Operating wind farm monitoring and performance optimization

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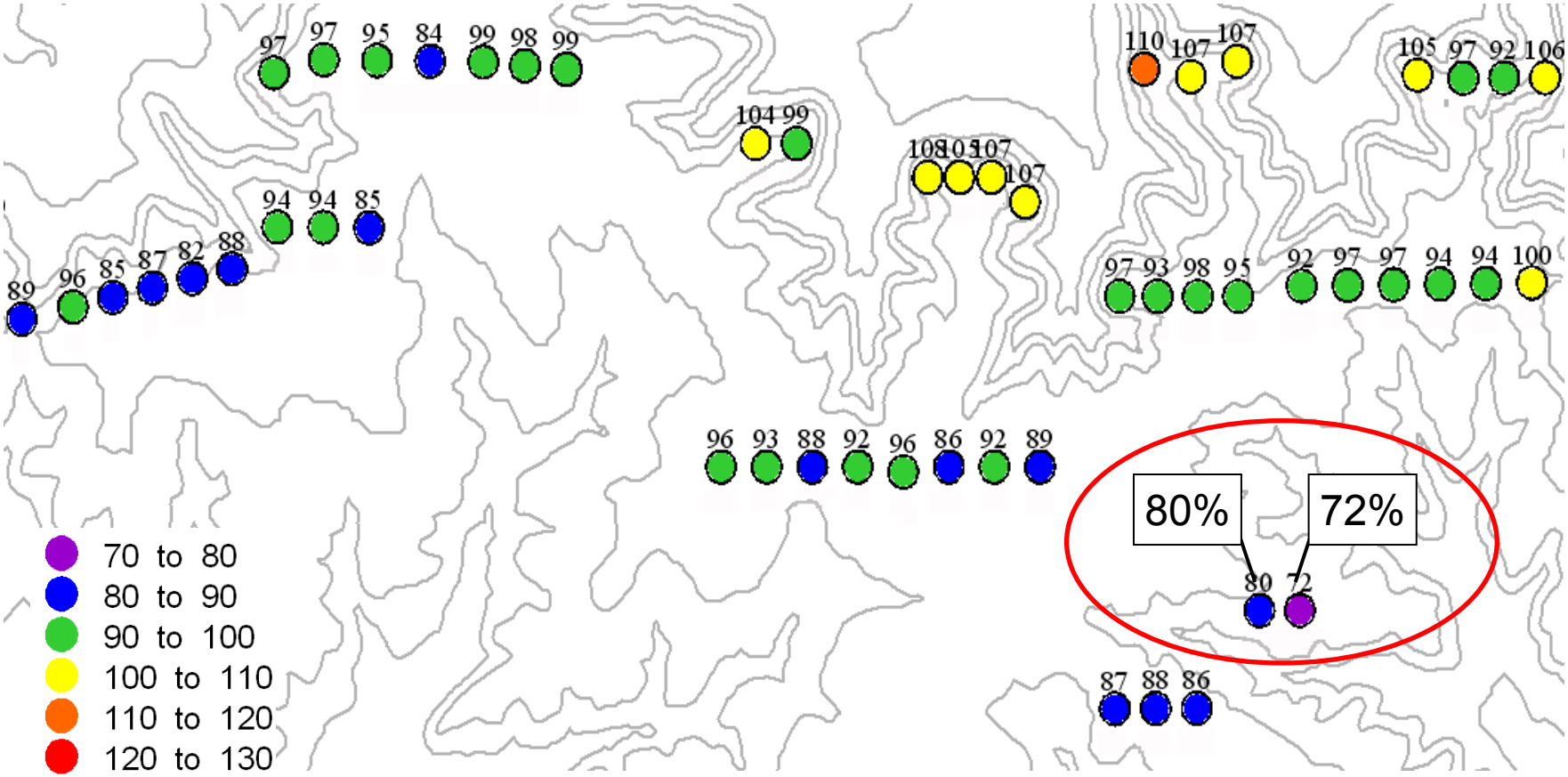
Wind farm performance map



% of average turbine production

Why analyze your operating wind farm?

- Understand individual turbine performance and identify frequent faults
- Quantify discrepancies between actual and forecast energy production
- Minimize uncertainty in the long-term forecast
- Maximize wind farm value

1% production loss on a 100MW wind farm results in $250k revenue loss

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Actual versus forecast production

Main causes of the energy production discrepancies:

1) **Windiness of operational period**
2) **Power performance**
3) **Availability**
4) **Uncertainty associated with the long-term forecast**

Effects of turbine performance and availability on production are controllable by analyzing operating wind farm data.

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Operational wind farm analyses – our experience

- GH has carried out performance analysis / monitoring of over 10GW of wind farms
  - Close to 15% of worldwide installed capacity
- In many cases corrective actions were successfully implemented following a GH performance assessment resulting in enhanced revenue
- Work to date has involved internationally widespread wind farms with operational periods from 6 months up to 15 years
- Over 1,000 wind farm years (or 25,000 turbine years) of operating wind farm production data studied to date

