Renewable energy consultants

GL Garrad Hassan

Banking on Wind: Resource Assessment

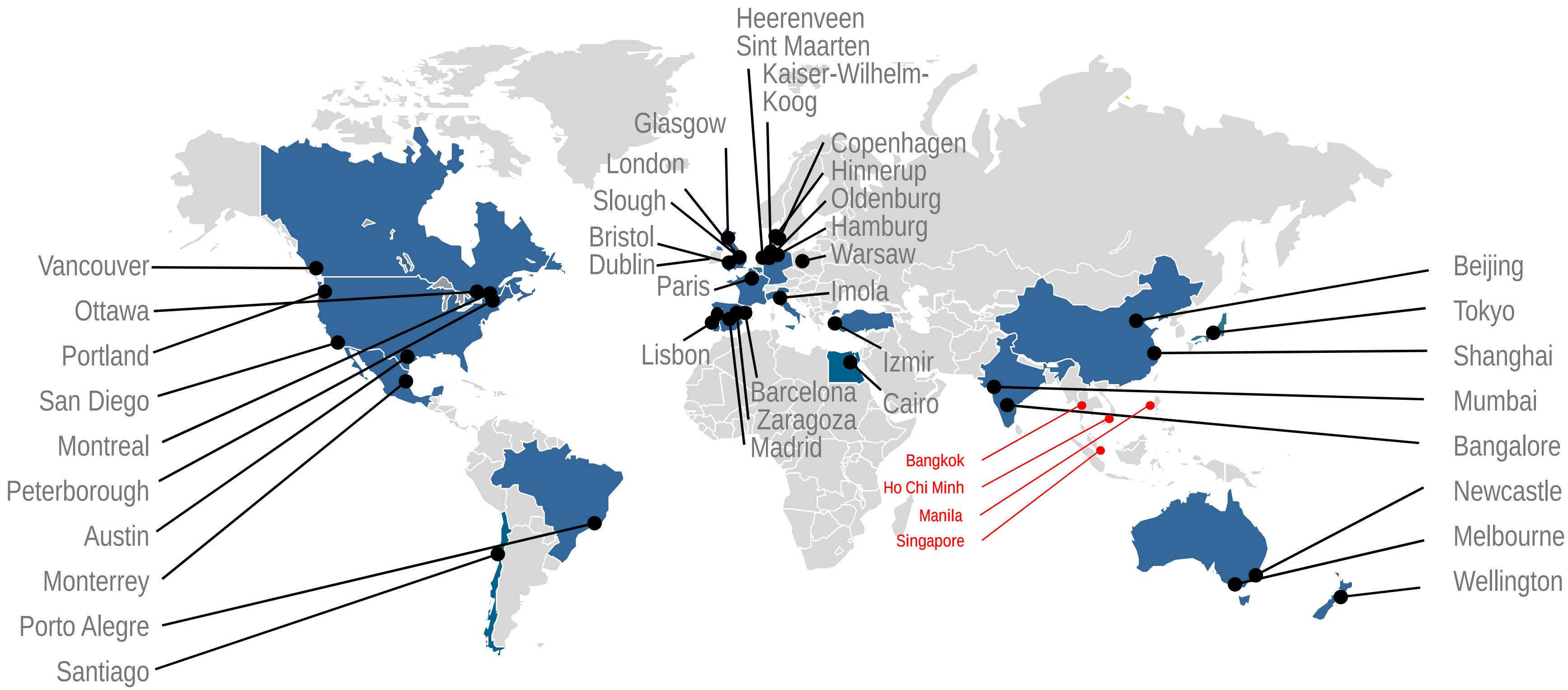
Graham Slack

Quantum Leap in Wind Power in Asia Forum

June 2011

GL Garrad Hassan

825 staff, in 41 locations, across 22 countries and 5 continents



Locations in red denote GL partner offices in the region.

Based On Experience

Since 1984 - over 25 years experience in the sector

Wind Farm Energy Assessment

- analysing 20,000 MW of new projects per year
- 25% of all projects worldwide

Operational Assessment

- 15% of the world's installed capacity

Due Diligence

- over 25% of the world's project financed wind farms
- world's largest wind farm portfolio acquisition

Independent Engineer

- the world's five largest wind farm financings
- the first project financed offshore wind farm

