Analysis of the capacity value of intermittent generation in the South-west Interconnected System

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Outline

- Review objectives
- Nature of capacity value
- Alternative methods of evaluation
- Review the market analysis
- Examine the results
- Consider uncertainty
- Options for simplification
- Make a choice
- Basis for further review

Objectives

- **Review whether capacity based on average output is a reasonable approximation to the capacity value of intermittent generation sources**
- **If not, then what other measures are available that**
  - Reflect the impact on system reliability
  - Are robust with acceptable volatility of measure
  - Are easy to understand and apply without detailed system modelling

Specific criteria stated by the IMO

- **In particular the selected methodology should:**
  - be operationally simple and minimize associated cost, complexity, volatility and uncertainty;
  - enable the calculation of capacity contribution values by plant owners using simple mathematical methods
  - derive values of capacity contribution from computations based on plant output (either recorded for existing plant or modelled for new plant) rather than through power system reliability modelling, but should be designed to provide results generally consistent with those that might be expected from a reliability modelling approach;
  - provide credits consistent with the contribution to reliability relative to scheduled plant and at penetration levels that might reasonably be expected over the coming decade;
  - provide sufficiently reliable results when applied to all anticipated intermittent generator types including wind, solar thermal, solar photovoltaic, wave and tidal power; and
  - adequately discriminate between individual plants based on reliability contribution and provide appropriate incentives for the appropriate design and location of new plant.

Consequences of error

- **If intermittent generation is undervalued**
  – Marginal projects would not be developed
  – System reliability would be greater than required
  – Renewable energy costs would be greater because more expensive projects would be developed elsewhere to meet the Renewable Energy Target
- **If intermittent generation is over-valued**
  – System reliability would be less than required
  – Customers would incur greater exposure to loss of supply
  – More local renewable energy may be developed
- **Risk is asymmetric for customers, so some conservatism is warranted**
  – Accurate assessment would minimise total energy costs

Perceptions of capacity value

- **Wind farms do not provide reliable capacity and therefore have little impact on system reliability**
- **Wind farms do not generate much on the very hottest of days and have little value when you need it**
  - Implies that the current method based on average power over three years is generous
- **Solar generation would provide much greater capacity value because output is high when it is hot and clear**
  - Implies that the current method would under-value capacity from solar resources

Methods of evaluation

- **Direct reliability method**
  - Model the system with and without the intermittent resource and find a firm resource that leaves the reliability unchanged
    - what reliability measurement parameters should be unchanged?
- **Indirect reliability method**
  - Use a system model to calculate hourly Loss of Load Probability
  - weight the value according to RE project production level
- **Output based calculations**
  - Average of output over critical loading periods defined by
    - System conditions such as system load level
    - Expected weather severity in terms of peak hours and seasons

Comparison of methods

	Advantages	Disadvantages
Direct reliability	• Can be precise if data are available. Provides the true benchmark	• Costly and data intensive • Dependent on market assumptions • Very volatile measure if number of simulations is low
Indirect reliability	• Moderately costly to apply • Does not need new system modelling for each application • Provides good match to direct reliability method • Stable against changes in supply conditions	• Measure can be quite volatile when critical system loading and project production data are limited and are then subsequently updated
Output based	• Low cost to apply • Lower volatility • Very easy to apply if data are available	• Limited by ability to select the right periods to obtain a realistic measure • Subject to volatility from limited data

