transfer method
Logger:NRG Symphonie	35262981		
I-pack: NRG Symphonie	31220518	97080719	E-mail
Power supply	**Sampling intervall**	**Storage intervall**	
12Vdc conn. to main grid	2 s	10 min	

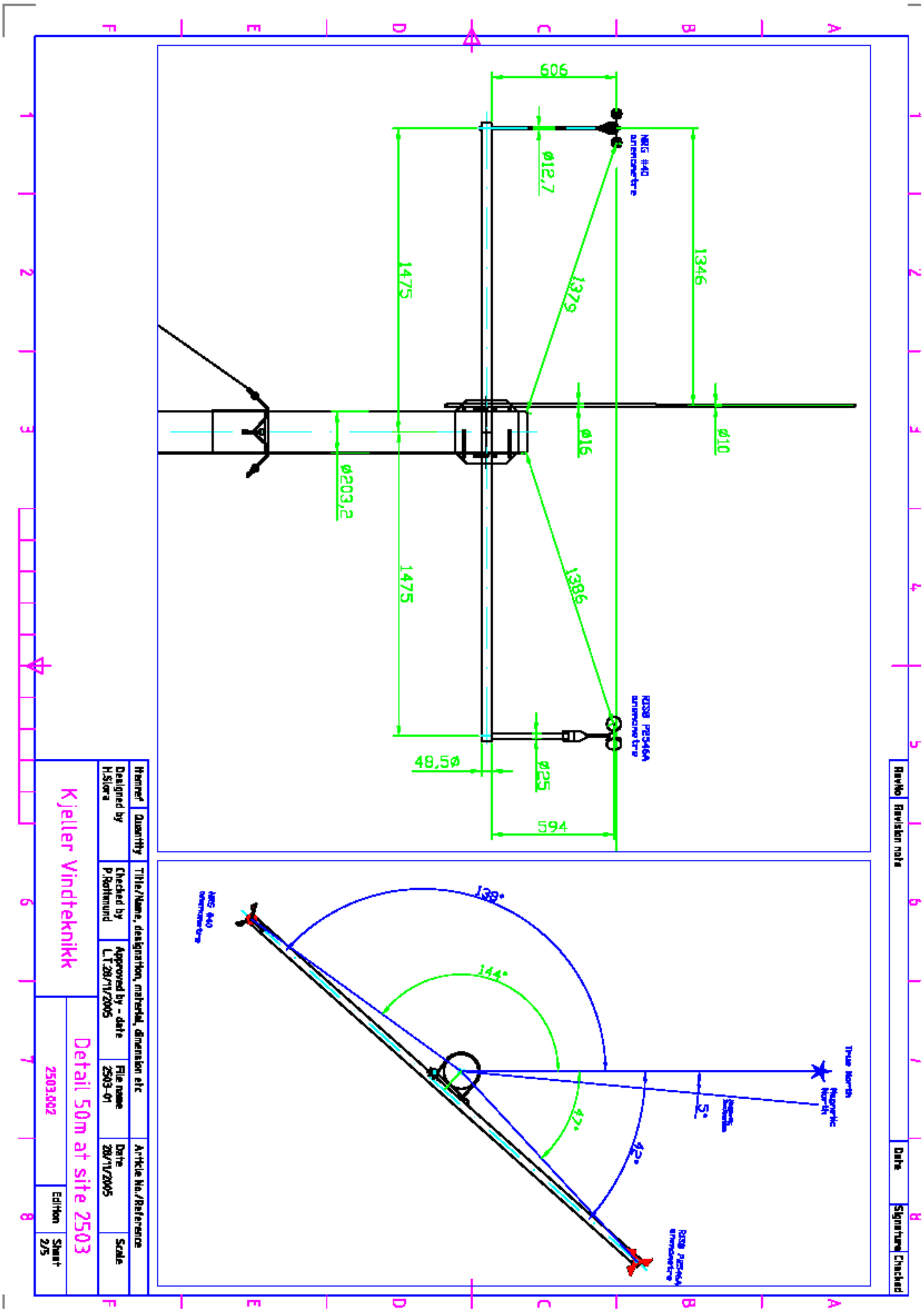
10. Additional information

True north is calculated with plus 5 dergres from magnetic north
* = Sensor direction 314 degrees
TempSensorer changed 10.11.2006

