

Wind Farm Performance Verification

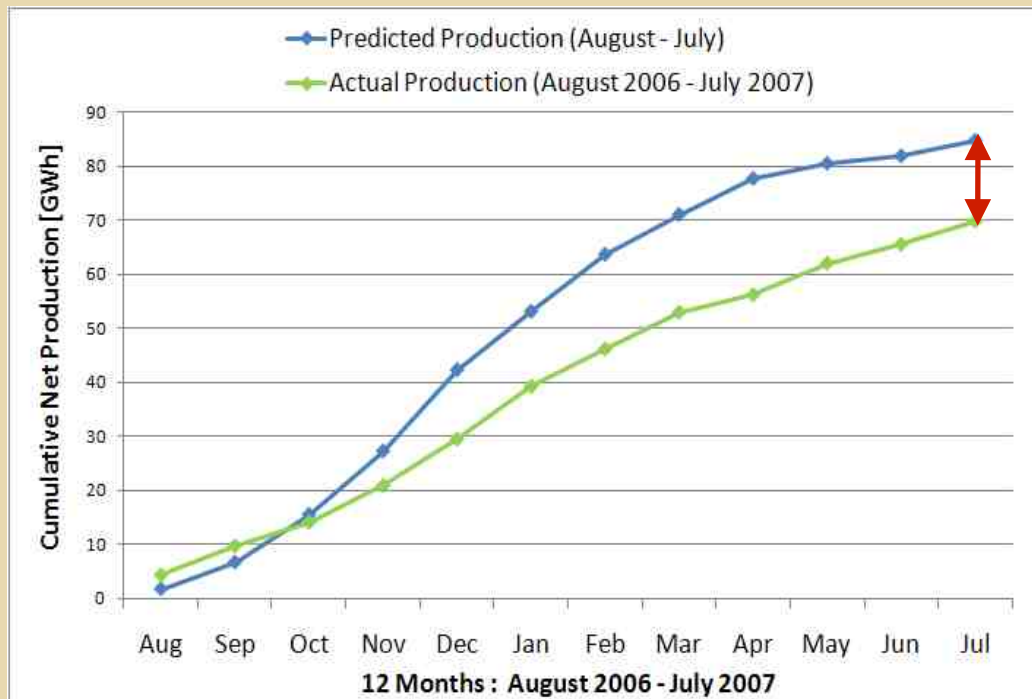
P. Stuart, A. Lucas, J. T. D. Slater, M. B. Anderson
Senior Technical Analyst

22 October 2008



Predicted Production vs. Actual Production

- Examine closely a single wind farm in RES's portfolio.
- Compare predicted production with actual monthly yields.



How do we close the gap?
(for future projects)

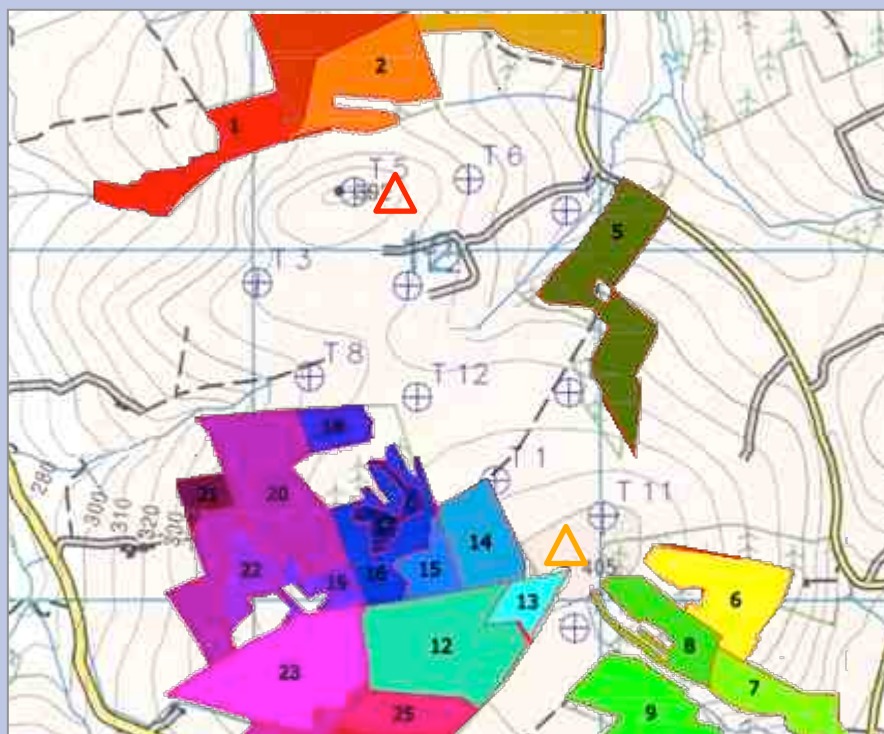
Predicted Annual Production = 78.5 GWh

Actual Annual Production = 69.7 GWh (11.2% lower than predicted)