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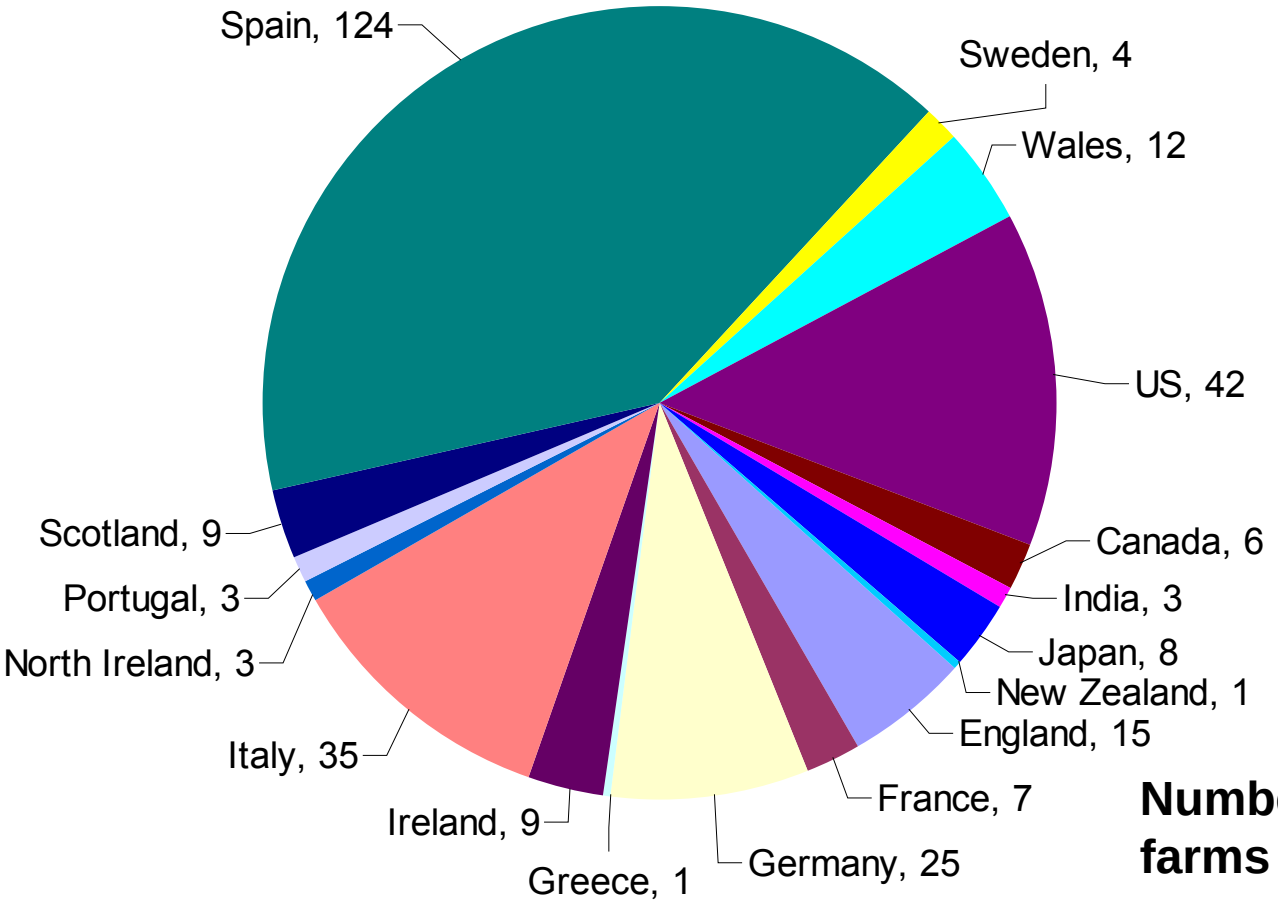
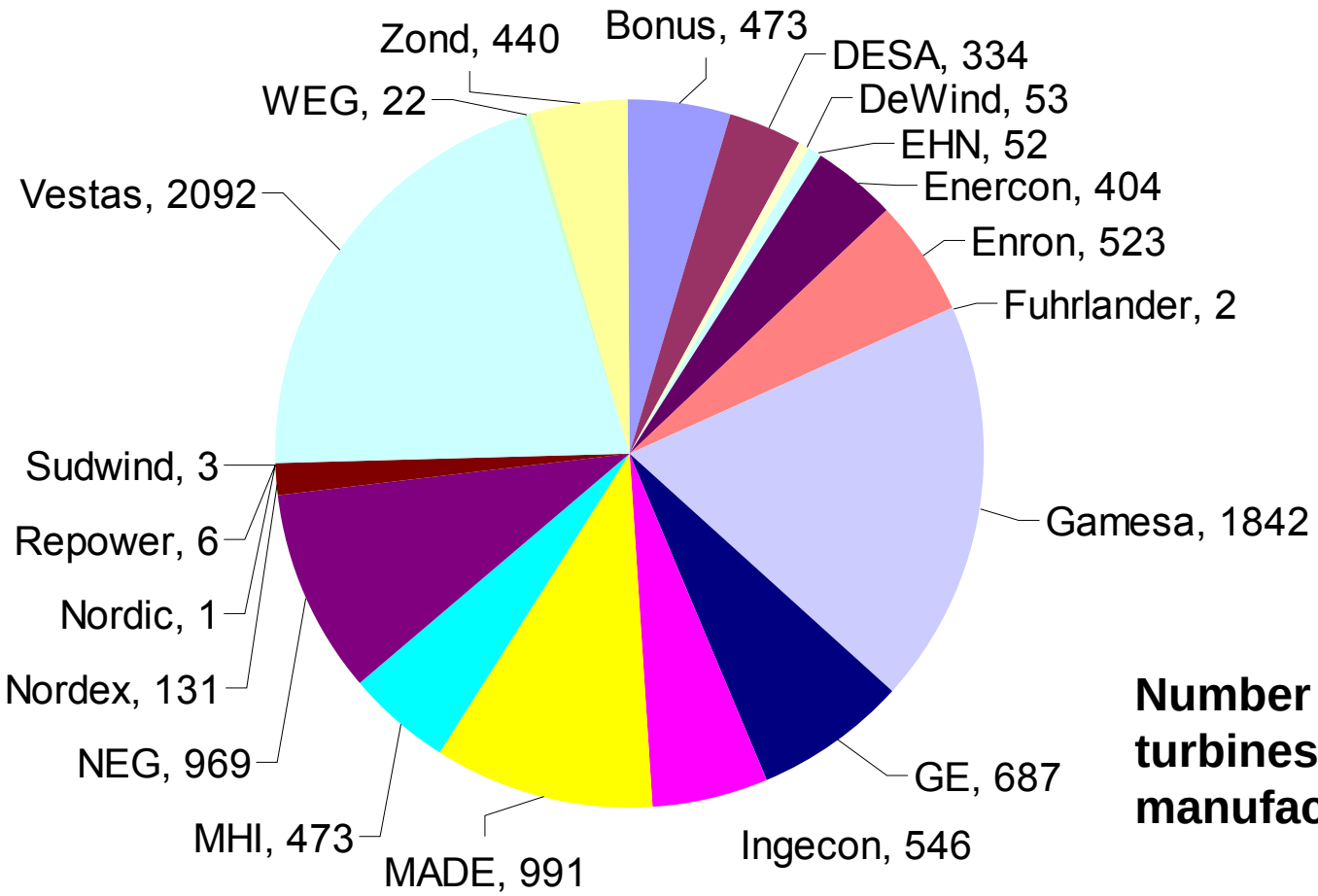
Operational wind farm analysis by country