Appendix B. Schematic drawing of the 2503 Rieppi site



Top boom of 2503 Rieppi



Appendix C. Uncertainty tables

Uncertainties, Vestas V112 3MW, hub height 84m

Annual mean wind speed mast		7.1	m/s	(49.1m a.g.l. main mast)
Annual mean wind speed park		7.3	m/s	(Hub height)
Energy sensitivity (dE/dU)	23.10 %	56.8	GWh/annum/(m/s)	

			Wind	Wind [m/s]	Energy [GWh
1. Uncertainties On Site Measurements					
Calibrations			1.0 %	0.07	
Configuration			3.0 %	0.22	
Instrument class			1.0 %	0.07	
Total			**3.3 %**	**0.24**	**1[illegible]**
2. Variability of Long-Term Average Wind Speed					
Number of years		7 years			
Standard deviation		0.183 m/s			
Average wind speed at ref. station		7.2 m/s			
Uncertainty wind ref. station		0.069 m/s			
Uncertainty related to site			**1.0 %**	**0.07**	[illegible]
3. Uncertainties Ref. Station Measurements (consistency)					
Change in instruments, Station moved, etc.					
No reference station used			**0.0 %**	**0.00**	[illegible]
4. Uncertainty in Correlation					
No reference station used			**0.0 %**	**0.00**	[illegible]
5. Horizontal extrapolation					
Assumed uncertainty in model			**5.0 %**	**0.37**	**2[illegible]**
6. Vertical extrapolation					
			3.5 %	**0.26**	**1[illegible]**
7. Future Wind Variability					
	Years	std/rot(N)			
	1	0.183	**2.5 %**	**0.19**	**1[illegible]**
	10	0.058	**0.8 %**	**0.06**	[illegible]
A1. Uncertainties Wind Speec	**1 Year**		**7.5 %**	**0.54**	**3[illegible]**
A2. Uncertainties Wind Speec	**10 Years**		**7.1 %**	**0.52**	**2[illegible]**
B. Wake Modelling					
Assumed uncertainty in model	3.0 %				[illegible]
C. Wind Distribution					
Weibul fit/freq.distrib., windrose etc.	1.5 %				[illegible]
D. Icing/blade degradiation	2.0 %				[illegible]
E. Power Curve	3.0 %				[illegible]
F. Electrical efficiency	1.0 %				[illegible]

Total Standard Uncertainties	Energy	Wind	GWh
1 Year	14.9 %	7.5 %	3[illegible]
10 Years	14.2 %	7.1 %	3[illegible]

Confidence limits — Net energy [GWh/annum

Probability of Exceedance	Z	PX/P50 (10y	1 year	10 years
10	-1.2816	118.2 %	262	260
25	-0.6745	109.6 %	242	241
50	**0**	100.0 %	**220**	**220**
75	0.6745	90.4 %	198	199
90	1.2816	81.8 %	178	180

Confidens limits wind (main mast) — Wind speed [m/s]

Probability of Exceedance	Z	1 year	10 years
10	-1.2816	**7.8**	7.7
25	-0.6745	**7.5**	7.4
50	**0**	**7.1**	**7.1**
75	0.6745	**6.7**	6.8
90	1.2816	**6.4**	6.5

Uncertainties, Siemens 2.3 MW 113, hub height 84m

Annual mean wind speed mast		7.2 m/s	(49.1m a.g.l. main mast)	
Annual mean wind speed park		7.3 m/s	(Hub height)	
Energy sensitivity (dE/dU)	23.30 %	46.6 GWh/annum/(m/s)		

			Wind	Wind [m/s]	Energy [GWh]
1. Uncertainties On Site Measurements					
Calibrations			1.0 %	0.07	
Configuration			3.0 %	0.22	
Instrument class			1.0 %	0.07	
Total			**3.3 %**	**0.24**	**11.3**
2. Variability of Long-Term Average Wind Speed					
Number of years		5 years			
Standard deviation	0.183 m/s				
Average wind speed at ref. station	7.2 m/s				
Uncertainty wind ref. station	0.082 m/s				
Uncertainty related to site			**1.1 %**	**0.08**	**3.9**
3. Uncertainties Ref. Station Measurements (consistency)					
Change in instruments, Station moved, etc.					
No reference station used			**0.0 %**	**0.00**	**0.0**
4. Uncertainty in Correlation					
No reference station used			**0.0 %**	**0.00**	**0.0**
5. Horizontal extrapolation					
Assumed uncertainty in model			**5.0 %**	**0.37**	**17.0**
6. Vertical extrapolation					
			3.5 %	**0.26**	**11.9**
7. Future Wind Variability					
	Years	std/rot(N)			
	1	0.183	**2.5 %**	**0.19**	**8.7**
	10	0.058	**0.8 %**	**0.06**	**2.7**
A1. Uncertainties Wind Speec 1 Year			**7.5 %**	**0.55**	**25.5**
A2. Uncertainties Wind Speec 10 Years			**7.1 %**	**0.52**	**24.1**
B. Wake Modelling					
Assumed uncertainty in model	3.0 %				**6.0**
C. Wind Distribution					
Weibul fit/freq.distrib., windrose etc.	1.5 %				**3.0**
D. Icing/blade degradiation	2.0 %				**4.0**
E. Power Curve	3.0 %				**6.0**
F. Electrical efficiency	1.0 %				**2.0**