Site Overview

- Moderately complex terrain. 11 multi-megawatt class turbines.
- Inhomogeneous forest cover 5-20m in height.
- Two 40m Masts (turbine hub height is 65m)

△ Mast A
△ Mast B

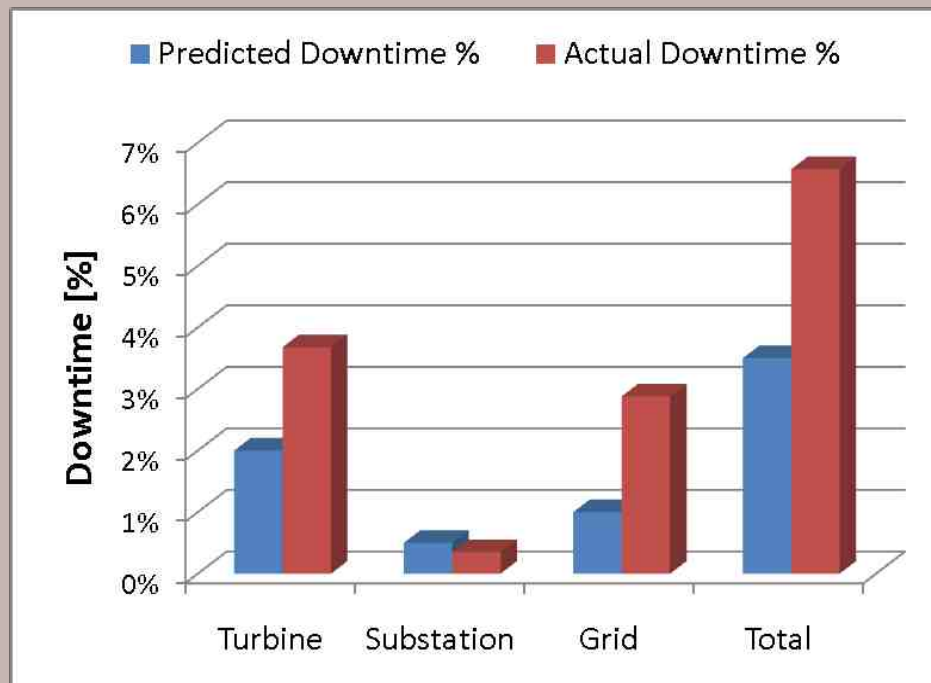


CURRENT FORESTRY MEAN HEIGHT (m)	GROWTH RATE	
1	12	0.4
2	15	0.4
3	15.5	0.4
4	10	0.5
5	10	0.5
6	6	0.5
7	16	0.5
8	8	0.4
9	8.5	0.5
10	9	0.5
11	11	0.5
12	12	0.4
13	9.5	0.3
14	7.5	0.3
15	8.5	0.3
16	11	0.3
17	12	0.3
18	10.5	0.3
19	9.5	0.3
20	13	0.3
21	16.5	0.4
22	12	0.4
23	16	0.5
24	17	0.5
25	15	0.5
26	16.5	0.5

Predicted Availability vs. Actual Availability

How often are the turbines, substation and grid unavailable?

- Prediction includes an adjustment for expected downtime.