Number of wind farms per country

Operational wind farm analysis by turbine manufacturer



Number of turbines per manufacturer

Detailed analysis of operating wind farm data

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Use SCADA data to:

- Graphically represent a wind farm's operation in time lapse animation
- Identify changes in power performance
- Assess availability
- Quantify energy losses / gains
- Estimate long-term energy

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Identify changes in power performance

Detailed Forensic analysis of SCADA data techniques are needed

Examples:

- Pitch control malfunction
- Blade damage / fouling
- Control program problem
- Blade angle resetting (stall regulated turbines)
- Aerodynamic enhancements
- Constrained operation

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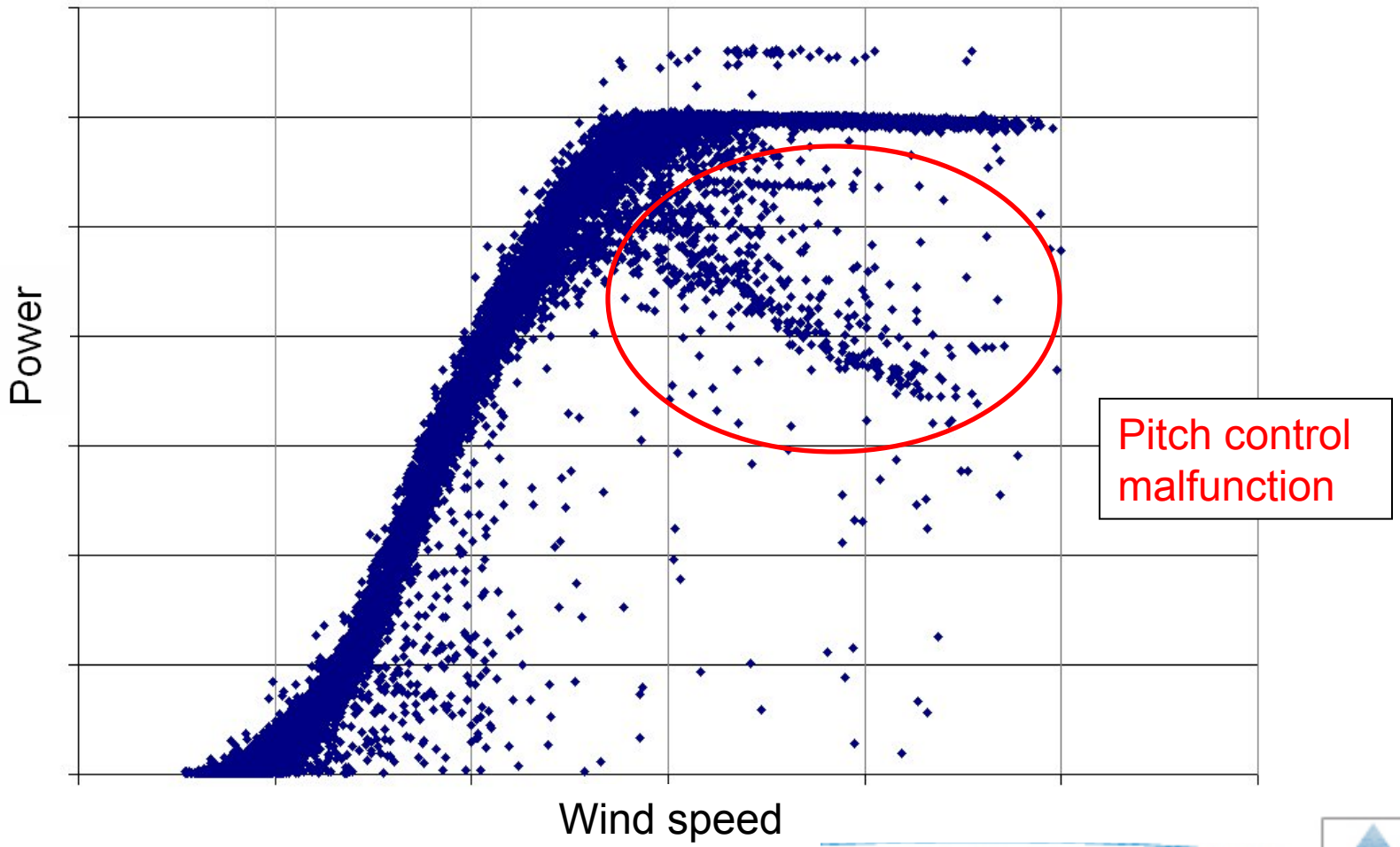
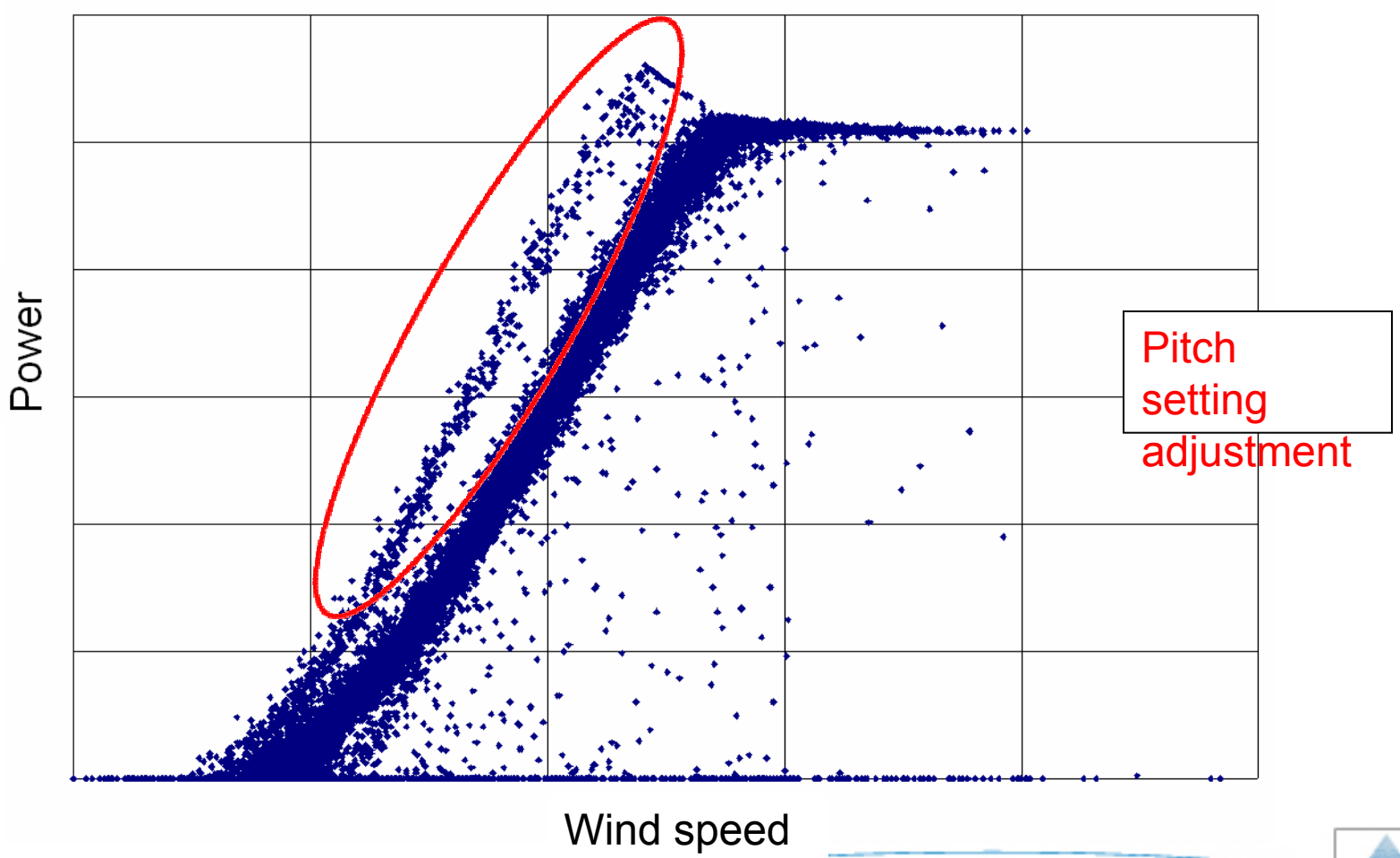
Example of poor power performance