Total Standard Uncertainties	Energy	Wind	GWh
1 Year	13.7 %	7.5 %	27.4
10 Years	13.1 %	7.1 %	26.1

Confidence limits			Net energy [GWh/annum]	
Probability of Exceedance	**Z**	**PX/P50 (10y**	**1 year**	**10 years**
10	-1.2816	116.7 %	235	234
25	-0.6745	108.8 %	219	218
50	**0**	100.0 %	**200**	**200**
75	0.6745	91.2 %	182	182
90	1.2816	83.3 %	165	167

Confidens limits wind (main mast)		Wind speed [m/s]	
Probability of Exceedance	**Z**	**1 year**	**10 years**
10	-1.2816	**7.9**	7.9
25	-0.6745	**7.6**	7.5
50	**0**	**7.2**	**7.2**
75	0.6745	**6.8**	6.9
90	1.2816	**6.5**	6.5

Uncertainties, Nordex N90 LS 2500, hub height 80m

Annual mean wind speed mast		7.2 m/s	(49.1 m above ground level main mast)	
Annual mean wind speed park		7.2 m/s	(hub height)	
Energy sensitivity (dE/dU)	25.99 %	46.4 GWh/annum/(m/s)		

			Wind	Wind [m/s]	Energy [GWh]
1. Uncertainties On Site Measurements					
Calibrations			1.0 %	0.07	
Configuration			3.0 %	0.22	
Instrument class			1.0 %	0.07	
Total			**3.3 %**	**0.24**	**11.1**
2. Variability of Long-Term Average Wind Speed					
Number of years	5 years				
Standard deviation	0.183 m/s				
Average wind speed at ref. station	7.2 m/s				
Uncertainty wind ref. station	0.082 m/s				
Uncertainty related to site			**1.1 %**	**0.08**	**3.8**
3. Uncertainties Ref. Station Measurements (consistency)					
Change in instruments, Station moved, etc.					
No reference station used			**0.0 %**	**0.00**	**0.0**
4. Uncertainty in Correlation					
No reference station used			**0.0 %**	**0.00**	**0.0**
5. Horizontal extrapolation					
Assumed uncertainty in model			**5.0 %**	**0.36**	**16.7**
6. Vertical extrapolation			**3.5 %**	**0.25**	**11.7**
7. Future Wind Variability	Years	std/rot(N)			
	1	0.183	**2.5 %**	**0.18**	**8.5**
	10	0.058	**0.8 %**	**0.06**	**2.7**
A1. Uncertainties Wind Speec	**1 Year**		**7.5 %**	**0.54**	**25.0**
A2. Uncertainties Wind Speec	**10 Years**		**7.1 %**	**0.51**	**23.7**
B. Wake Modelling					
Assumed uncertainty in model	3.0 %				**5.4**
C. Wind Distribution					
Weibul fit/freq.distrib., windrose etc.	1.5 %				**2.7**
D. Icing/blade degradiation	2.0 %				**3.6**
E. Power Curve	3.0 %				**5.4**
F. Electrical efficiency	1.0 %				**1.8**

Total Standard Uncertainties	Energy	Wind	GWh
1 Year	14.9 %	7.5 %	26.6
10 Years	14.2 %	7.1 %	25.3

Confidence limits			Net energy [GWh/annum]	
Probability of Exceedance	**Z**	**PX/P50 (10y**	**1 year**	**10 years**
10	-1.2816	118.2 %	213	211
25	-0.6745	109.6 %	197	196
50	**0**	100.0 %	**179**	**179**
75	0.6745	90.4 %	161	162
90	1.2816	81.8 %	145	146

