



Havøygavlen Wind Farm

Operational experience in turbulent
conditions

Lars Tallhaug

Zadar, Croatia 5.May 2010

Kjeller Vindteknikk AS

- Consultancy company.
- 20 employees.
- Founded in 1998.
- Main office in Norway (Oslo) and branch office in Sweden (Stockholm).
- Main working areas:
 - Wind measurements (about 200 met masts up to now)
 - Wind analysis. Production estimates.
 - Meteorological modeling.
 - Short-term forecasting
- Meso-scale wind and icing maps can be downloaded from: www.vindteknikk.no



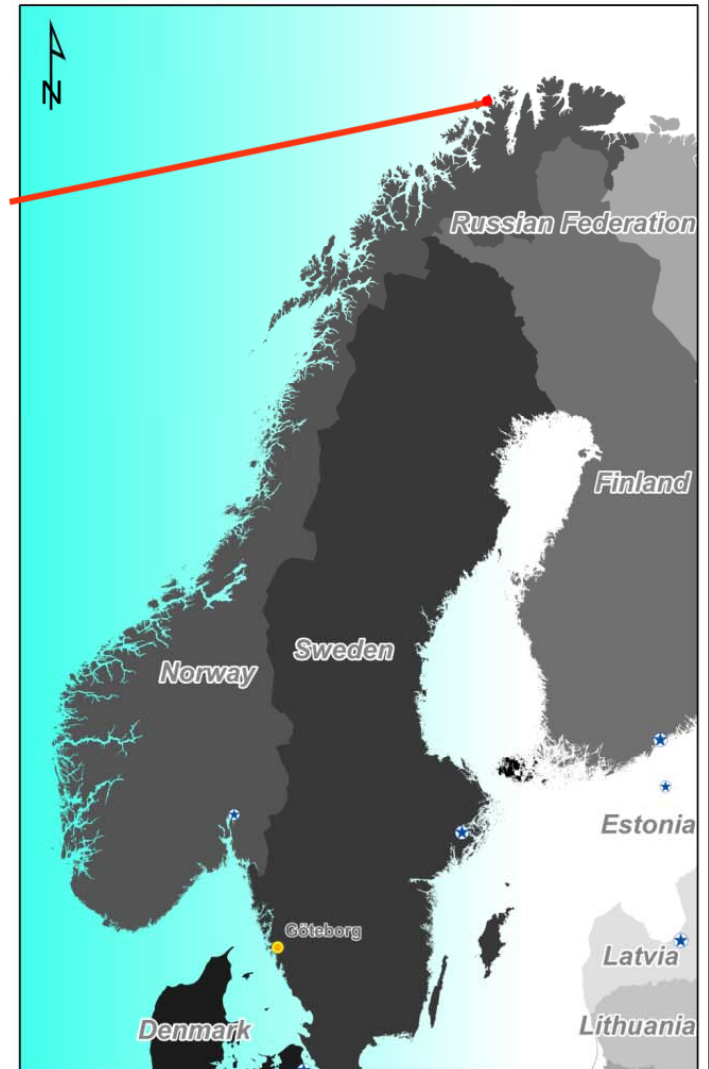
Outline

- Organization
- Overview of the Wind Farm
- Climatic conditions
- Description of the turbulence conditions.
- Analysis of the availability.
- Possible turbulence induced problems.

Organization

- Norsk Miljøkraft: Project development.
- Kjeller Vindteknikk AS
 - Wind measurements.
 - Post-construction production calculation (2y after).
- Intercon IS
 - Wind farm design
 - Pre-construction production calculation.
- NORDEX: Turn-key wind turbines.
- Arctic Wind AS (Statoil): Owner and operator.

Havøygavlen wind farm





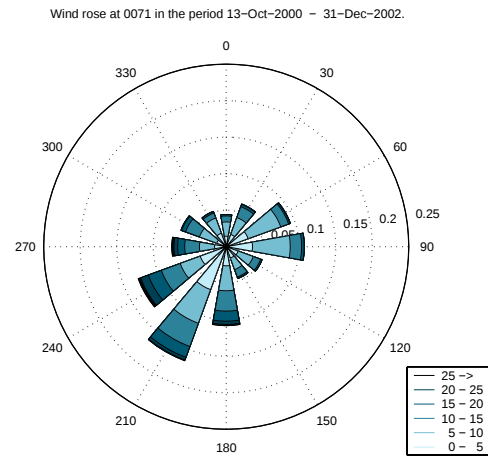
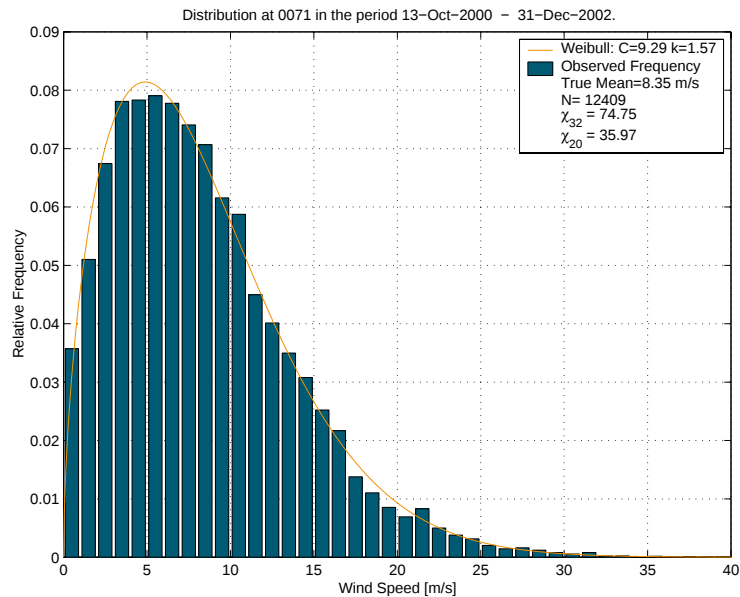
Havøygavlen WF

- 16 Nordex 2.5MW wind turbines
- Hub height 80m and rotor diameter 80m
- Installed Summer 2002.
- Located at 71 deg north
- Altitude 280 m above sea level.