Short Term Forecasting

- over 20% of the world's operational wind capacity

Wind Resource

Wind resource is fundamental

- energy is proportional to V^3
- Small wind error > large energy error

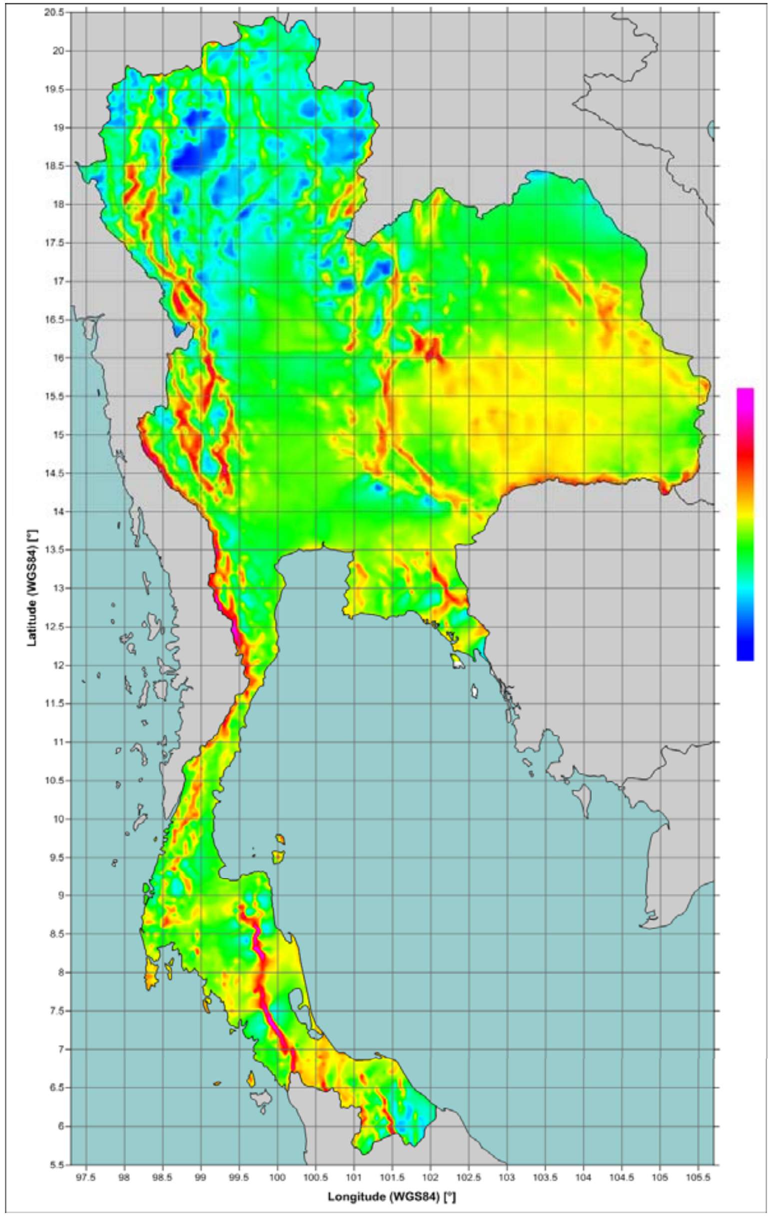
Mean wind speed AND distribution

- Mesoscale wind maps for site ID
- Reference wind data crucial

Assessment of energy production is a critical project risk

Wind is critical input to energy prediction

So good wind monitoring is a critical project need



Methodology Overview

Analyse and predict the long-term wind regime at site masts

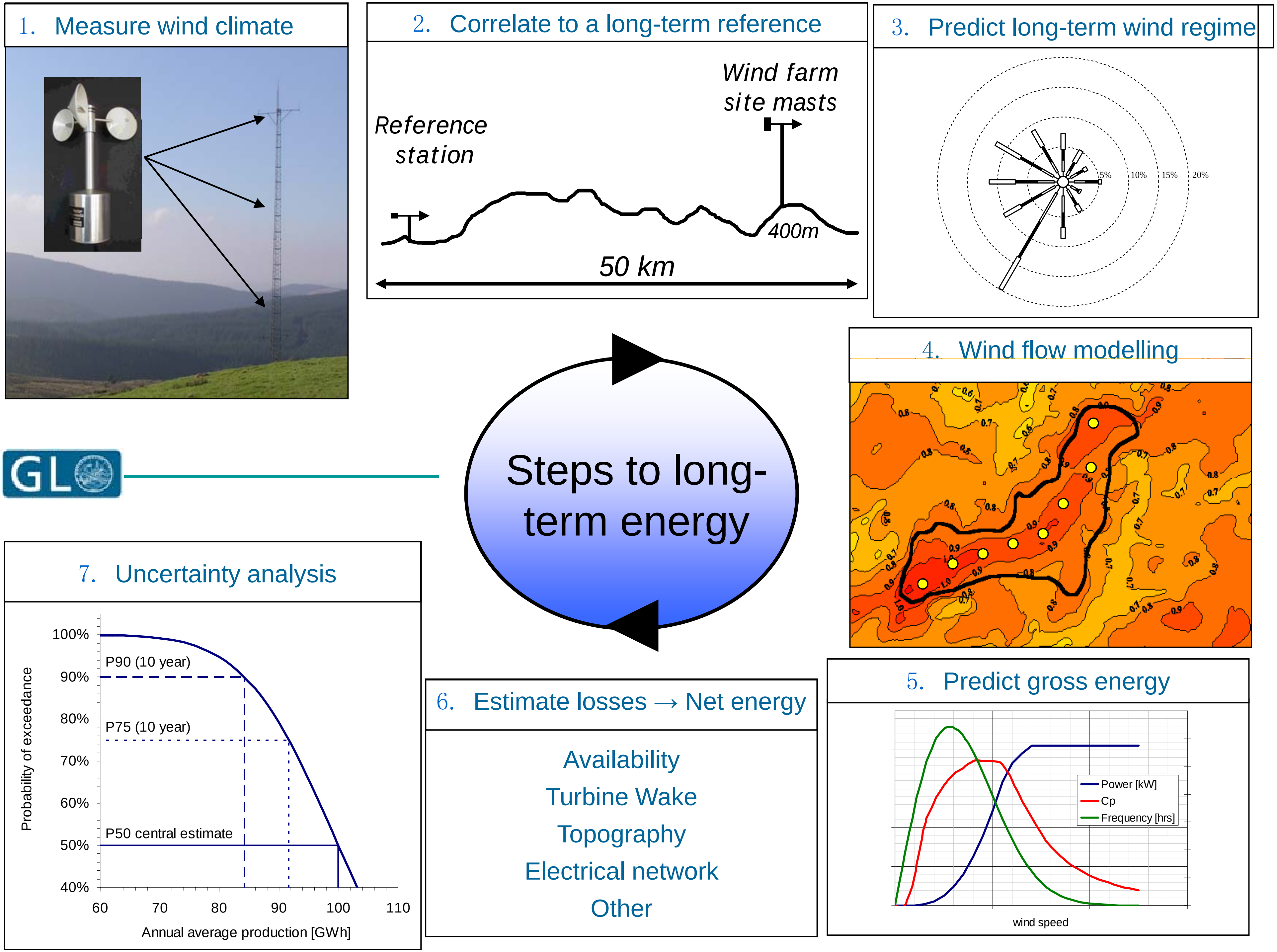
Predict the wind speed variations over the site