Confidens limits wind (main mast)		Wind speed [m/s]	
Probability of Exceedance	**Z**	**1 year**	**10 years**
10	-1.2816	**7.9**	7.9
25	-0.6745	**7.6**	7.5
50	**0**	**7.2**	**7.2**
75	0.6745	**6.8**	6.9
90	1.2816	**6.5**	6.5

Appendix D. WindPRO printouts

Project:
Rieppi_2012

Printed/Page
12.06.2012 14:55 / 1

Licensed user:
Kjeller Vindteknikk AS
Gunnar Randres vei 12
NO-2007 Kjeller
(+47) 480 50 480
David Edward Weir / david.weir@vindteknikk.no

Calculated:
12.06.2012 13:02/2.7.490

PARK - Main Result

Calculation: 2012 Vestas V112

Wake Model N.O. Jensen (EMD) : 2005

Calculation Settings

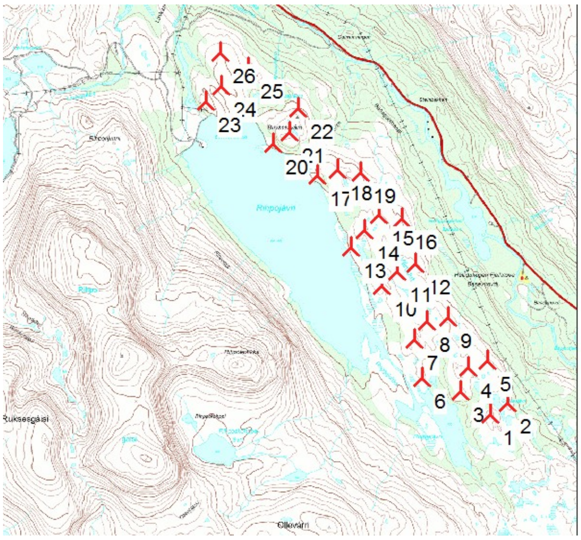
Air density calculation mode	Individual per WTG
Result for WTG at hub altitude	1.208 kg/m³ to 1.217 kg/m³
Air density relative to standard	99.1 %
Hub altitude above sea level (asl)	564.0 m to 644.0 m
Annual mean temperature at hub alt.	-3.6 °C to -3.1 °C
Pressure at WTGs	934.4 hPa to 943.9 hPa

Wake Model Parameters

From angle [°]	To angle [°]	Terrain type	Wake Decay Constant
345.0	15.0		0.100
15.0	45.0		0.100
45.0	75.0		0.100
75.0	105.0		0.100
105.0	135.0		0.100
135.0	165.0		0.050
165.0	195.0		0.050
195.0	225.0		0.075
225.0	255.0		0.100
255.0	285.0		0.075
285.0	315.0		0.075
315.0	345.0		0.050

Wake calculation settings

Angle [°] start	Angle [°] end	Angle [°] step	Wind speed [m/s] start	Wind speed [m/s] end	Wind speed [m/s] step
0.5	360.0	1.0	0.5	30.5	1.0



Scale 1:125 000

New WTG

Resource file(s)

\\kvtsrv01.vindteknikk.local\kvt\KUNDER\025_Troms Kraft\002_Rieppi\Analyser_Juni2012\11_WAsP\Wind_maps\wrg84m_rixcorr.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-11.9% [MWh]	GROSS (no loss) Free WTGs [MWh/y]	Specific results¤) Park efficiency [%]	Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	249 889.5	220 152.6	276 369.7	90.4	32.2	8 467.4	2 822	7.3

¤) Based on Result-11.9%

Calculated Annual Energy for each of 26 new WTGs with total 78.0 MW rated power

	Terrain	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-11.9% [MWh]	Park Efficiency [%]	Mean wind speed [m/s]
1	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	10 071.9	8 873	94.3	7.30
2	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 611.0	8 467	94.5	7.11
3	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 786.2	8 622	91.9	7.28
4	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 545.7	8 410	87.6	7.36
5	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 488.5	8 359	90.8	7.22
6	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 279.9	8 176	95.8	6.83
7	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 407.1	8 288	90.8	7.12
8	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 091.6	8 010	86.9	7.20
9	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	8 950.2	7 885	86.6	7.17
10	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 183.7	8 091	87.9	7.15
11	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 218.0	8 121	86.6	7.28
12	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 630.4	8 484	89.2	7.39
13	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	8 678.4	7 646	88.6	6.86
14	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 420.5	8 299	87.3	7.33
15	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 172.2	8 081	87.4	7.22
16	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 305.9	8 198	91.3	7.11
17	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 302.3	8 195	88.7	7.16
18	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 511.6	8 380	87.0	7.38
19	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 078.3	7 998	86.8	7.16
20	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	10 577.3	9 319	93.3	7.50
21	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	11 093.7	9 774	90.4	7.98
22	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	10 433.0	9 191	91.4	7.59
23	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	10 050.2	8 854	97.7	7.07
24	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	10 025.9	8 833	94.1	7.23
25	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	9 585.9	8 445	91.3	7.15

To be continued on next page...