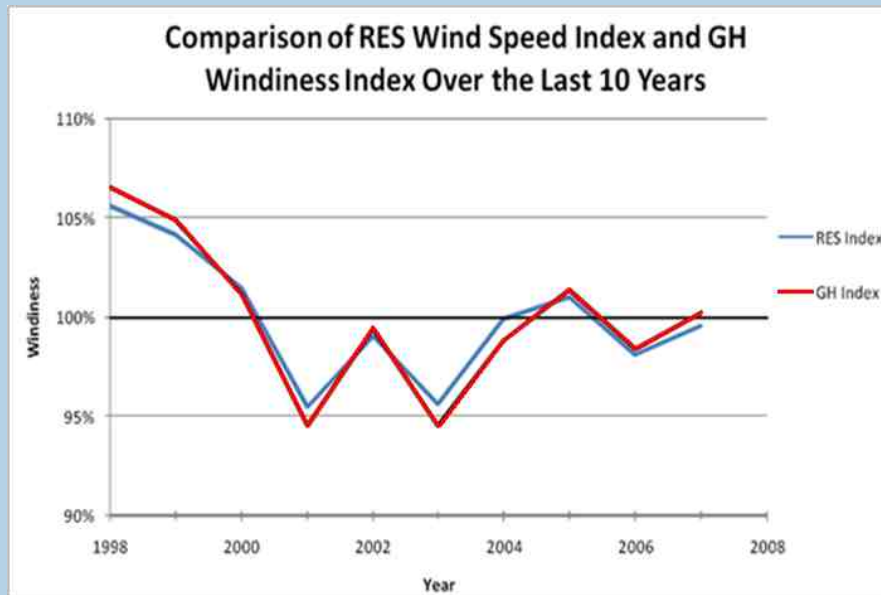


- Downtime = 100% - Availability
- Overall downtime is 3.41% higher than predicted.
- Correcting for availability still leaves 7.8% of over prediction to explain.

Inter-Annual Wind Speed Variation - Windiness

How windy is the year of operation under consideration?

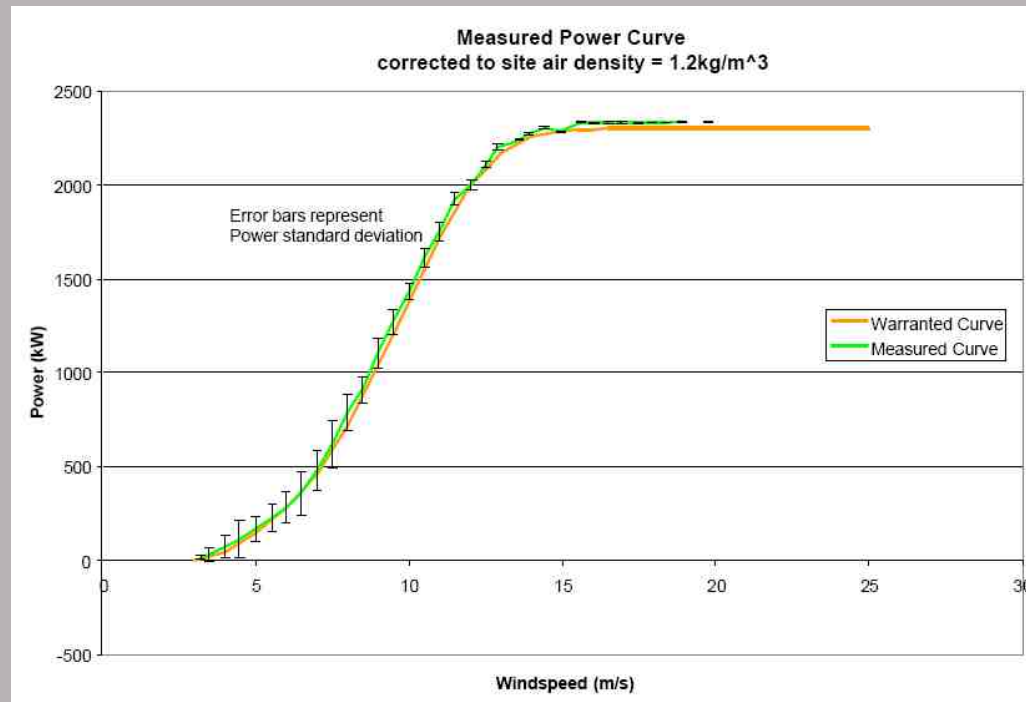
- Inter-annual wind speed variations are ~ 6%.
- For every 1% change in wind speed a 1.7% change in energy is expected.
- Classify windiness using reference station or a windiness index.



- RES Index → 3.3% underproduction.
- GH Index → 1.0% underproduction.
- Met station → 3.5% underproduction.
- Up to 3.5% of under production can be explained by low windiness between August 06 - July 07.