Climatic overview

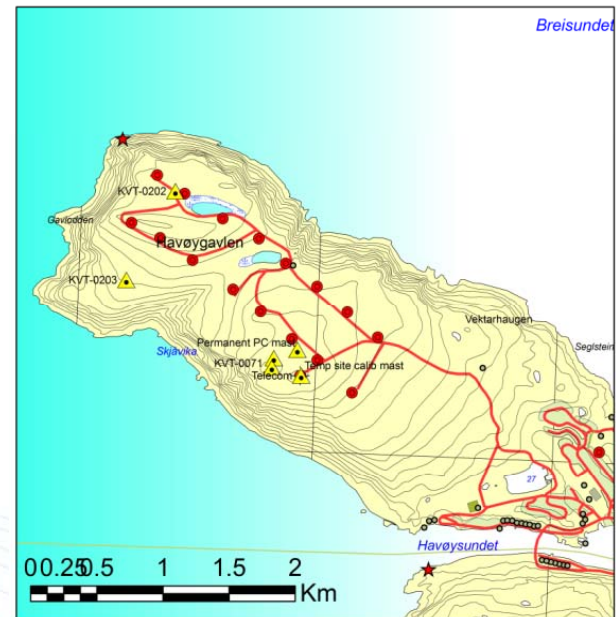
- Costal climate.
 - Annual mean temperature 0 °C
 - Monthly average during winter -6°C
 - Monthly average during summer 8°C
- In-cloud icing events registered in about 9 days/year. Short periods, and light icing.
- Estimated annual average wind speed at most favorable location; 8.9m/s 50m above ground.
- Extreme wind speed 55m/s (50y return period). 46.6m/s was observed during measurement period. Both 10min averages.

Climatic overview



Pre-construction measurements

- 3 X 50m met masts.
- 10min average wind speed and direction in all masts.
- Measurements ended in 2001.

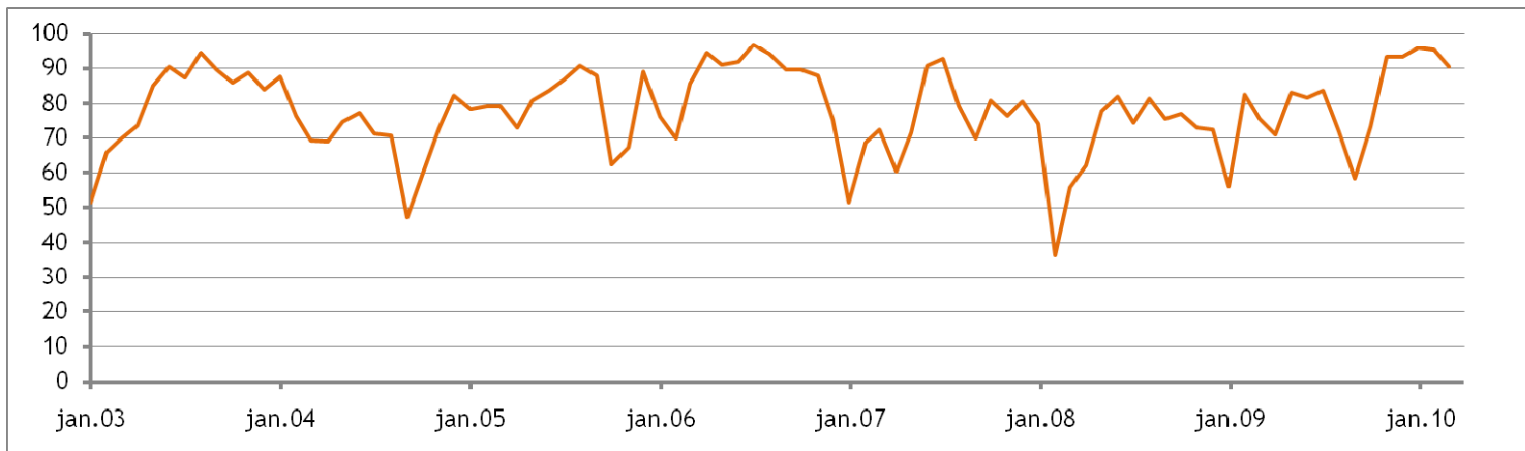


Energy Production

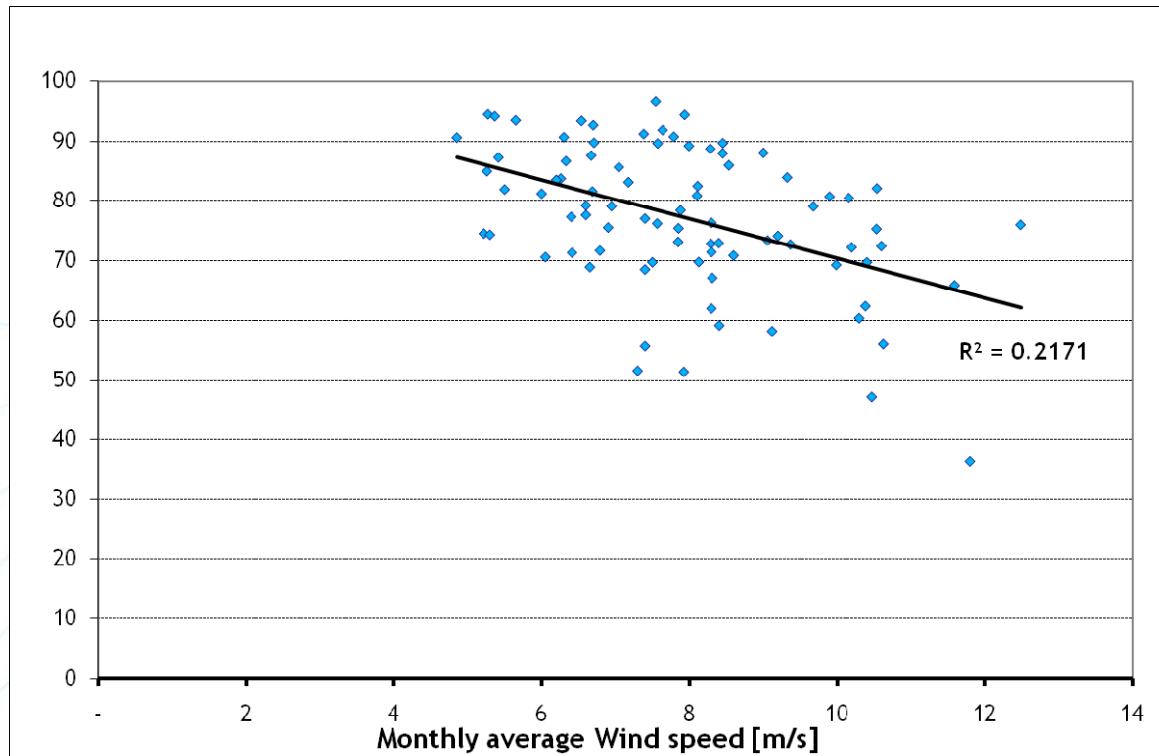
- Pre-construction estimate: 120GWh
- Post-construction estimate: 104GWh
 - Or: 2600 full load hours.
 - Or: Capacity factor 0.30
 - Or: 1290 kWh/m² swept area.
 - All assuming 97% availability.