Licensed user:
Kjeller Vindteknikk AS
Gunnar Randres vei 12
NO-2007 Kjeller
(+47) 480 50 480
David Edward Weir / david.weir@vindteknikk.no

PARK - Main Result

Calculation: 2012 Vestas V112

...continued from previous page

	Terrain	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-11.9% [MWh]	Park Efficiency [%]	Mean wind speed [m/s]
26	A	Yes	VESTAS	V112-3 000	3 000	112.0	84.0	EMD	Level 0 - Mode 0 - Estimated - 08-2010	10 390.0	9 154	93.0	7.46

WTG siting

	UTM WGS84 Zone: 34 East	North	Z [m]	Row data/Description
	UTM WGS84 Zone: 34			
1 New	487 733	7 674 411	560.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (27)
2 New	488 030	7 674 567	540.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (28)
3 New	487 271	7 674 833	560.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (29)
4 New	487 438	7 675 231	549.8	VESTAS V112 3000 112.0 !O! hub: 84.0 m (31)
5 New	487 770	7 675 308	543.5	VESTAS V112 3000 112.0 !O! hub: 84.0 m (32)
6 New	486 651	7 675 131	520.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (30)
7 New	486 595	7 675 773	540.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (33)
8 New	486 819	7 676 060	540.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (34)
9 New	487 180	7 676 078	531.4	VESTAS V112 3000 112.0 !O! hub: 84.0 m (35)
10 New	486 141	7 676 717	530.8	VESTAS V112 3000 112.0 !O! hub: 84.0 m (36)
11 New	486 410	7 676 930	540.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (37)
12 New	486 735	7 677 025	540.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (38)
13 New	485 680	7 677 410	503.2	VESTAS V112 3000 112.0 !O! hub: 84.0 m (41)
14 New	485 933	7 677 672	535.9	VESTAS V112 3000 112.0 !O! hub: 84.0 m (42)
15 New	486 194	7 677 900	520.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (43)
16 New	486 586	7 677 800	499.2	VESTAS V112 3000 112.0 !O! hub: 84.0 m (39)
17 New	485 240	7 678 658	510.3	VESTAS V112 3000 112.0 !O! hub: 84.0 m (46)
18 New	485 584	7 678 720	520.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (45)
19 New	485 970	7 678 624	500.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (44)
20 New	484 564	7 679 254	511.8	VESTAS V112 3000 112.0 !O! hub: 84.0 m (47)
21 New	484 855	7 679 427	556.5	VESTAS V112 3000 112.0 !O! hub: 84.0 m (48)
22 New	485 032	7 679 796	511.2	VESTAS V112 3000 112.0 !O! hub: 84.0 m (149)
23 New	483 518	7 680 067	500.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (49)
24 New	483 787	7 680 298	500.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (50)
25 New	484 266	7 680 559	480.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (52)
26 New	483 825	7 680 851	500.0	VESTAS V112 3000 112.0 !O! hub: 84.0 m (51)

Licensed user:
Kjeller Vindteknikk AS
Gunnar Randres vei 12
NO-2007 Kjeller
(+47) 480 50 480
David Edward Weir / david.weir@vindteknikk.no