Predict gross energy output of all turbines

Predict likely energy losses

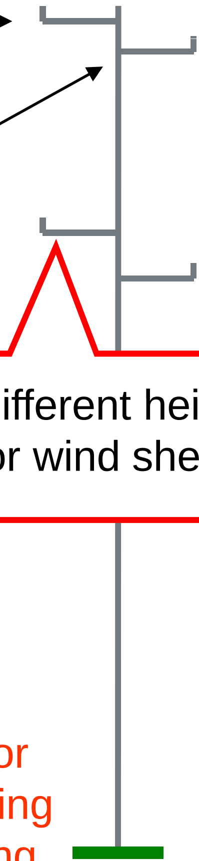
Result: Predicted long-term net energy output of the wind farm

At each step quantify the mean value AND the uncertainty



1. Measure wind climate
2. Correlate to a long-term reference
Wind farm site masts
Reference station
400m
50 km
3. Predict long-term wind regime
5%
10%
15%
20%
4. Wind flow modelling
Steps to long-term energy
5. Predict gross energy
Power [kW]
Cp
Frequency [hrs]
wind speed
6. Estimate losses → Net energy
Availability
Turbine Wake
Topography
Electrical network
Other
7. Uncertainty analysis
100%
90%
80%
70%
60%
50%
40%
P90 (10 year)
P75 (10 year)
P50 central estimate
Probability of exceedance
60
70
80
90
100
110
Annual average production [GWh]

1. Measure wind climate

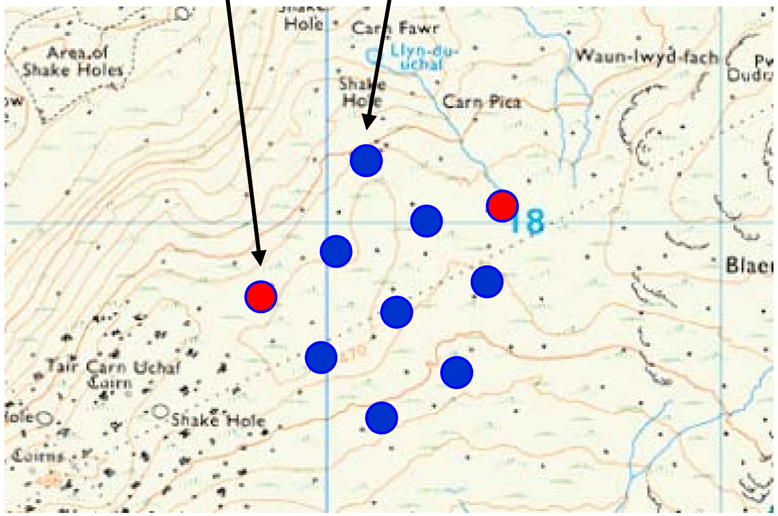


Good quality instruments
Close to hub height
Mounting on mast
> One year of data
Calibration & records

Different heights for wind shear

Care for shadowing and icing

Masts in red   Turbines in blue



Masts at representative locations <1km

Care for local features & flow separation issues

Uncertainty can be minimised through well designed measurement plans

2. Correlate to a long-term reference

Short-term measurement

Site data

Long-term measurement

Reference station

Absolute accuracy not vital

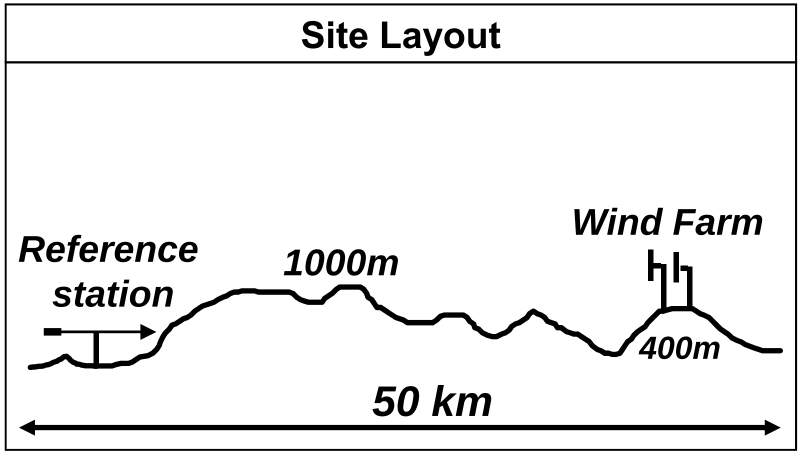
Consistency is vital

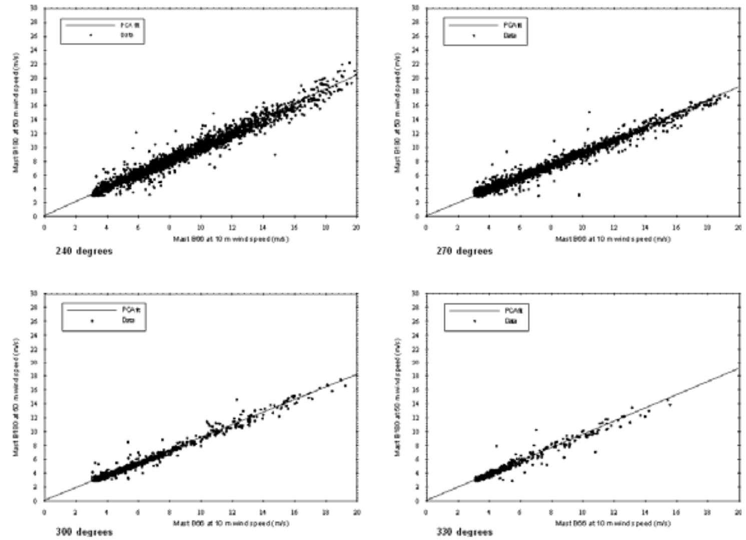
Often there is no reference station

Inspect reference site

Methodology

Measure Correlate Predict (MCP)