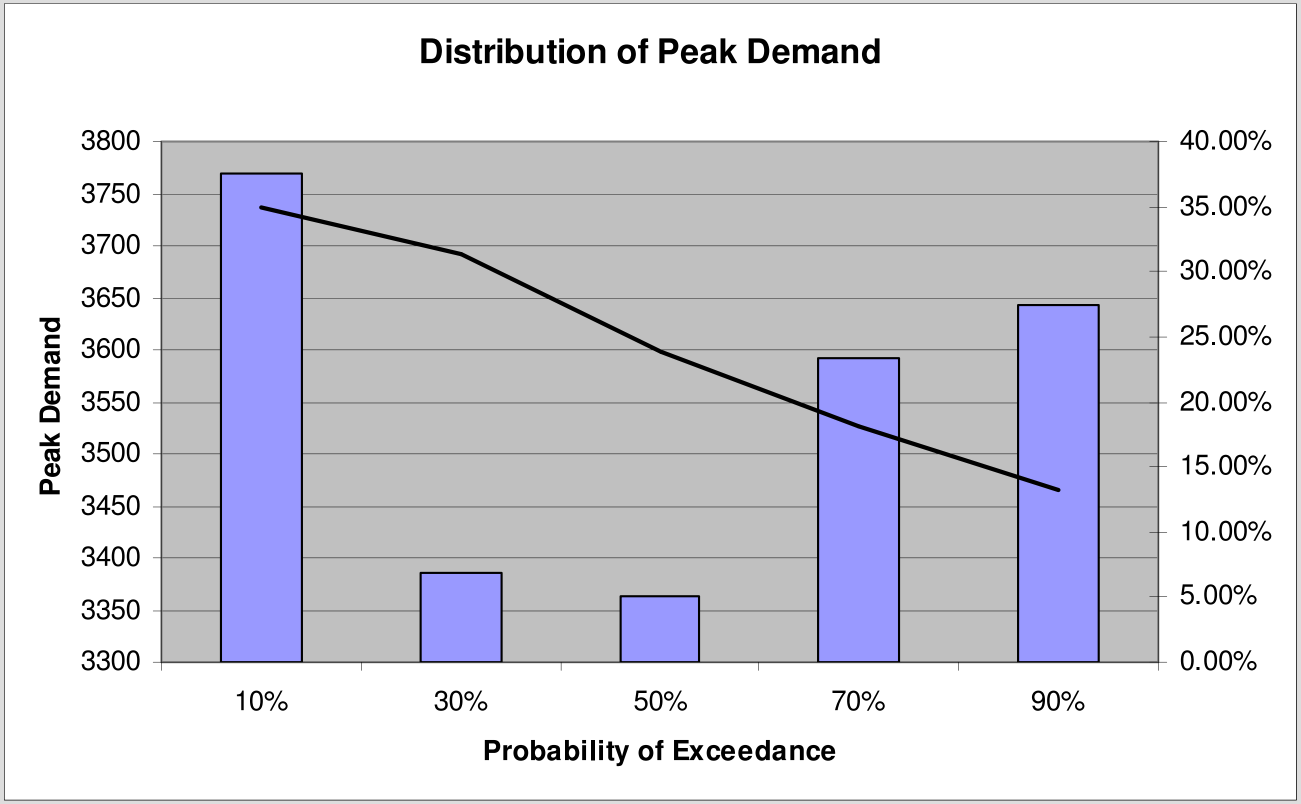
Market analysis to date

- **Set up 1000 simulations of 2012/13 capacity year for five peak demands and two reserve margins (RM3 at 3.21% and RM7 at 7.27% reserve factors)**
- **0.473 GWh unserved energy represents 0.002%**

POE	**10%**	**30%**	**50%**	**70%**	**90%**	**Weighted**
Weight	37.48%	6.78%	5.00%	23.31%	27.42%	100%
USE RM3 (GWh)	1.1080	0.2849	0.0474	0.0181	0.0096	0.4438
USE RM7 (GWh)	0.2599	0.0612	0.0106	0.0017	0.0005	0.1026

Peak demand distribution

- Peak demand distribution based on historical data
- Converted to discrete equivalent with 5% minimum weighting
- Weightings are sensitive to historical data