Availability

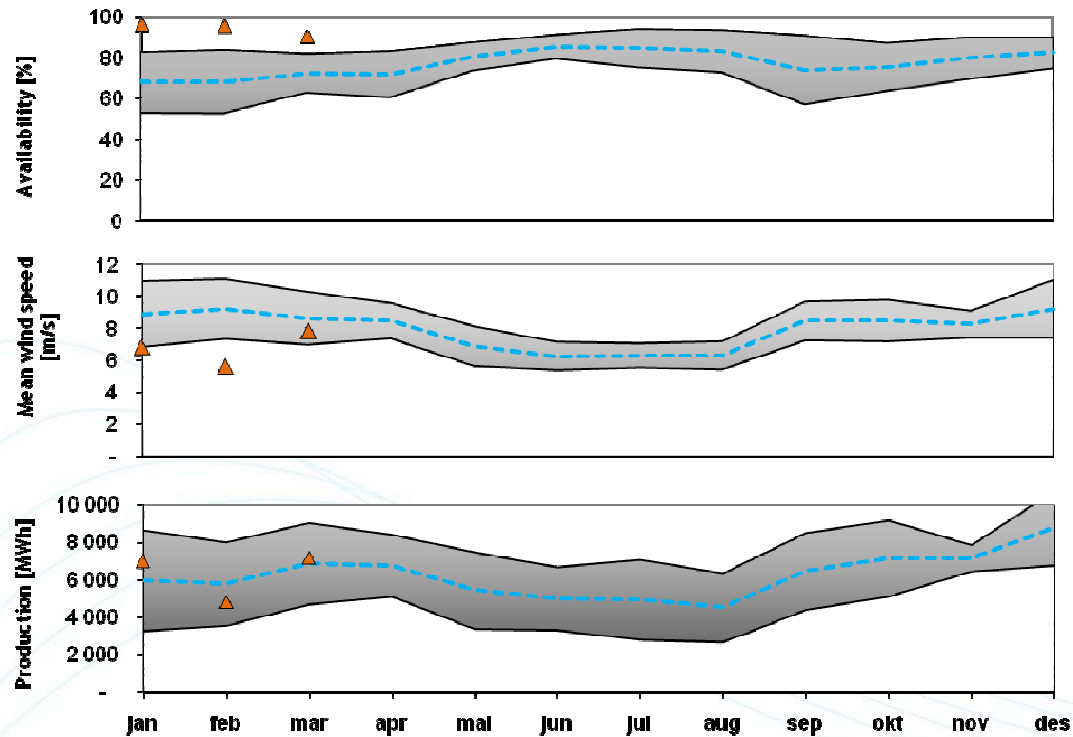
Monthly averages



Availability vs wind speed



Variations over the year



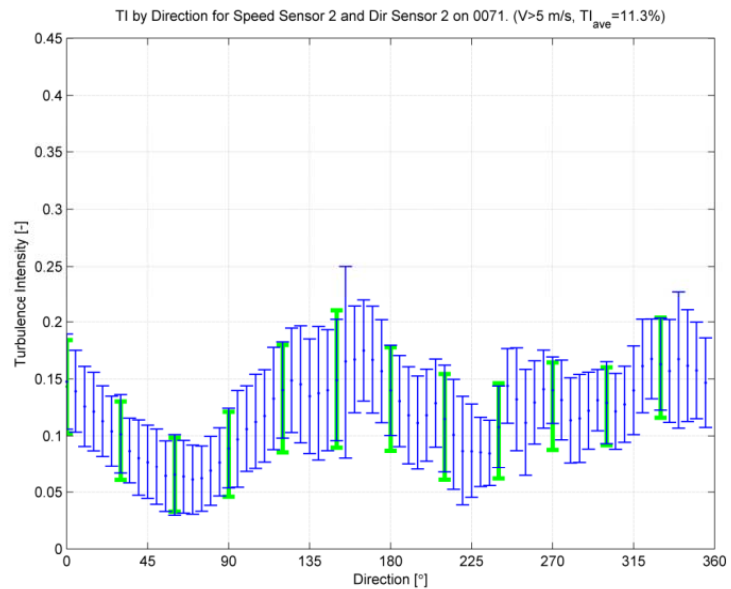
Energy Production

- Average production: 77GWh
- Average availability: 77%

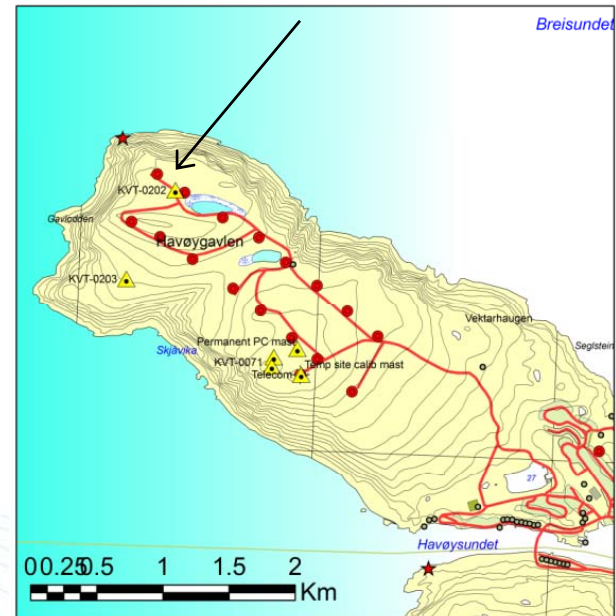
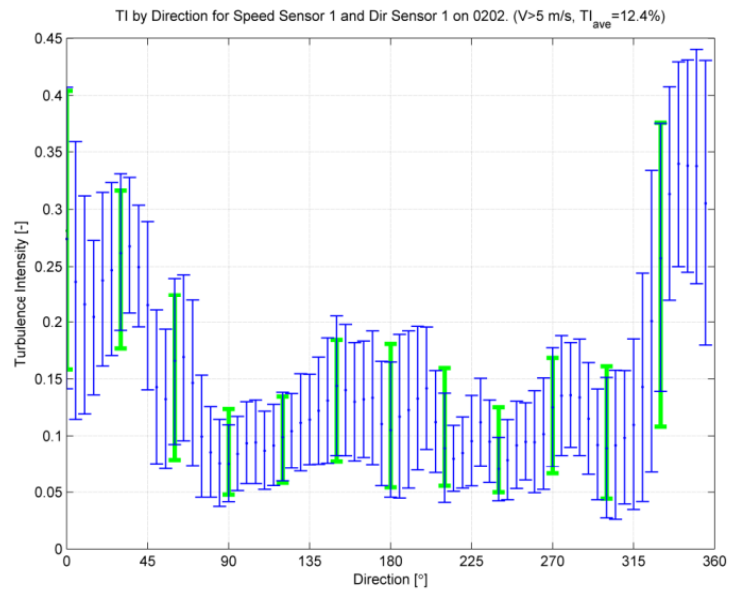
Major technical problems

- Nacelle collapsed October 2002 due to human error. Turbine #7
- Many technical problems with pitch, yaw, batteries and oil. Major upgrade in 2004.
- 22kV transformer fire.
- Roof of nacelle blown off in a heavy storm.
- Gear problems.
- One turbine lost a blade and collapsed February 2008. Turbine #4.