Additional example of poor power performance



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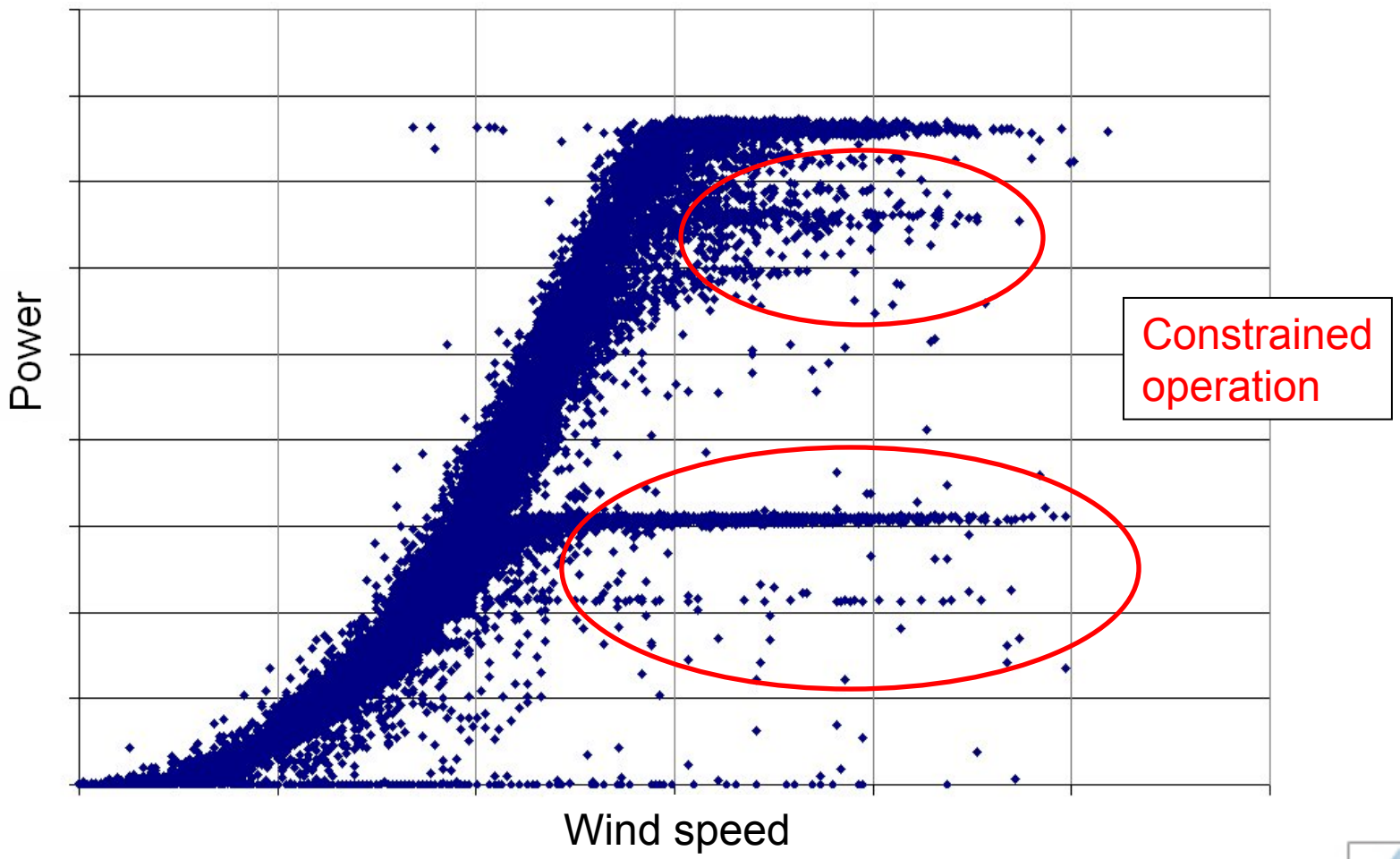
Final example of poor power performance



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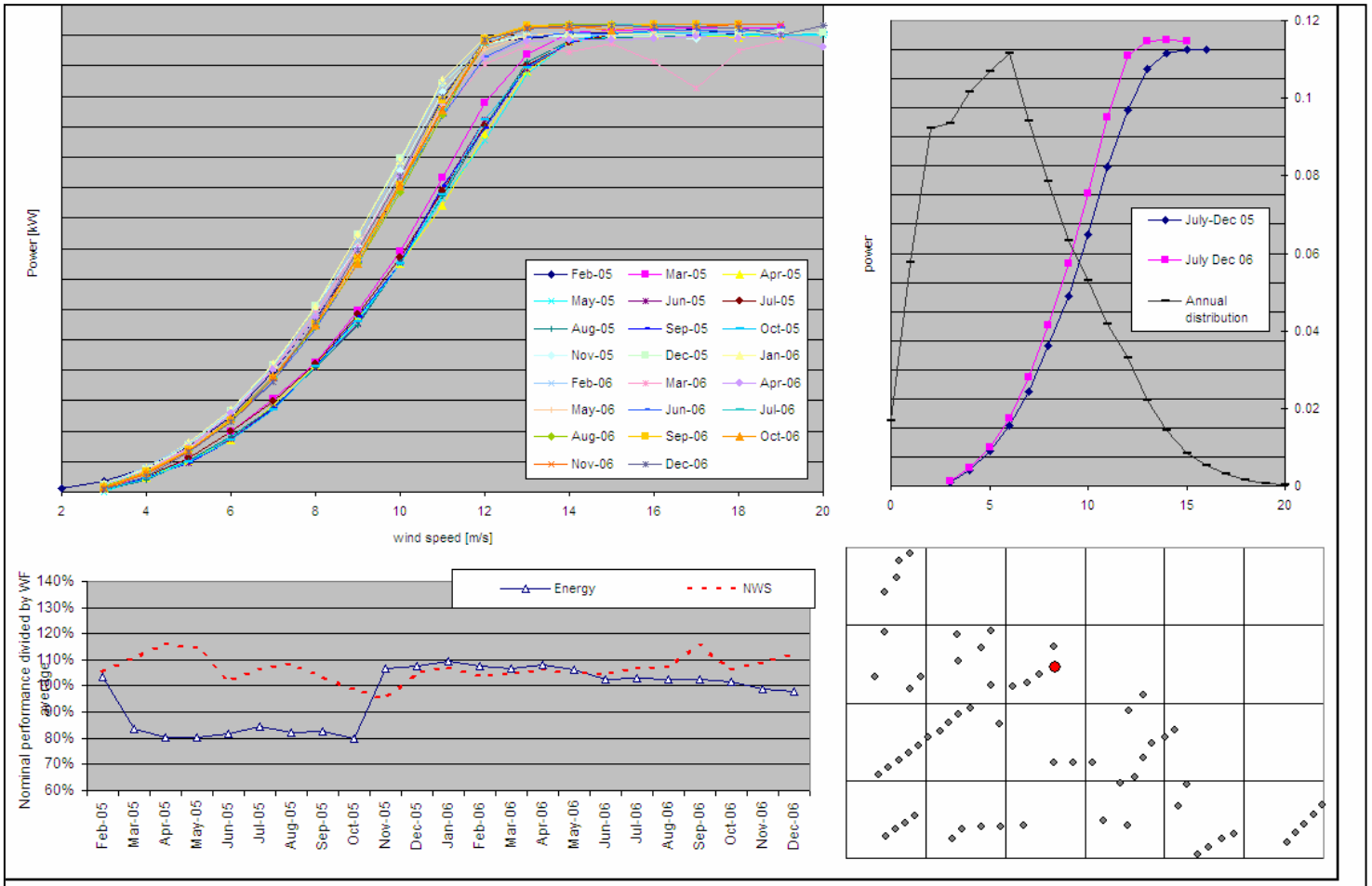
Power curve tracking tools