Calculated:
13.06.2012 11:51/2.7.490

PARK - Main Result

Calculation: Siemens_113_2012

Wake Model N.O. Jensen (EMD) : 2005

Calculation Settings

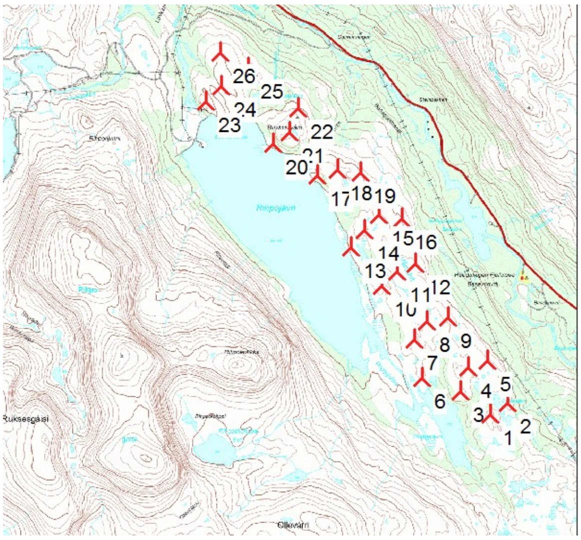
Air density calculation mode	Individual per WTG
Result for WTG at hub altitude	1.206 kg/m³ to 1.216 kg/m³
Air density relative to standard	99.0 %
Hub altitude above sea level (asl)	573.0 m to 653.0 m
Annual mean temperature at hub alt.	-3.6 °C to -3.1 °C
Pressure at WTGs	933.3 hPa to 942.8 hPa

Wake Model Parameters

From angle [°]	To angle [°]	Terrain type	Wake Decay Constant
345.0	15.0		0.100
15.0	45.0		0.100
45.0	75.0		0.100
75.0	105.0		0.100
105.0	135.0		0.100
135.0	165.0		0.050
165.0	195.0		0.050
195.0	225.0		0.075
225.0	255.0		0.100
255.0	285.0		0.075
285.0	315.0		0.075
315.0	345.0		0.050

Wake calculation settings

Angle [°] start	end	step	Wind speed [m/s] start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Scale 1:125 000

New WTG

Resource file(s)

\\kvtsrv01.vindteknikk.local\kvt\KUNDER\025_Troms Kraft\002_Rieppi\Analyser_Juni2012\11_WAsP\Wind_maps\wrg93m_rixcorr.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-11.9% [MWh]	GROSS (no loss) Free WTGs [MWh/y]	Park efficiency [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	227 283.6	200 236.8	249 655.7	91.0	38.2	7 701.4	3 348	7.3

¤) Based on Result-11.9%

Calculated Annual Energy for each of 26 new WTGs with total 59.8 MW rated power

	Terrain	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-11.9% [MWh]	Park Efficiency [%]	Mean wind speed [m/s]
1	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	9 125.7	8 040	94.5	7.30
2	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 781.4	7 736	94.7	7.11
3	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 894.9	7 836	92.3	7.28
4	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 671.4	7 640	88.4	7.36
5	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 662.7	7 632	91.4	7.22
6	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 549.8	7 532	95.9	6.83
7	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 594.1	7 571	91.2	7.12
8	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 318.1	7 328	87.7	7.20
9	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 216.5	7 239	87.4	7.17
10	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 400.5	7 401	88.6	7.15
11	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 407.9	7 407	87.4	7.28
12	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 733.7	7 694	89.8	7.39
13	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 026.3	7 071	89.3	6.86
14	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 561.6	7 543	88.1	7.33
15	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 368.4	7 373	88.1	7.22
16	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 513.0	7 500	91.9	7.11
17	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 499.1	7 488	89.4	7.16
18	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 643.8	7 615	87.9	7.38
19	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 325.4	7 335	87.9	7.16
20	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	9 467.9	8 341	93.7	7.50
21	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	9 839.5	8 669	91.2	7.98
22	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	9 363.6	8 249	92.1	7.59
23	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	9 128.9	8 043	97.9	7.07
24	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	9 080.8	8 000	94.5	7.23

To be continued on next page...

Project:
Siemens_2012_after_windpro_crash

Licensed user:
Kjeller Vindteknikk AS
Gunnar Randres vei 12
NO-2007 Kjeller
(+47) 480 50 480
David Edward Weir / david.weir@vindteknikk.no

Calculated:
13.06.2012 11:51/2.7.490

PARK - Main Result

Calculation: Siemens_113_2012

...continued from previous page

	Terrain	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-11.9% [MWh]	Park Efficiency [%]	Mean wind speed [m/s]
25	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	8 756.7	7 715	92.0	7.15
26	A	Yes	Siemens	SWT-2.3-113-2 300	2 300	113.0	93.0	EMD	Level 0 - - Standard setting 0dB -	9 351.8	8 239	93.5	7.46