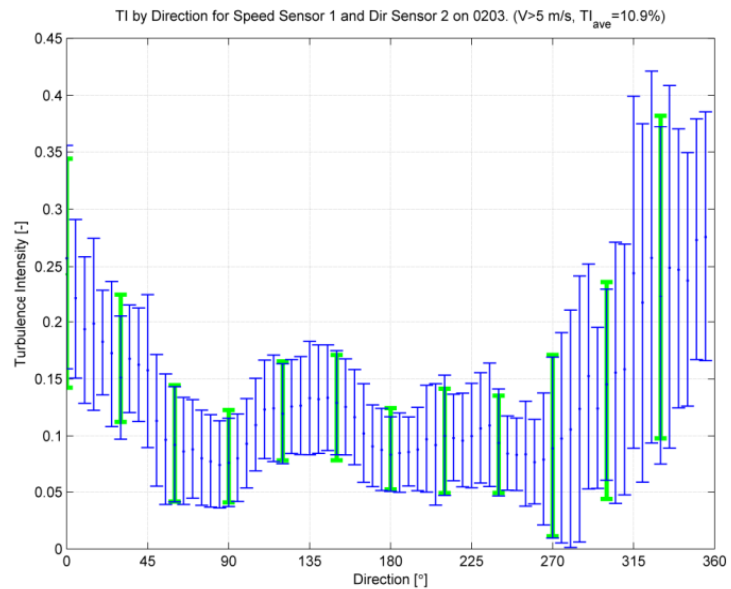
Turbulence mast 0071



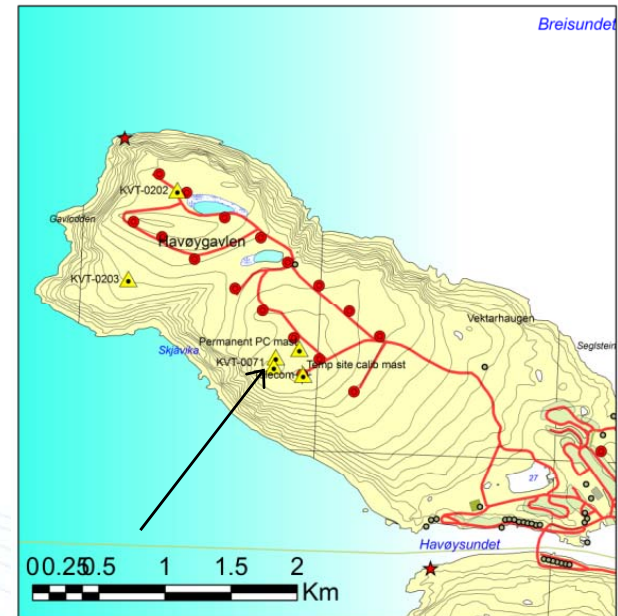
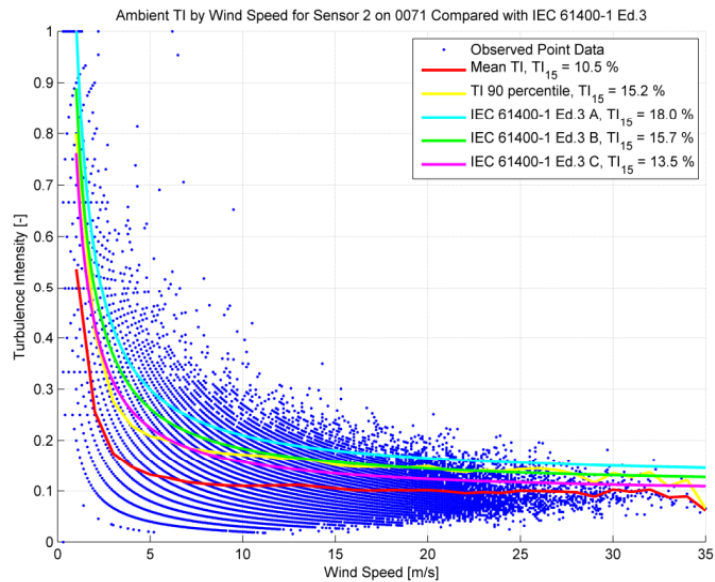
Turbulence mast 0202



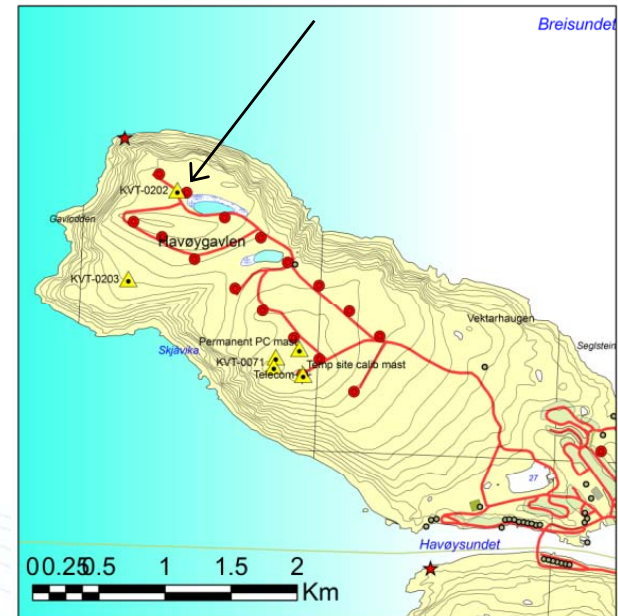
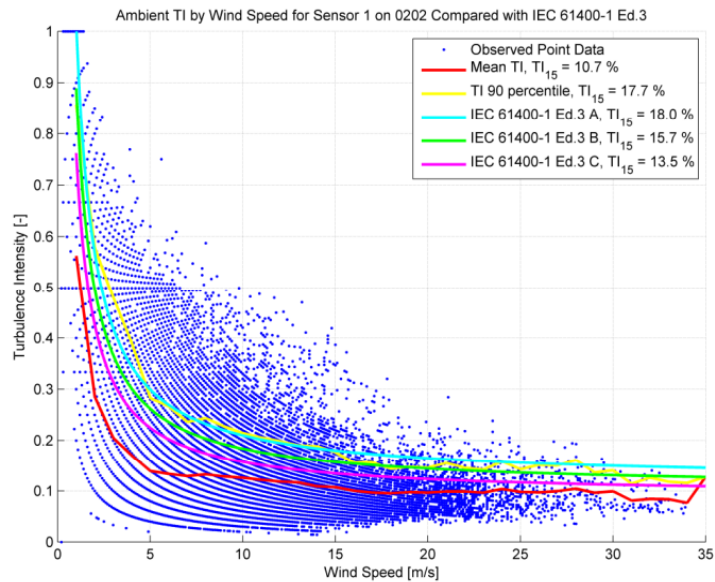
Turbulence mast 0203