Turbine ID **840006093** **NACP Analysis**
Comment **20% increase in Nov 02**
Offset **86**

NEXT

Month	2	3	4	5	6	7	8	9	10	11	12	1	2
NWS	1.051436	1.10813	1.16042	1.14601	1.01862	1.06092	1.08528	1.03394	0.98951	0.9525	1.04695	1.06994	1.04054
Energy	1.033874	0.83365	0.80388	0.80443	0.81778	0.84455	0.82307	0.82689	0.79722	1.06694	1.07832	1.09362	1.07638

Assess Availability

- Run-Time Availability (RTA) calculated based on SCADA data
  - The amount of time that the turbines were fully available to “run” as a fraction of the total time
- Establish if down-time correlated with high wind speed (e.g. utility enforced down-time or high wind faults)
- Establish if down-time correlated with loss of communications of the SCADA system
- Validate the manufacturer’s reported availability figures
- Assess Liquidated Damages or availability bonuses

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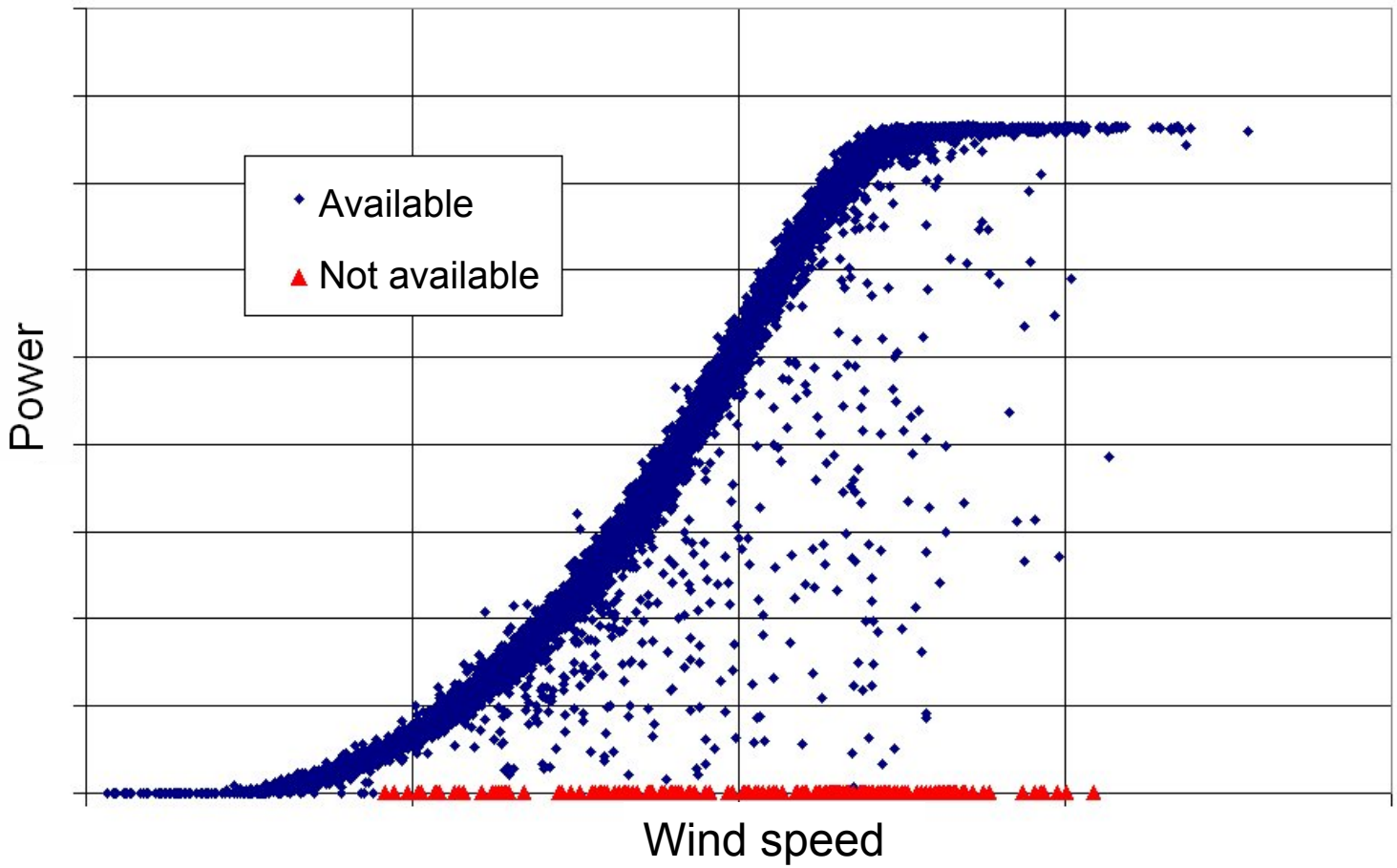
Availability check using power and wind speed only