Power Performance

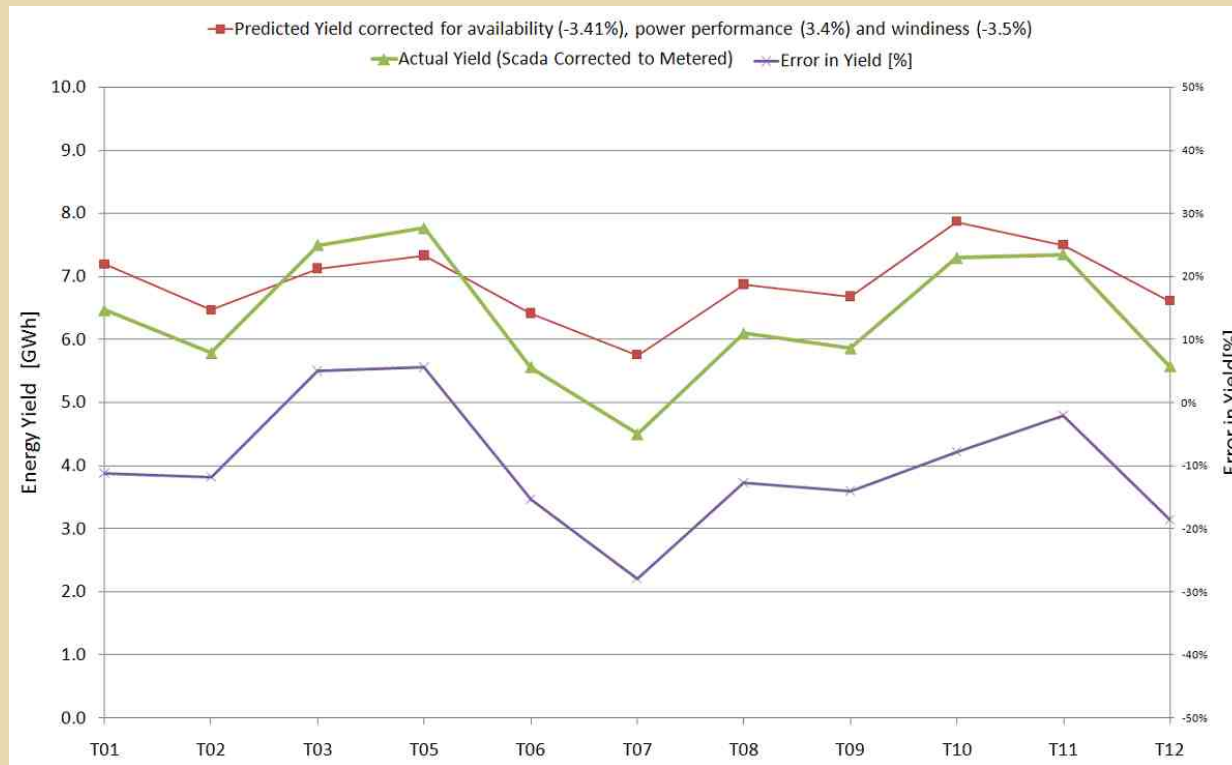
Are we getting the right amount of power for a given wind speed?



- Power performance (at T3) confirms that the turbines are not underperforming.
- In fact the Annual Average Energy Production at T3 is 103.4% ± 4.5%.

Individual Turbine Yields

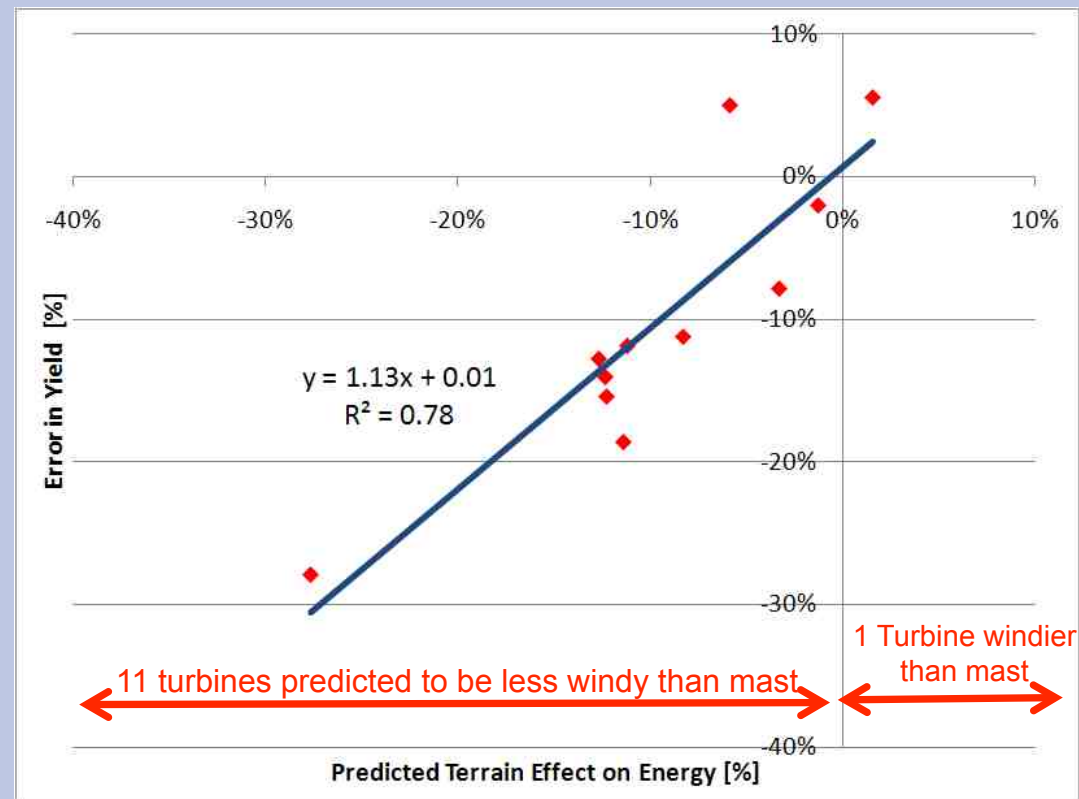
How do individual turbine yields compare with that predicted?