WTG siting

	UTM WGS84 Zone: 34 East	North	Z [m]	Row data/Description
1 New	487 733	7 674 411	560.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (27)
2 New	488 030	7 674 567	540.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (28)
3 New	487 271	7 674 833	560.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (29)
4 New	487 438	7 675 231	549.8	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (31)
5 New	487 770	7 675 308	543.5	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (32)
6 New	486 651	7 675 131	520.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (30)
7 New	486 595	7 675 773	540.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (33)
8 New	486 819	7 676 060	540.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (34)
9 New	487 180	7 676 078	531.4	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (35)
10 New	486 141	7 676 717	530.8	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (36)
11 New	486 410	7 676 930	540.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (37)
12 New	486 735	7 677 025	540.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (38)
13 New	485 680	7 677 410	503.2	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (41)
14 New	485 933	7 677 672	535.9	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (42)
15 New	486 194	7 677 900	520.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (43)
16 New	486 586	7 677 800	499.2	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (39)
17 New	485 240	7 678 658	510.3	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (46)
18 New	485 584	7 678 720	520.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (45)
19 New	485 970	7 678 624	500.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (44)
20 New	484 564	7 679 254	511.8	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (47)
21 New	484 855	7 679 427	556.5	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (48)
22 New	485 032	7 679 796	511.2	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (149)
23 New	483 518	7 680 067	500.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (49)
24 New	483 787	7 680 298	500.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (50)
25 New	484 266	7 680 559	480.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (52)
26 New	483 825	7 680 851	500.0	Siemens SWT-2.3-113 2300 113.0 !O! hub: 93.0 m (51)

Project:	Printed/Page
Rieppi_2012	12.06.2012 14:56 / 1

Licensed user:
Kjeller Vindteknikk AS
Gunnar Randres vei 12
NO-2007 Kjeller
(+47) 480 50 480
David Edward Weir / david.weir@vindteknikk.no
Calculated:
12.06.2012 12:51/2.7.490

PARK - Main Result

Calculation: 2012 Nordex N117

Wake Model N.O. Jensen (EMD) : 2005

Calculation Settings

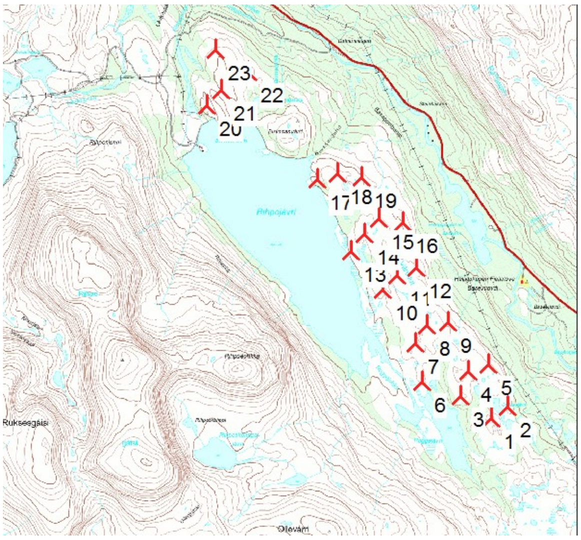
Air density calculation mode	Individual per WTG
Result for WTG at hub altitude	1.208 kg/m³ to 1.218 kg/m³
Air density relative to standard	99.4 %
Hub altitude above sea level (asl)	560.0 m to 640.0 m
Annual mean temperature at hub alt.	-3.6 °C to -3.0 °C
Pressure at WTGs	934.9 hPa to 944.4 hPa

Wake Model Parameters

From angle [°]	To angle [°]	Terrain type	Wake Decay Constant
345.0	15.0		0.100
15.0	45.0		0.100
45.0	75.0		0.100
75.0	105.0		0.100
105.0	135.0		0.100
135.0	165.0		0.050
165.0	195.0		0.050
195.0	225.0		0.075
225.0	255.0		0.100
255.0	285.0		0.075
285.0	315.0		0.075
315.0	345.0		0.050

Wake calculation settings

Angle [°]			Wind speed [m/s]		
start	end	step	start	end	step
0.5	360.0	1.0	0.5	30.5	1.0



Scale 1:125 000

New WTG

Resource file(s)

\\kvtsrv01.vindteknikk.local\kvt\KUNDER\025_Troms Kraft\002_Rieppi\Analyser_Juni2012\11_WAsP\Wind_maps\wrg80m_rixcorr.wrg