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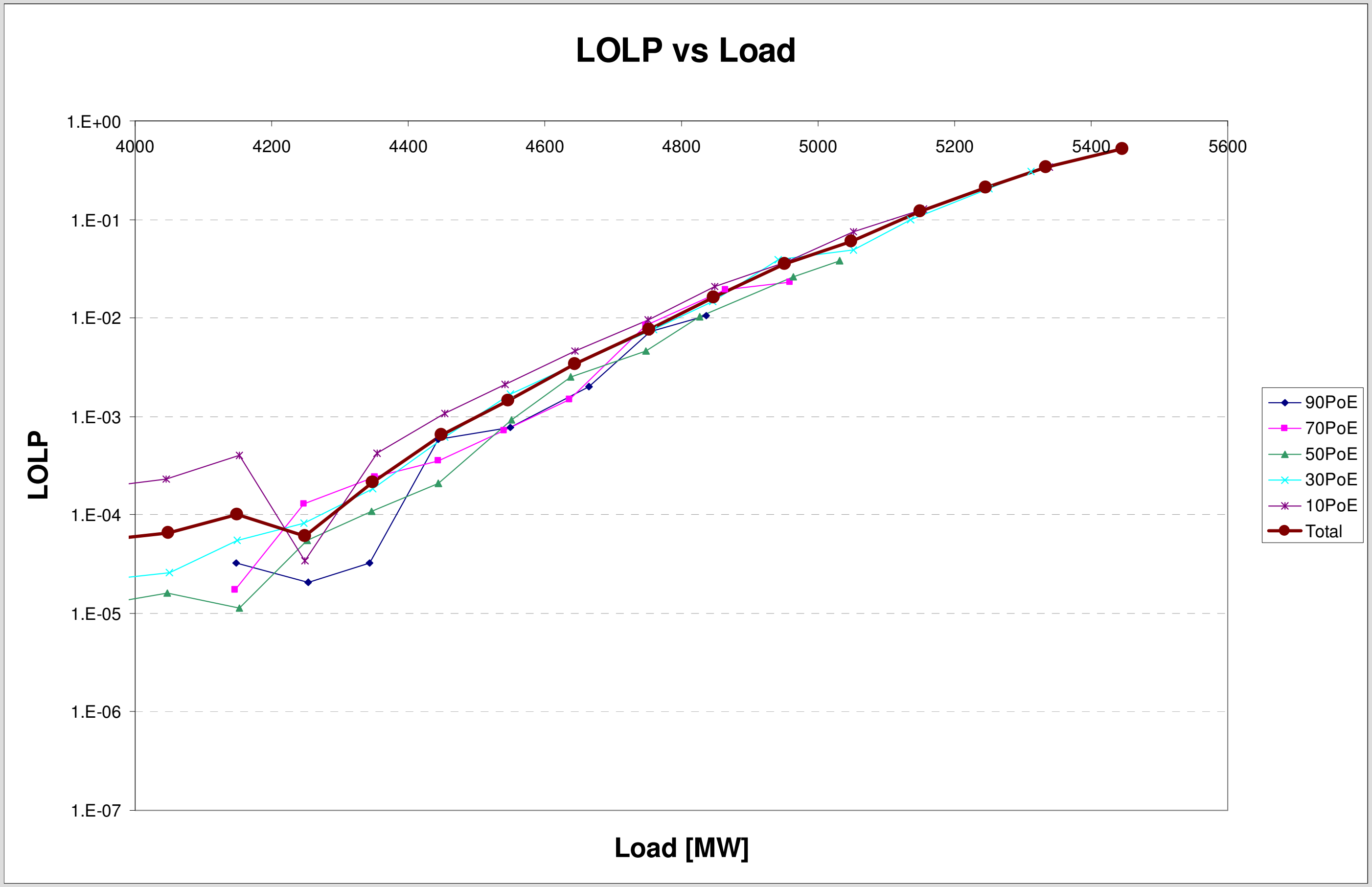
Selected reference years

- Identified five annual profiles that approximate 10%, 30%, 50%, 70% and 90% POE exceedance peak demands

Load Profiles		POE
1	2003/04	10%
2	2004/05	30%
3	2002/03	50%
4	2006/07	70%
5	2008/09	90%