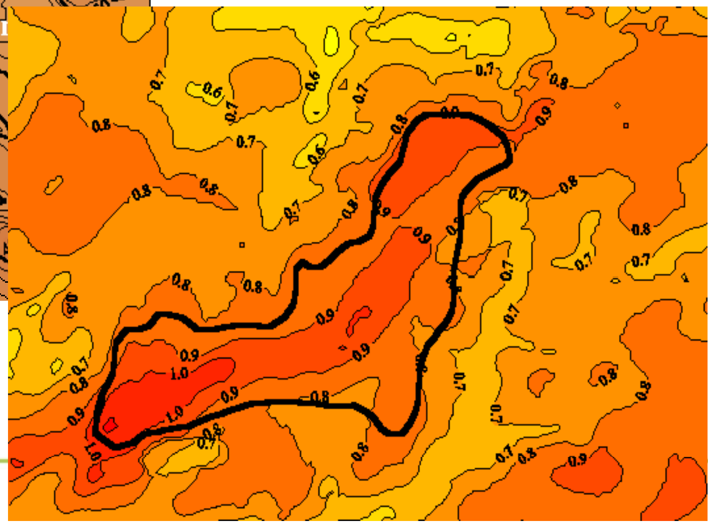




3. Wind flow modelling

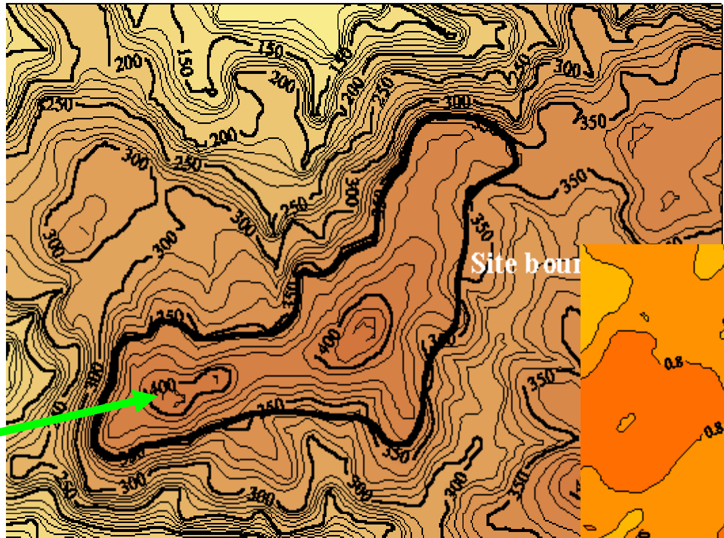
WAsP model is most common
CFD is appearing but be careful –
different and complicated does not mean better

Wind speed map



Mast

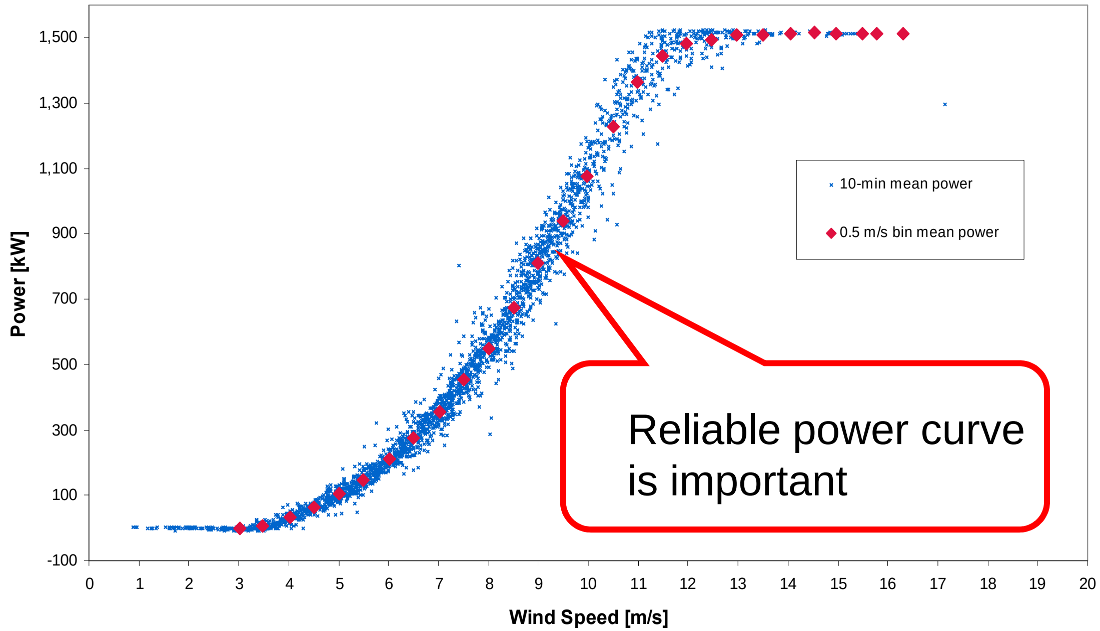
Terrain Map

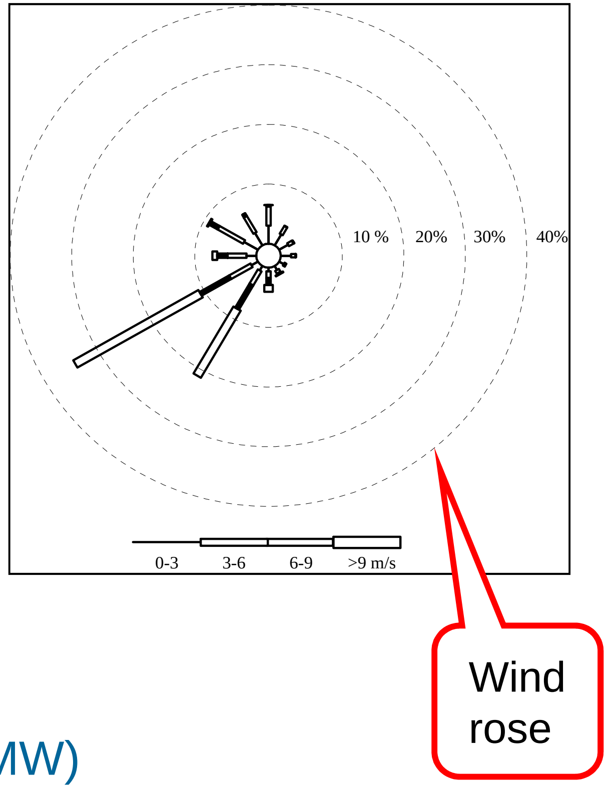


Human Intervention

This process has uncertainty

4. Predict Gross Energy





Combine:

Power curve – power output at each wind speed (MW)

Wind distribution – time spent at each wind speed over one year (hours)

Gives total MWh in each year

Losses: minimise by modelling wake and topographical losses

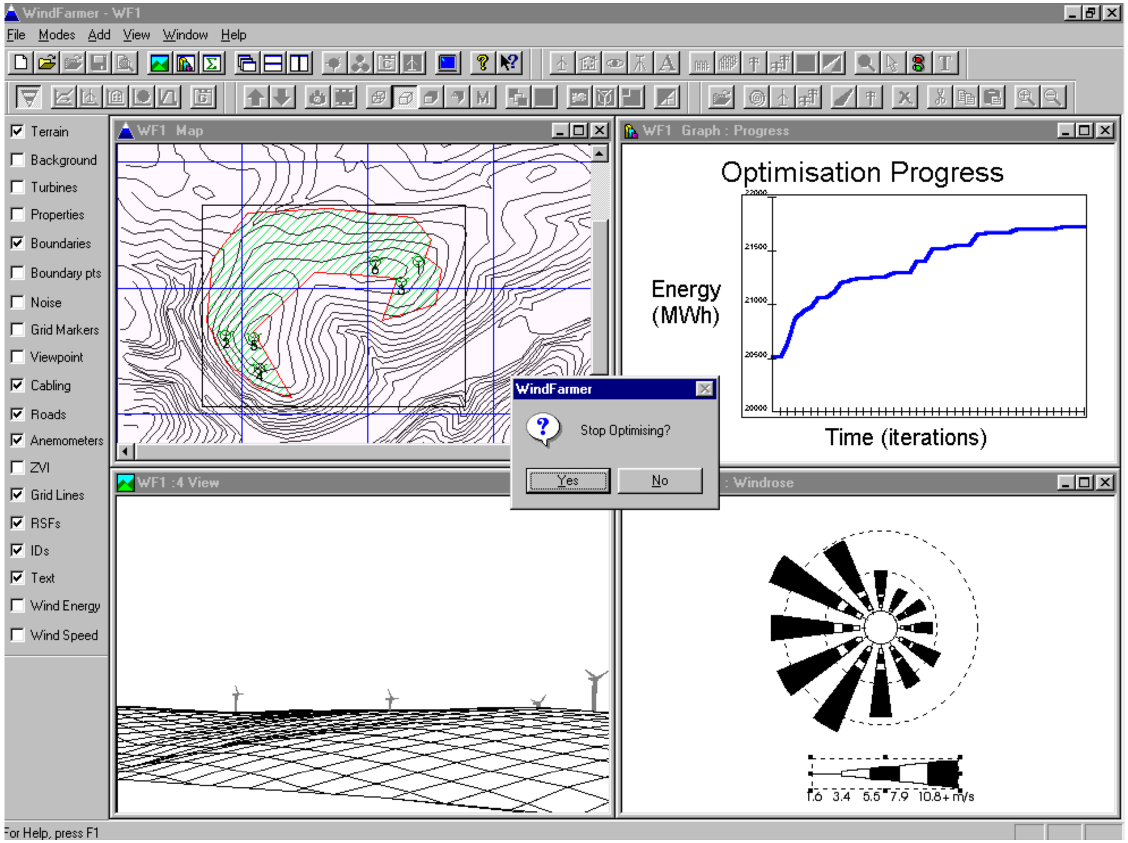
If turbine spacing too small, reduced energy and high turbulence: -ve turbine life

So preferred layout is a compromise between highest wind areas, low wake effects

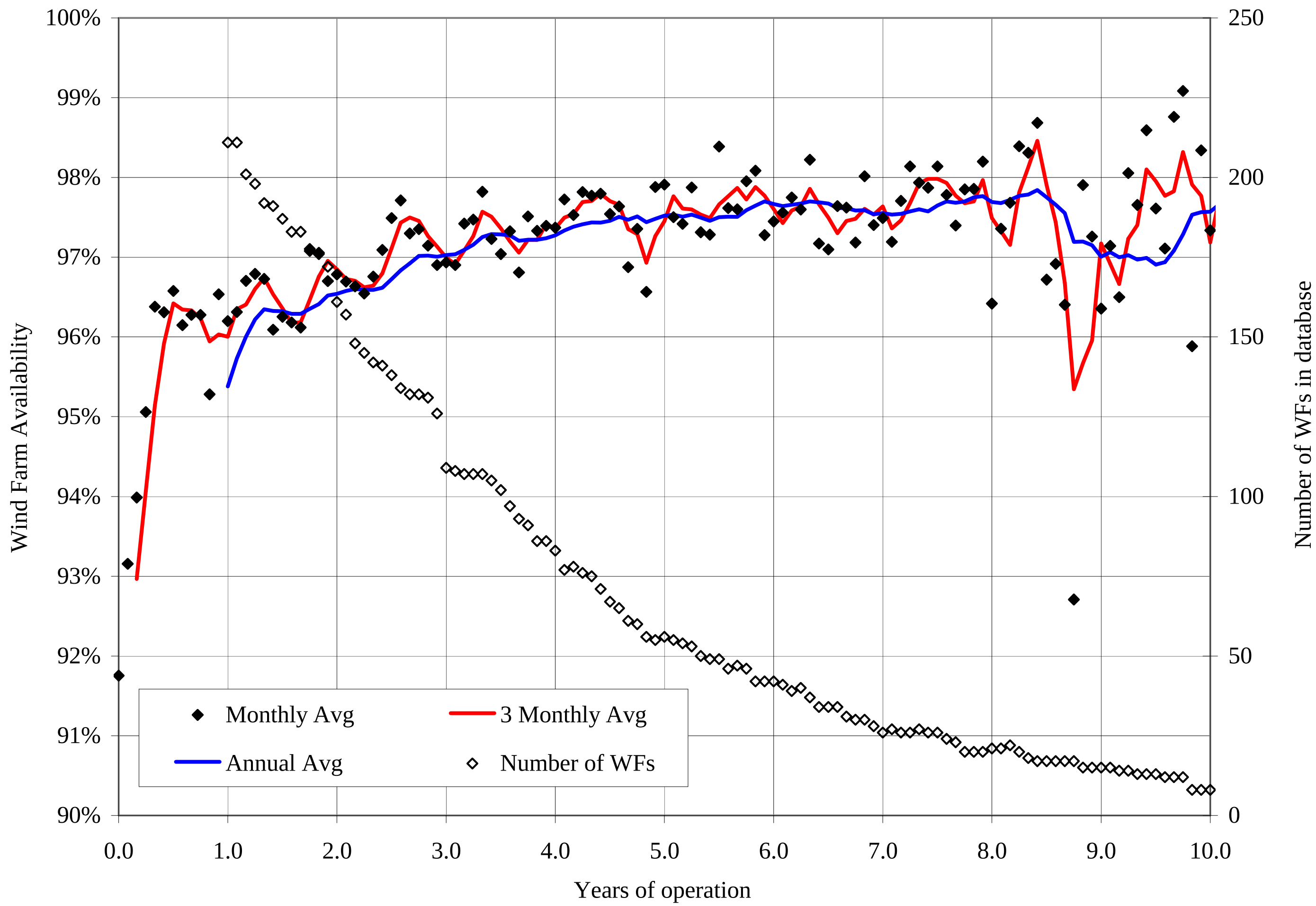
Analytical tools exist for wind farm modeling, including wake losses