- Errors are too large to attributed primarily to the wake model (wake effects ~10%).
- The roughness / orography models appear to underestimate the level of variation across the site.

Wind Flow Modelling

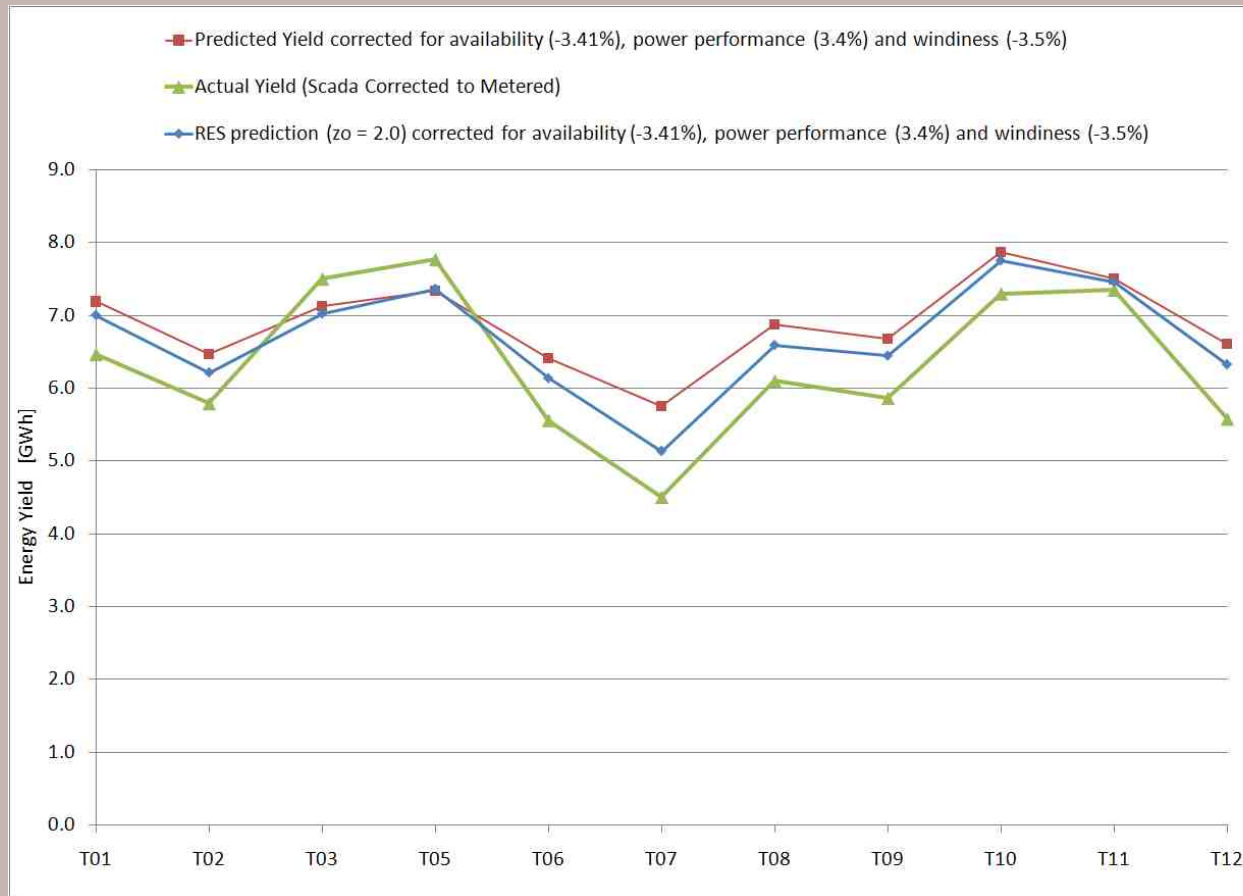
- Plot error in yield vs. predicted terrain effect



- Error correlates with the predicted terrain effect.