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Reconciling actual production to budgeted production

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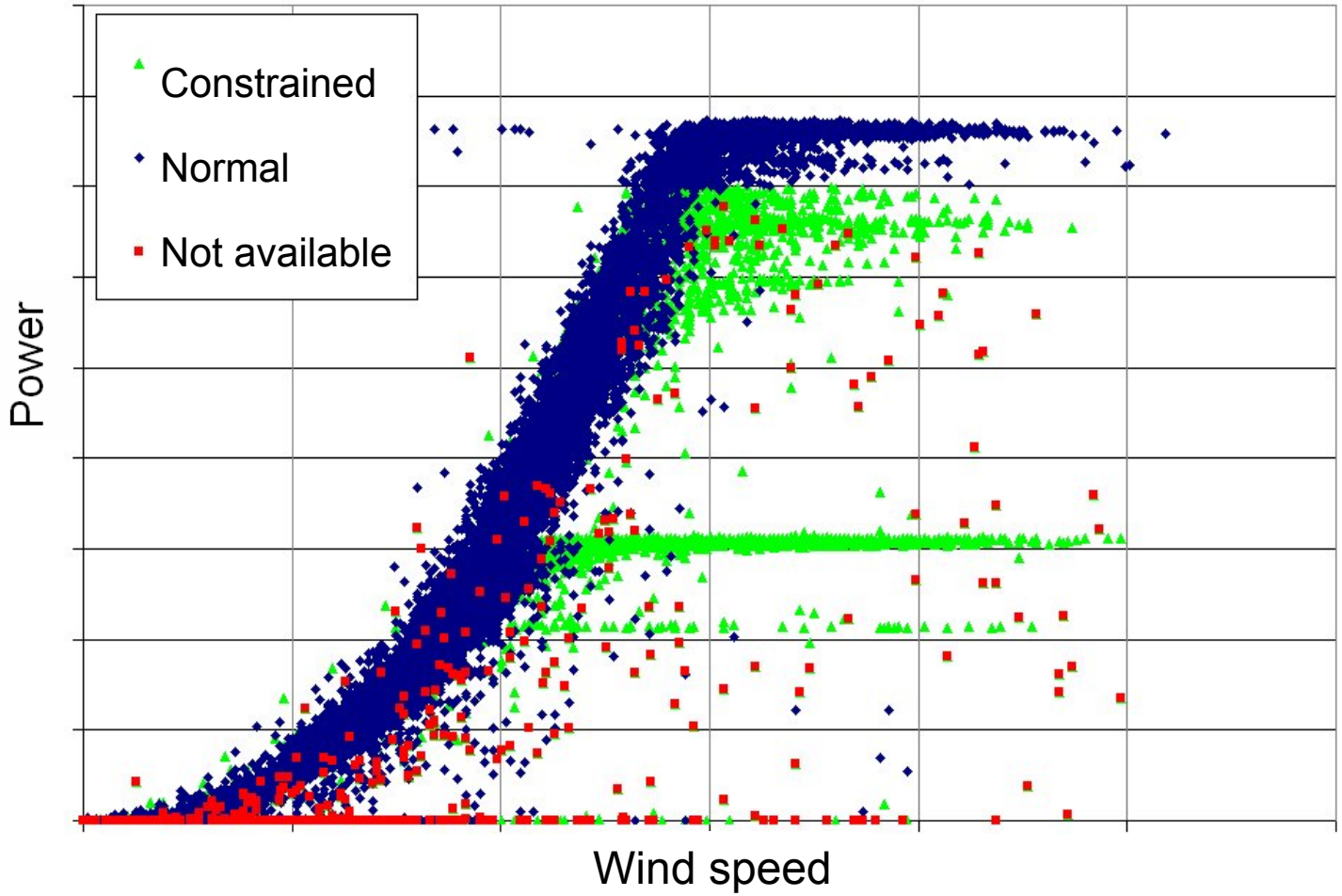
Identify periods of poor power performance