Calculated Annual Energy for Wind Farm

WTG combination	Result PARK [MWh/y]	Result-11.9% [MWh]	GROSS (no loss) Free WTGs [MWh/y]	Park efficiency [%]	Specific results¤) Capacity factor [%]	Mean WTG result [MWh/y]	Full load hours [Hours/year]	Mean wind speed @hub height [m/s]
Wind farm	202 762.3	178 633.6	221 608.4	91.5	36.9	7 766.7	3 236	7.2

¤) Based on Result-11.9%

Calculated Annual Energy for each of 23 new WTGs with total 55.2 MW rated power

	Terrain	WTG type Valid	Manufact.	Type-generator	Power, rated [kW]	Rotor diameter [m]	Hub height [m]	Power curve Creator	Name	Annual Energy Result [MWh]	Result-11.9% [MWh]	Park Efficiency [%]	Mean wind speed [m/s]
1	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	9 256.6	8 155	94.5	7.30
2	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 892.2	7 834	94.7	7.11
3	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	9 030.0	7 955	92.4	7.28
4	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 824.4	7 774	88.6	7.36
5	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 781.2	7 736	91.5	7.22
6	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 716.6	7 679	96.0	6.83
7	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 750.2	7 709	91.4	7.12
8	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 446.1	7 441	87.8	7.20
9	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 333.8	7 342	87.5	7.17
10	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 571.3	7 551	88.9	7.15
11	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 538.3	7 522	87.6	7.28
12	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 838.1	7 786	89.9	7.39
13	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 232.4	7 253	89.9	6.86
14	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 734.0	7 695	88.6	7.33
15	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 515.1	7 502	88.5	7.22
16	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 627.3	7 601	92.1	7.11
17	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 874.8	7 819	91.8	7.16
18	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 964.7	7 898	89.8	7.38
19	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	8 550.3	7 533	88.8	7.16
20	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	9 304.8	8 198	98.0	7.07
21	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	9 423.2	8 302	96.4	7.23
22	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	9 235.7	8 137	95.3	7.15
23	A	Yes	NORDEX	N117-2 400	2 400	117.0	80.0	EMD	Level 0 - calculated - - 01-2011	9 320.9	8 212	95.0	7.25

Project:
Rieppi_2012

Printed/Page
12.06.2012 14:56 / 2

Licensed user:
Kjeller Vindteknikk AS
Gunnar Randres vei 12
NO-2007 Kjeller
(+47) 480 50 480
David Edward Weir / david.weir@vindteknikk.no

Calculated:
12.06.2012 12:51/2.7.490

PARK - Main Result

Calculation: 2012 Nordex N117

WTG siting

	UTM WGS84 Zone: 34 East	North	Z	Row data/Description
	UTM WGS84 Zone: 34		[m]	
1 New	487 733	7 674 411	560.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (181)
2 New	488 030	7 674 567	540.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (182)
3 New	487 271	7 674 833	560.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (183)
4 New	487 438	7 675 231	549.8	NORDEX N117 2400 117.0 !O! hub: 80.0 m (185)
5 New	487 770	7 675 308	543.5	NORDEX N117 2400 117.0 !O! hub: 80.0 m (186)
6 New	486 651	7 675 131	520.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (184)
7 New	486 595	7 675 773	540.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (187)
8 New	486 819	7 676 060	540.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (188)
9 New	487 180	7 676 078	531.4	NORDEX N117 2400 117.0 !O! hub: 80.0 m (189)
10 New	486 141	7 676 717	530.8	NORDEX N117 2400 117.0 !O! hub: 80.0 m (190)
11 New	486 410	7 676 930	540.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (191)
12 New	486 735	7 677 025	540.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (192)
13 New	485 680	7 677 410	503.2	NORDEX N117 2400 117.0 !O! hub: 80.0 m (194)
14 New	485 933	7 677 672	535.9	NORDEX N117 2400 117.0 !O! hub: 80.0 m (195)
15 New	486 194	7 677 900	520.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (196)
16 New	486 586	7 677 800	499.2	NORDEX N117 2400 117.0 !O! hub: 80.0 m (193)
17 New	485 240	7 678 658	510.3	NORDEX N117 2400 117.0 !O! hub: 80.0 m (199)
18 New	485 584	7 678 720	520.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (198)
19 New	485 970	7 678 624	500.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (197)
20 New	483 518	7 680 067	500.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (202)
21 New	483 787	7 680 298	500.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (203)
22 New	484 266	7 680 559	480.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (205)
23 New	483 762	7 680 985	484.0	NORDEX N117 2400 117.0 !O! hub: 80.0 m (204)