This allows optimised layouts to increase energy capture

WindFarmer is one example



Losses: Turbine availability



Result: Net energy prediction

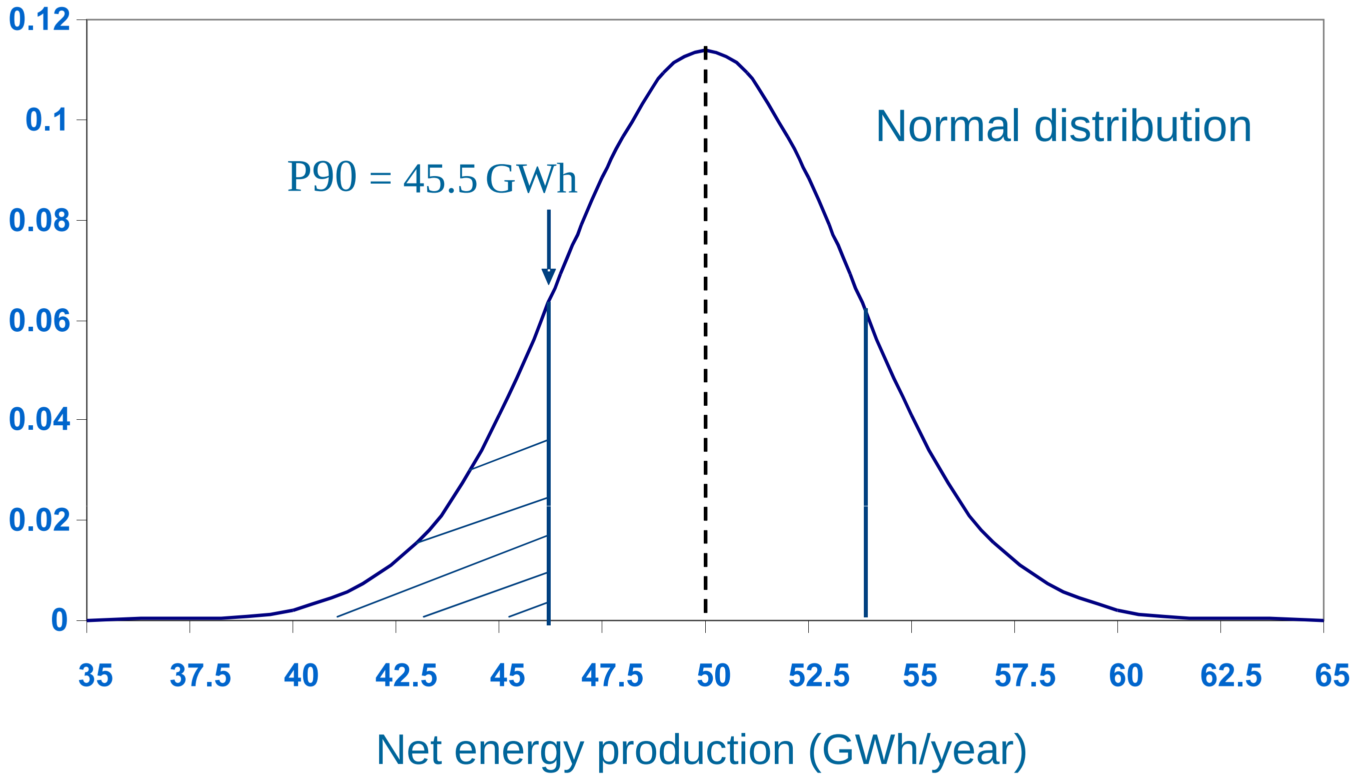
Rated Power	**50**	**MW**
Gross Output	**170**	**GWh/annum**
Wake effect	98.7%	Calculated
Electrical efficiency	97.0%	Calculated
Availability	97.0%	GH assumption
Icing and blade degradation	99.5%	GH assumption
High wind hysteresis	99.2%	Calculated
Substation maintenance	99.8%	Typical value
Utility downtime	100.0%	GH assumption
Power curve adjustment	98.5%	GH assumption
Columnar control loss	100.0%	GH assumption
Cold weather shut down	100.0%	GH estimate
Wake effect of future projects	100.0%	GH assumption to be covered in the Finance Agreement
Net output	**153.2**	**GWh/annum**