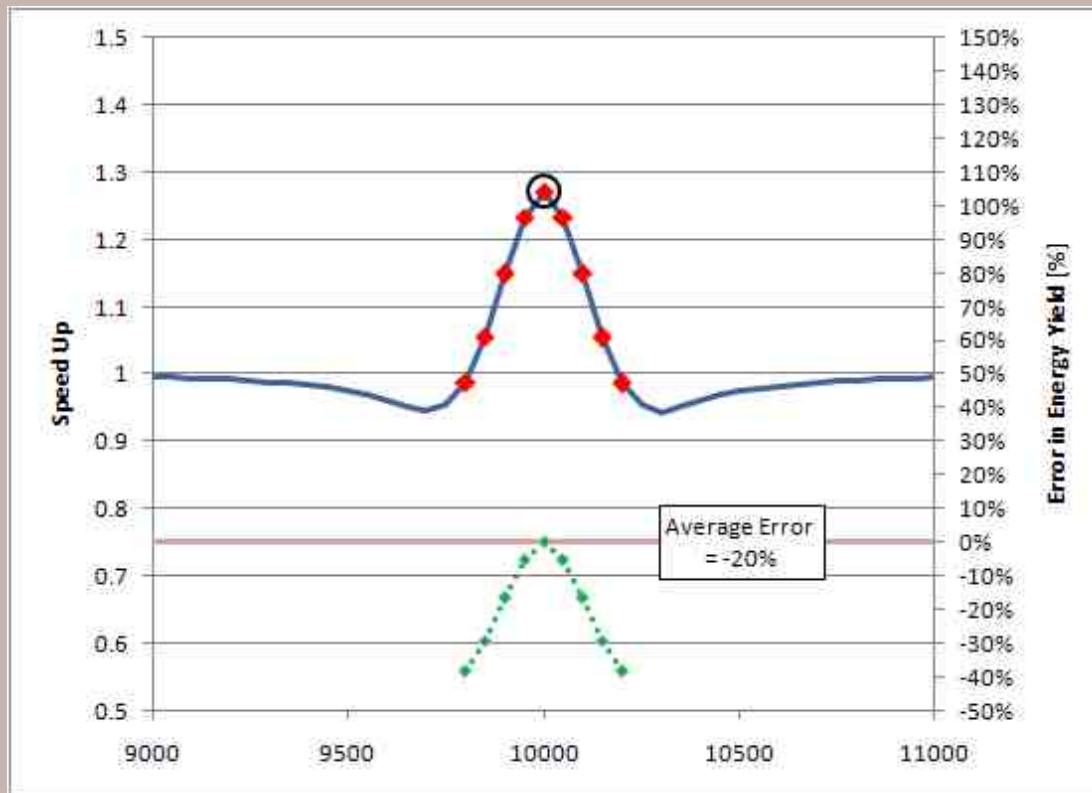
Wind Flow

Increasing roughness in orography model improves agreement.



Symmetric Hill

- Consider 9 turbines on a symmetric hill.
- Assume a 1.7% change in yield for a 1% change in wind speed.
- Assume Error in Yield \approx Terrain Effect (as on example wind farm).



- Placing the mast at the base of the hill results in 7 turbines being under-predicted.
- Placing the mast at the top of the hill results in 8 turbines being over-predicted.
- Placing mast half way up the hill minimises the error.

Conclusions

- Availability and windiness are two major reasons for the difference between the predicted and actual yields.
- The power performance of the turbines exceeds expectations.
 - Underperformance of the wind farm is not due to the underperformance of the turbines.
- The choice of meteorological mast location is crucial. Placing the mast on top of the hill causes a systematic over prediction of turbines lower down the hill.
- Installing multiple meteorological masts is a further means of mitigating the limitations of flow models.
- Increasing the roughness within the orographic model is found to improve agreement.
- More work needed; more years of operation, other wind farms etc.

nes

power for good