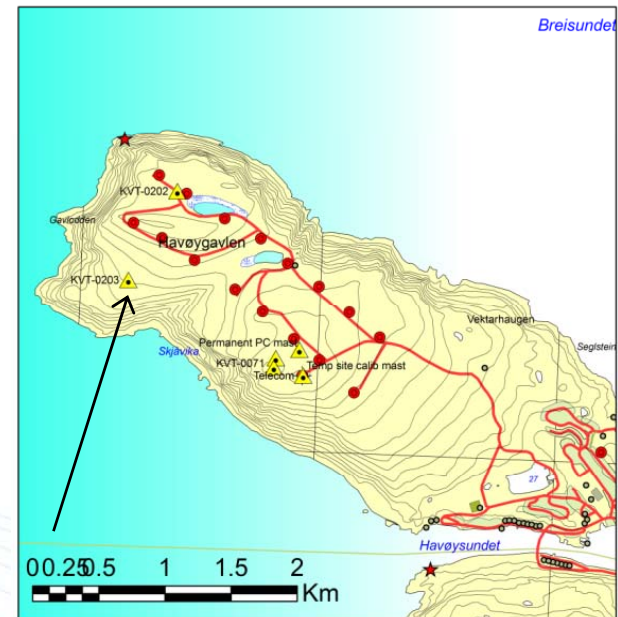
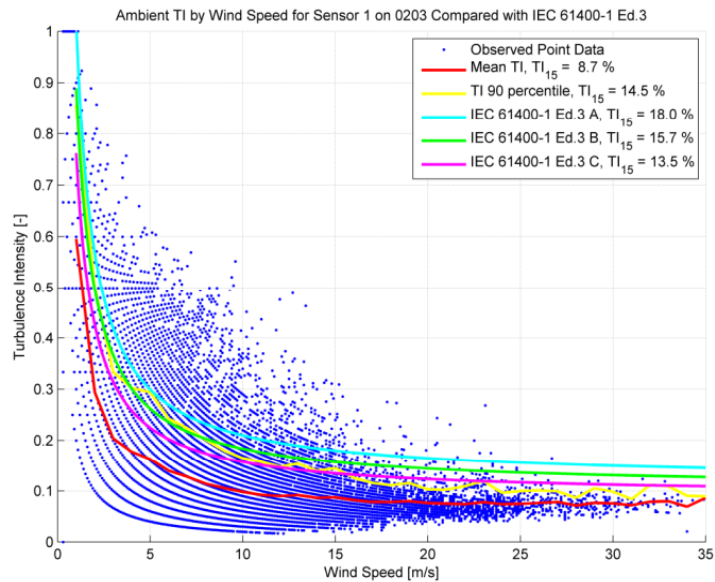
Turbulence mast 0071



Turbulence mast 0202



Turbulence mast 0203

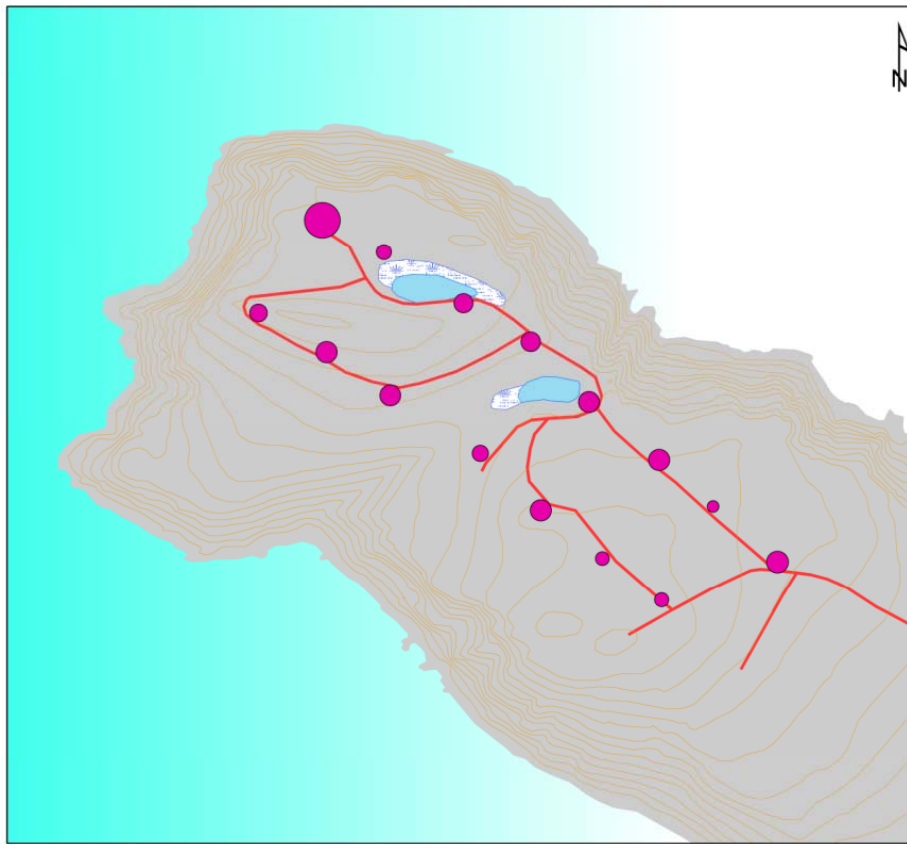


Turbulence and WF operation

- Measurements shows that the turbulence is generated locally.
- Turbulence might lead to operational and fatigue problems.
 - Blade repair.
 - Yaw motor activity.
 - Availability
- Detailed data during last winter (Oct2009/March2010) has been available.
- Indicators for turbulence has been searched for.