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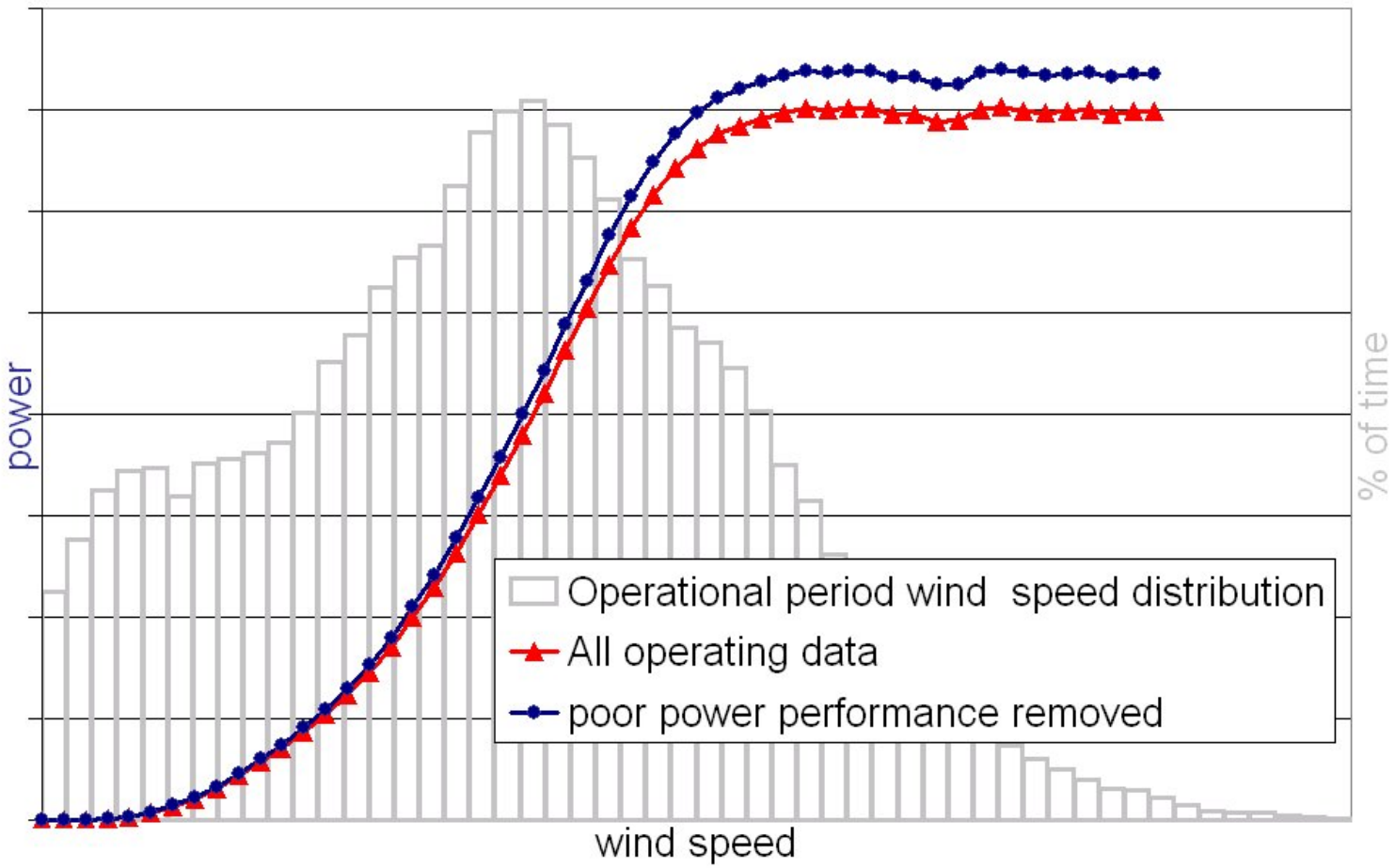
How much energy has been lost?



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Reconciling wind farm production

Expected energy	**375**	**GWh**
Metered energy	**338**	**GWh**
Difference	**(37)**	**GWh**

	Losses	Gains	
Wind speed lower than long-term	10	-	GWh
Availability lower than forecast	**8**	**-**	**GWh**
Power performance issues quantified	**13**	**-**	**GWh**
Forecast error	6	-	GWh

Potential for 6% increase in production or $1.5m in revenue annually

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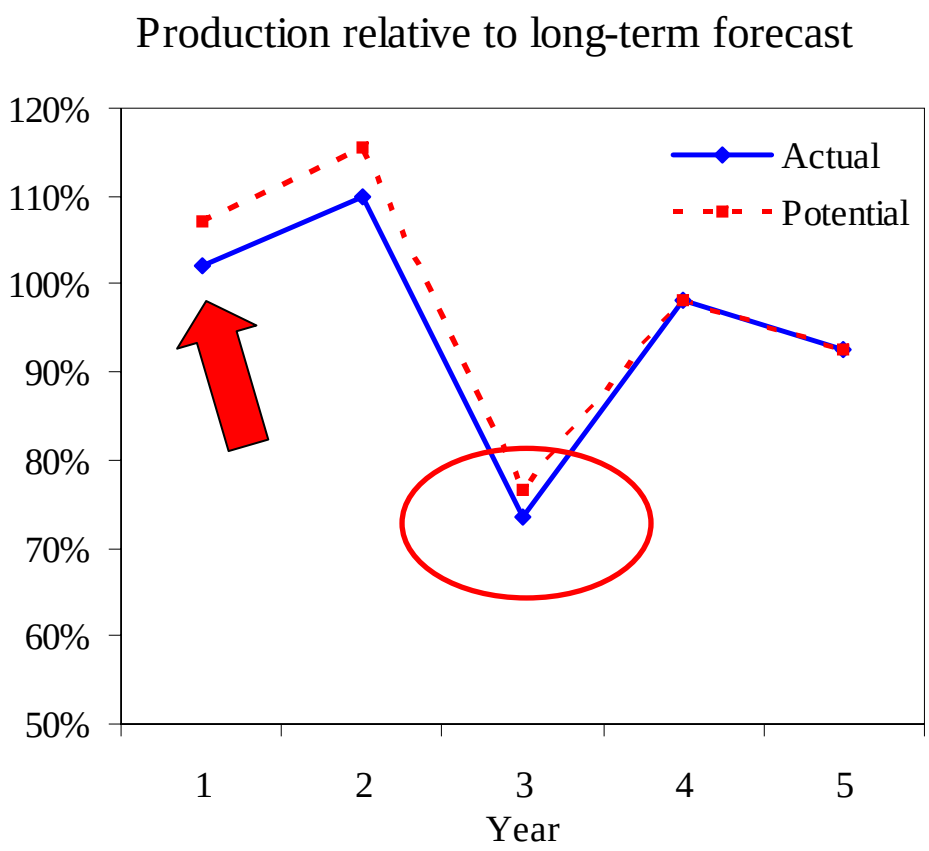
Reconciling wind farm production



Don’t leave detailed performance analysis until a lower than budget year!

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Conclusions

- Regular monitoring of operating wind farm data can identify unnecessary losses associated with:
  1) Individual turbine power performance
  2) Frequent faults and other availability losses
- Through the monitoring of operating wind farm data, these losses can be quantified.
- Ultimately, regular monitoring will improve the performance of the entire wind farm.

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