Result: Uncertainty

Source of uncertainty	Wind speed		Energy output	
	[%]	[m/s]	[%]	[GWh/annum]
Anemometer accuracy	2.5%	0.21		1.4
Consistency of reference	1.0%	0.08		0.6
Correlation accuracy Mast A to Mast B	1.4%	0.12		0.8
Shear 40 m to 60 m	2.0%	0.17		1.1
Variability of 8.8 year period	2.0%	0.17		1.1
Overall historical wind speed		**0.35**		**2.3**
Wake and topographic calculation			4.0%	1.3
Performance and availability			1.0%	0.3
Substation metering			0.3%	0.1
Future wind variability (1 year)	6.0%	0.50		3.4
Future wind variability (10 years)	1.9%	0.16		1.1
Overall energy uncertainty (1 year)				**4.3**
Overall energy uncertainty (10 years)				**2.9**

Probability Distribution

- Mean = 50 GWh/year
- Standard deviation = 3.5 GWh/year (in this example)

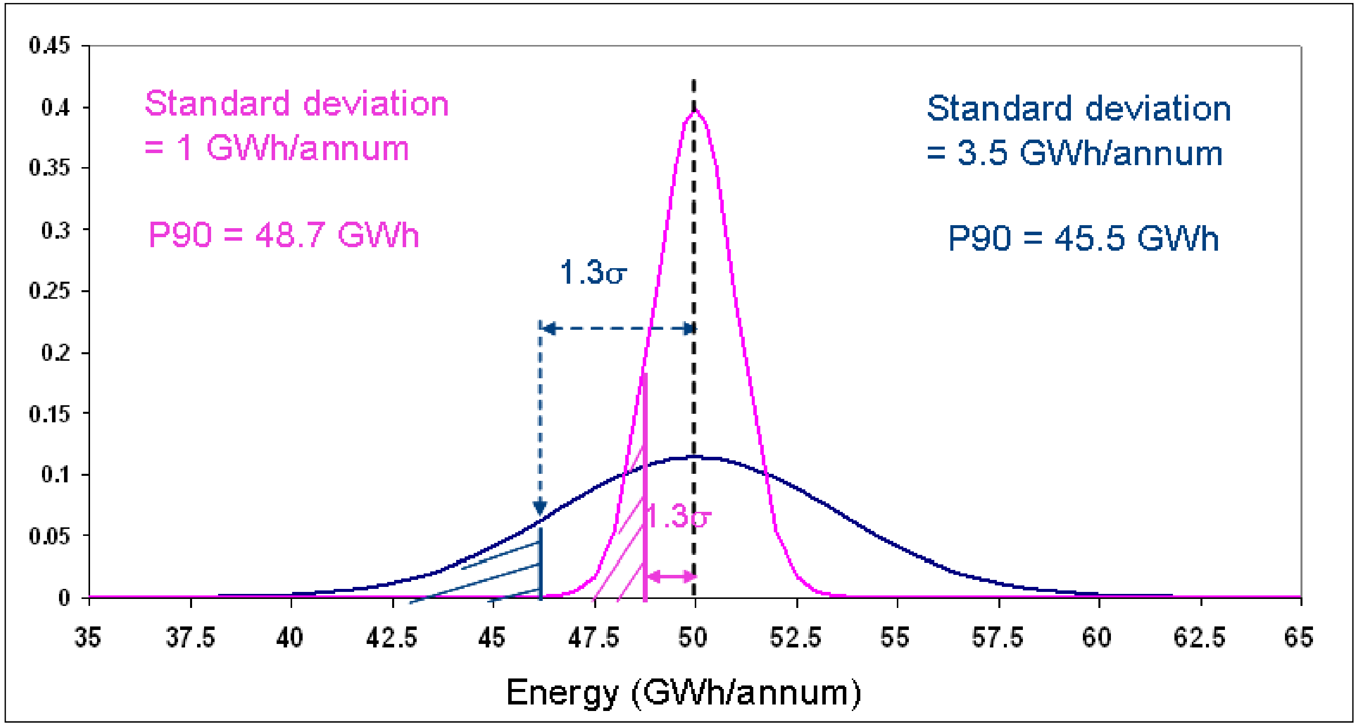


Financing Issues

Uncertainty in energy production dependant on several issues

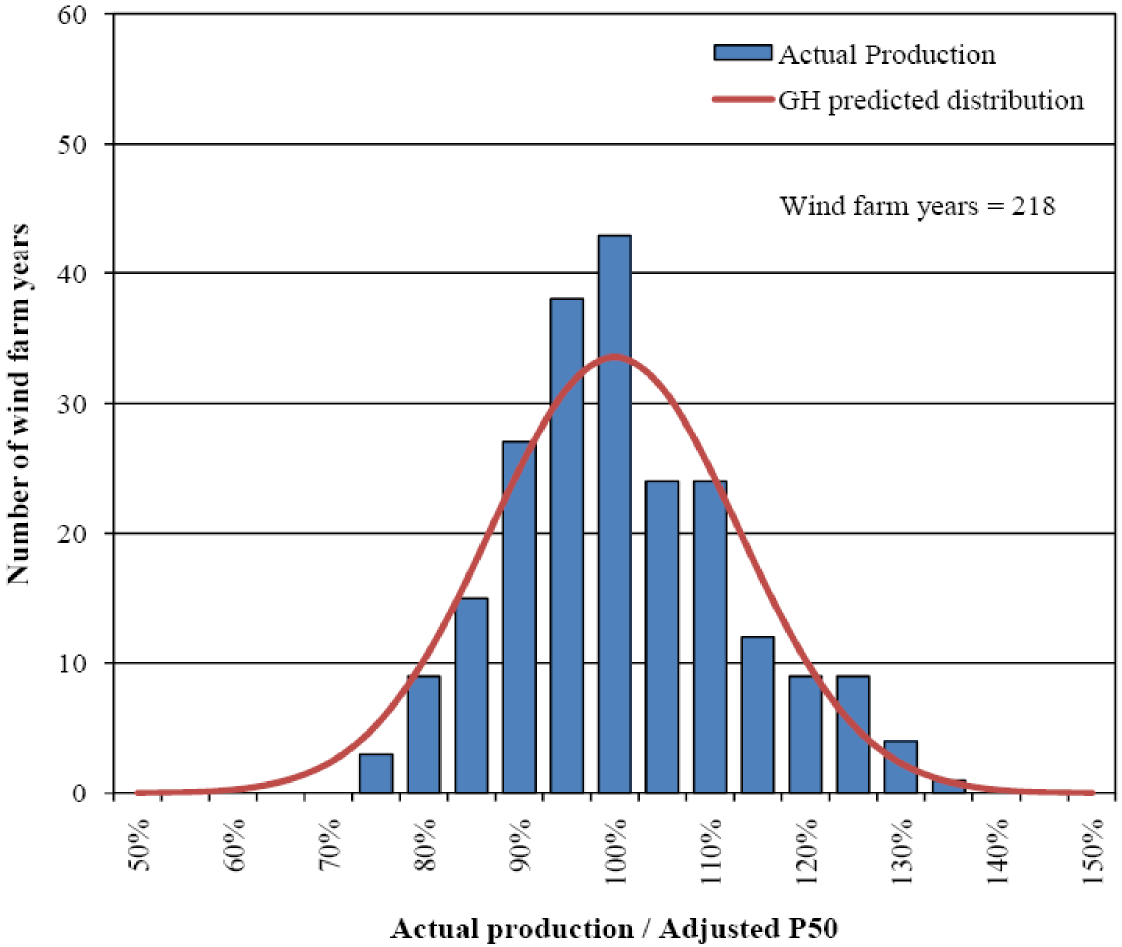
- Monitoring plan for site, grid reliability, supply warranties, O+M contracts, turbine reliability and availability