Blade repair

Valid for entire operational period



Havøygavlen Vindkraftverk			
Figure/Drawing Title:			
Estimated Hours for Blade Repairing			
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By:	pyg	Date:	11/01/10
Checked:	pyg	Date:	11/01/10
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Datum:	WGS84 zone 35	Projection:	UTM

0 0.125 0.25 0.5 km

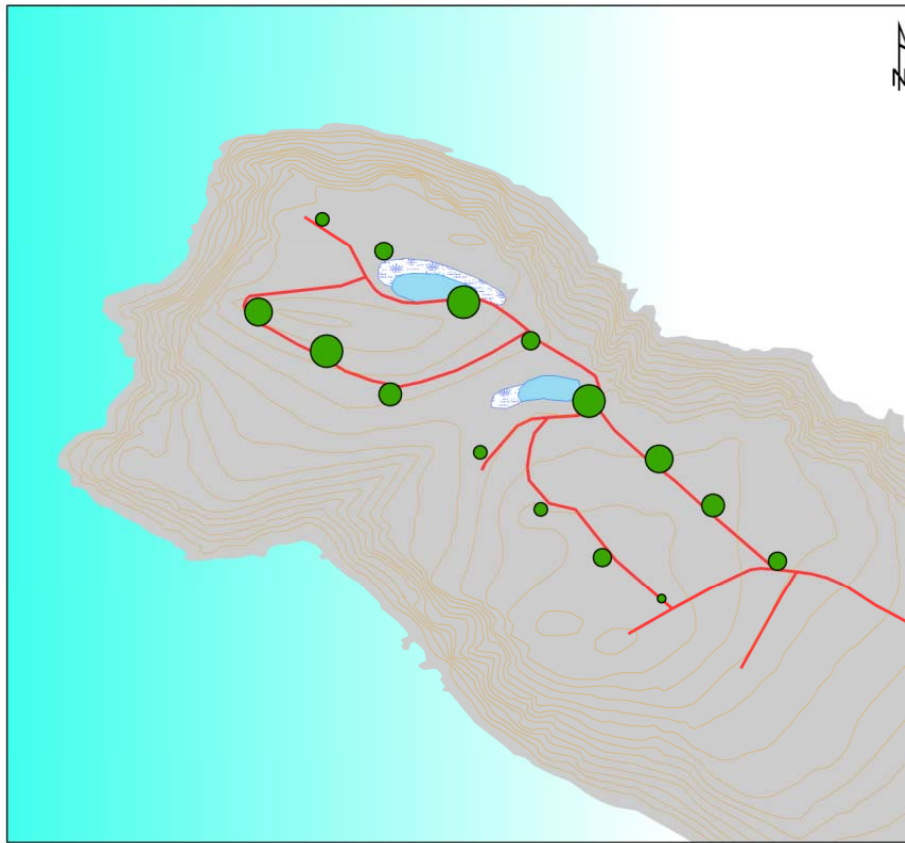
Legend

Blade Repairing hours 2009

Blade_rep



Availability



Havøygavlen Vindkraftverk

Figure/Drawing Title:

Contract Availability oct09 - mar10

File Name:	Statist_Havøygavlen_driftsforfaring.mxd	Rev:	Rev 1
By: FRK	Date: 12/01/10	Checked: Hestabø	Date: 05/04/11
Scale: 1:15 000	Page Size: A4		
Date: WGS84 zone 35	Projection: UTM		

0 0.125 0.25 0.5 km

Legend

Contractual Availabilit

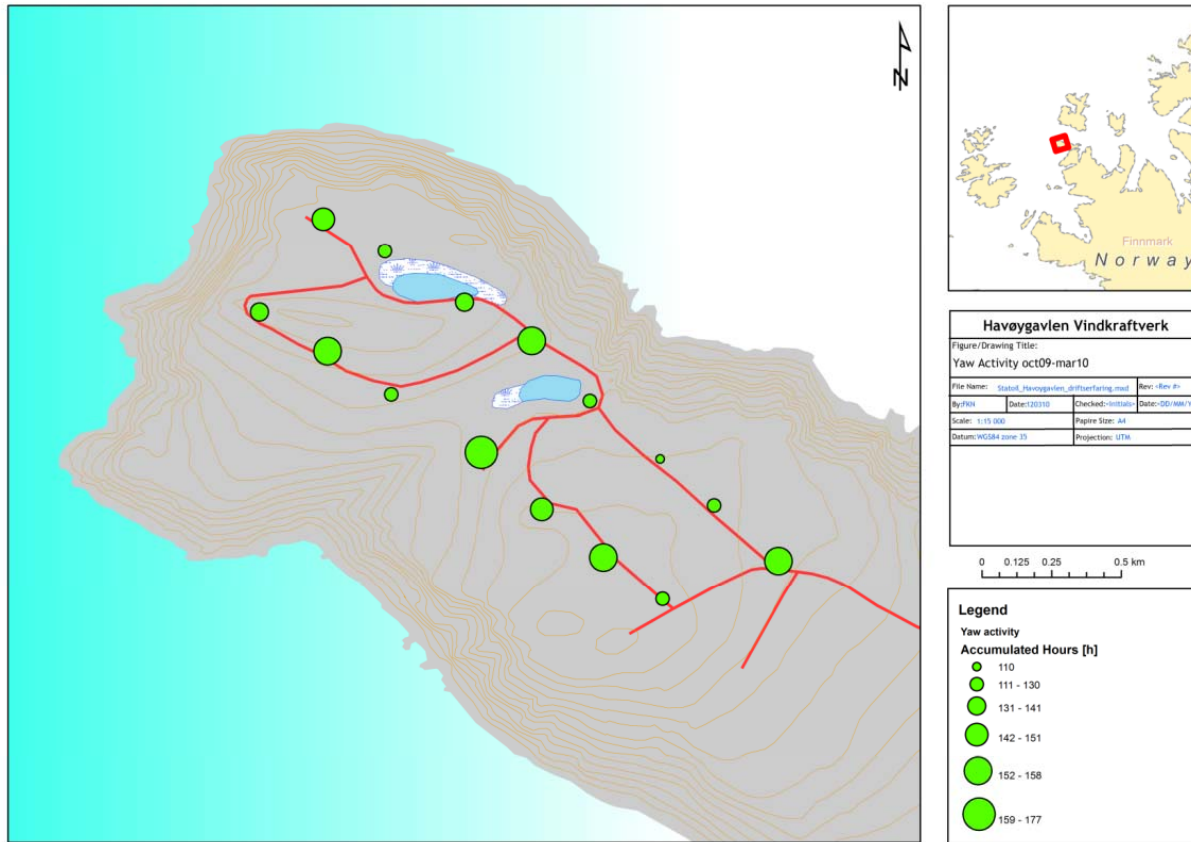
Contractual Availabilit

- 0.784
- 0.785 - 0.903
- 0.904 - 0.936
- 0.937 - 0.954
- 0.955 - 0.960
- 0.961 - 0.972

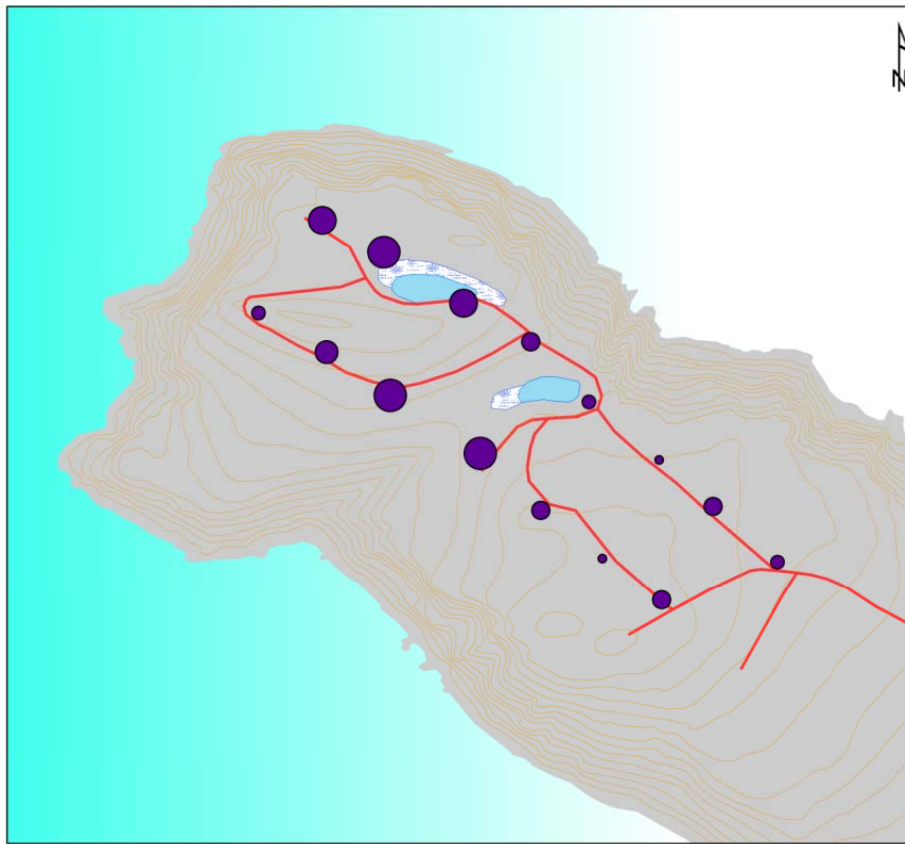


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Yaw motor activity



Slanting wind



Havøygavlen Vindkraftverk

Figure/Drawing Title:

Slanting Wind oct09-mar10

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Datum: WGS84 zone 35	Projection: UTM		

0 0.125 0.25 0.5 km

Legend

Slanting wind

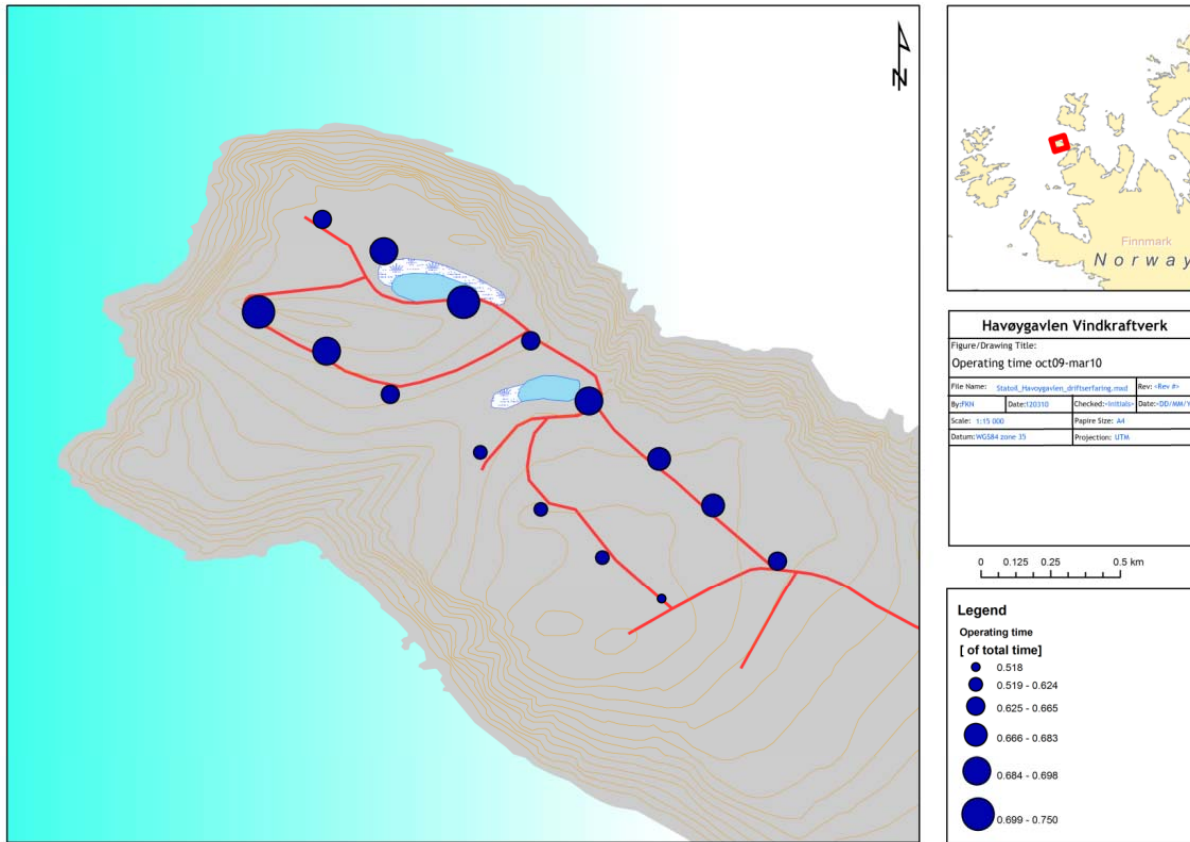
Accumulated hours [h]