Uncertainty reflected in probability of exceedence values:



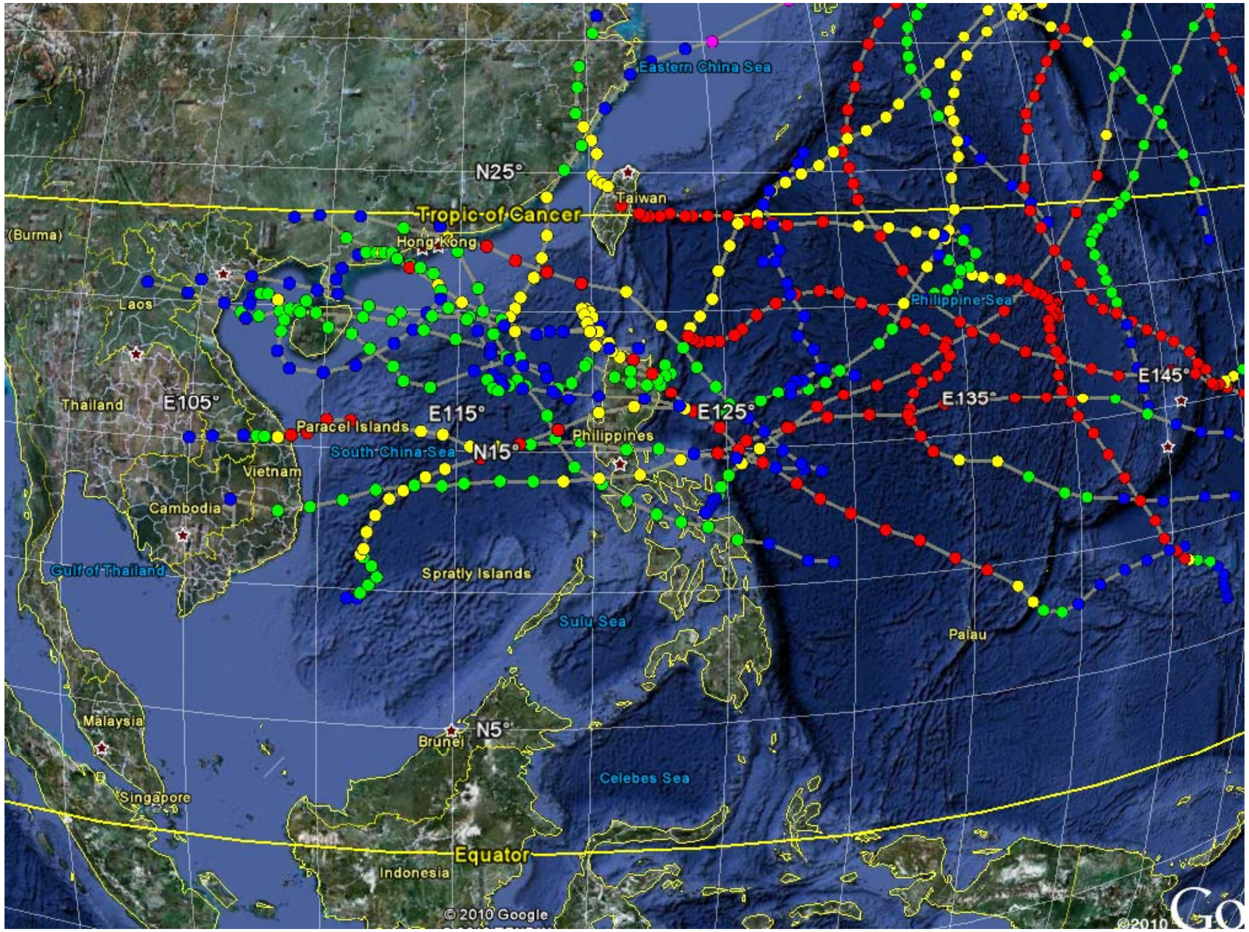
Validation of methodology – UK data

Adjusted for windiness and availability, using current methods
Actual/predicted P50 values = 100.2%



Other benefits of measurement - Extreme wind speeds

Typhoons frequent over much of north Pacific (2009 data):



Conclusions

Accurate wind assessment is critical
- Good quality instruments
- Well mounted to avoid flow distortion
- Adequate number of tall masts
- Calibration and records

Combine with reference data to assess the long-term wind resource

Uncertainty assessment is critical to assess technical risks

Enough operational data to demonstrate the analytical process is robust: confidence for investors and lenders