- 1 - 3
- 4 - 11
- 12 - 28
- 29 - 37
- 38 - 51
- 52 - 97

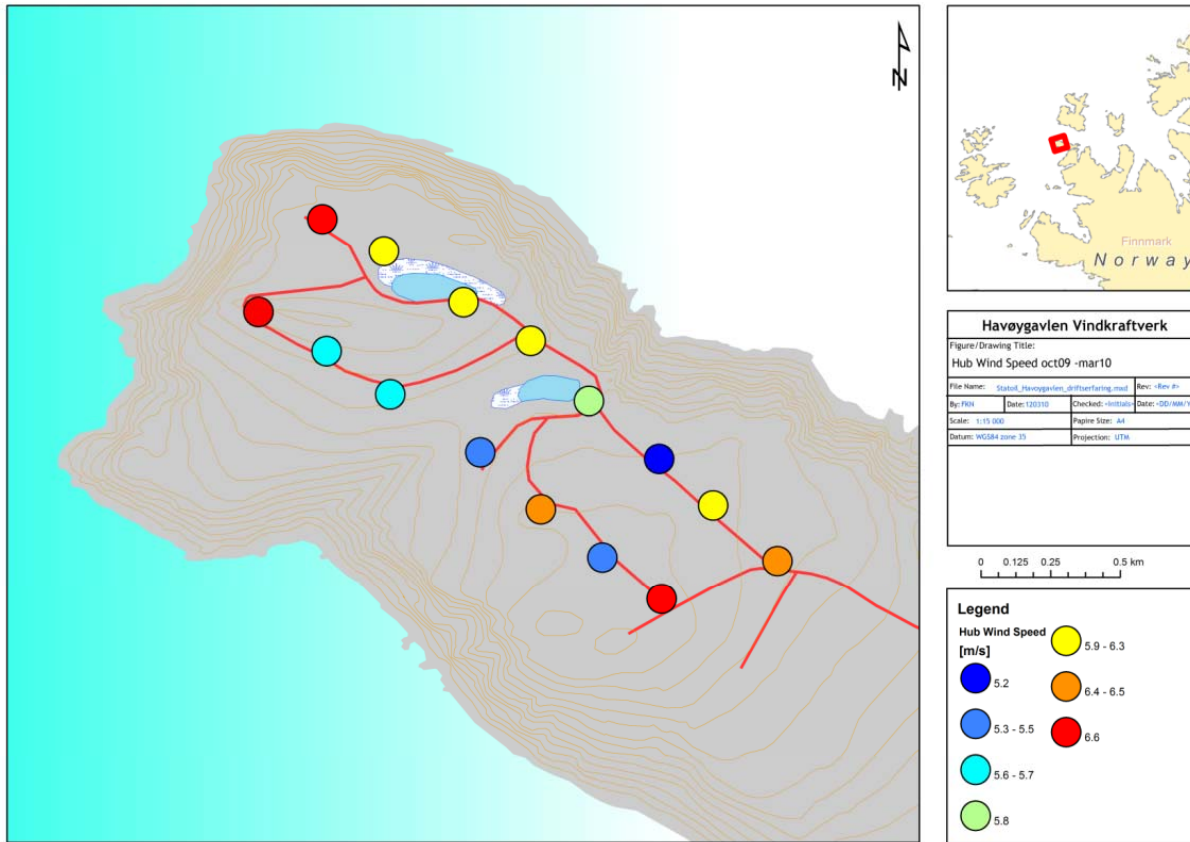


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Operating time



Hub height wind speed



Havøygavlen Vindkraftverk

Figure/Drawing Title:

Hub Wind Speed oct09 -mar10

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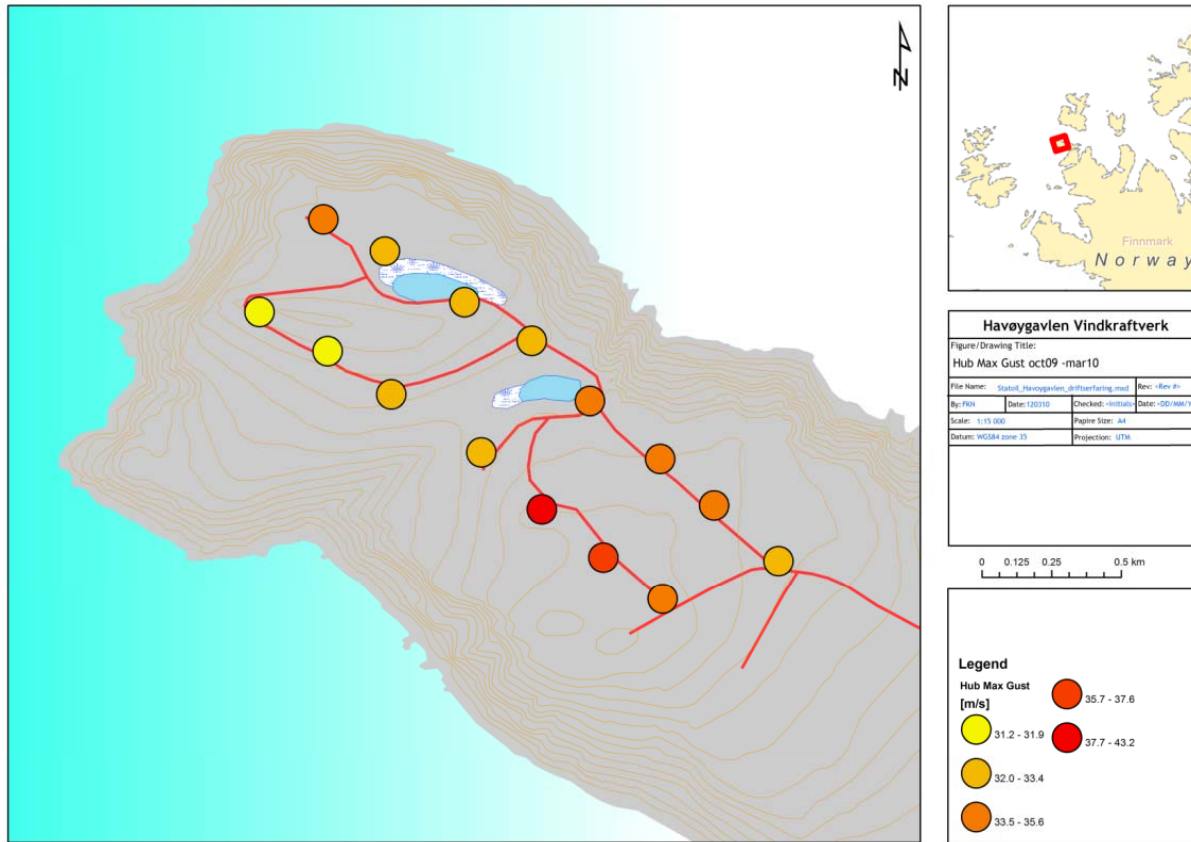
Legend

Hub Wind Speed [m/s]	Yellow circle	5.9 - 6.3
Blue circle	Orange circle	6.4 - 6.5
Light blue circle	Red circle	6.6
Cyan circle		
Light green circle		



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Maximum wind gust



Summary and conclusions

- The wind farm has not been able to capture the available energy in the wind due to low availability.
- Low availability caused by both technical and site specific issues.
- Havøygavlen WF has a local turbulence problem.
- Availability decreases with wind speed.
- Re-organizing the O&M has increased the availability significantly.
- Thanks to Statoil for preparing operational data.