LOLP Functions

- **LOLP versus load for scheduled generation measured over the whole year**



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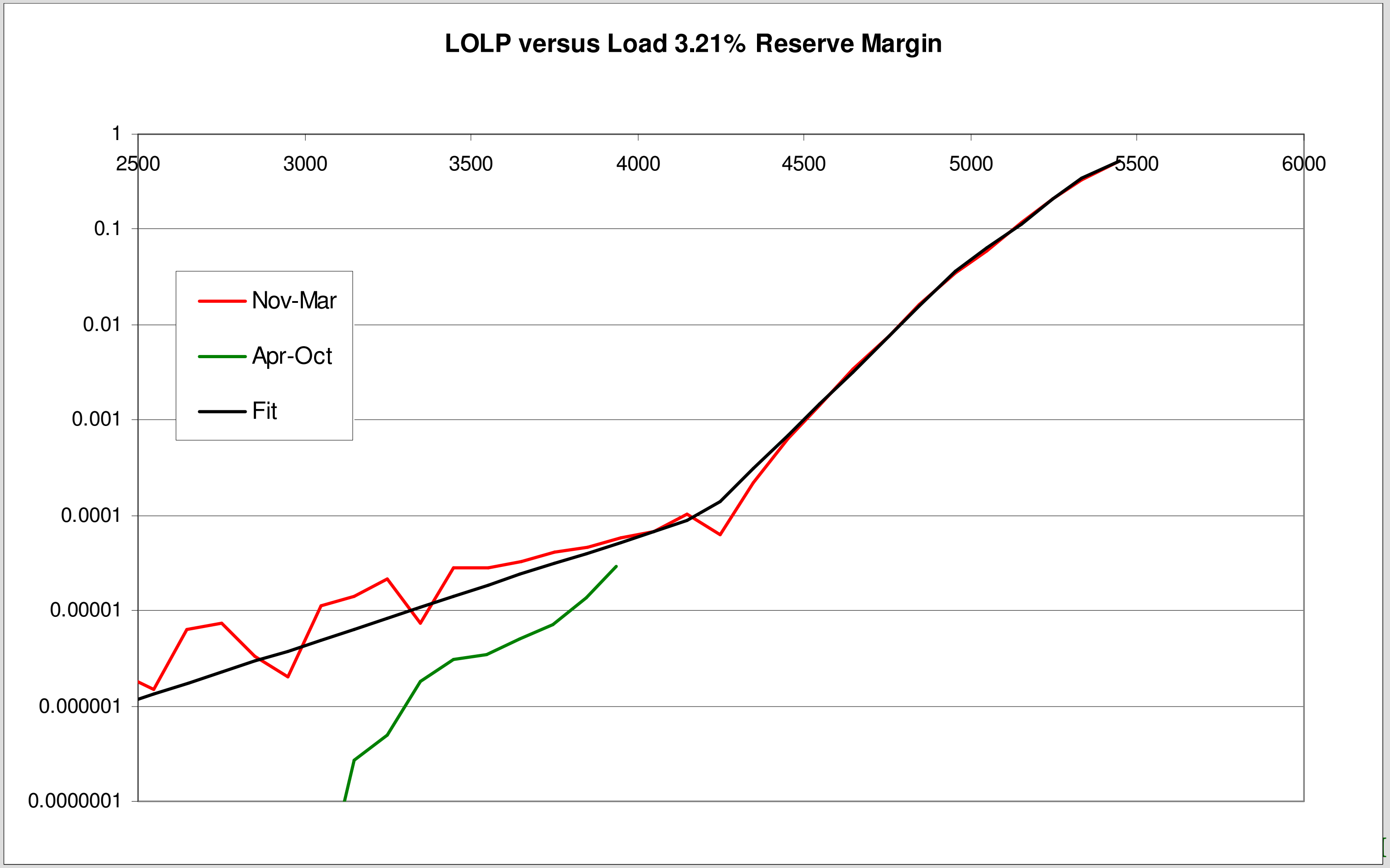
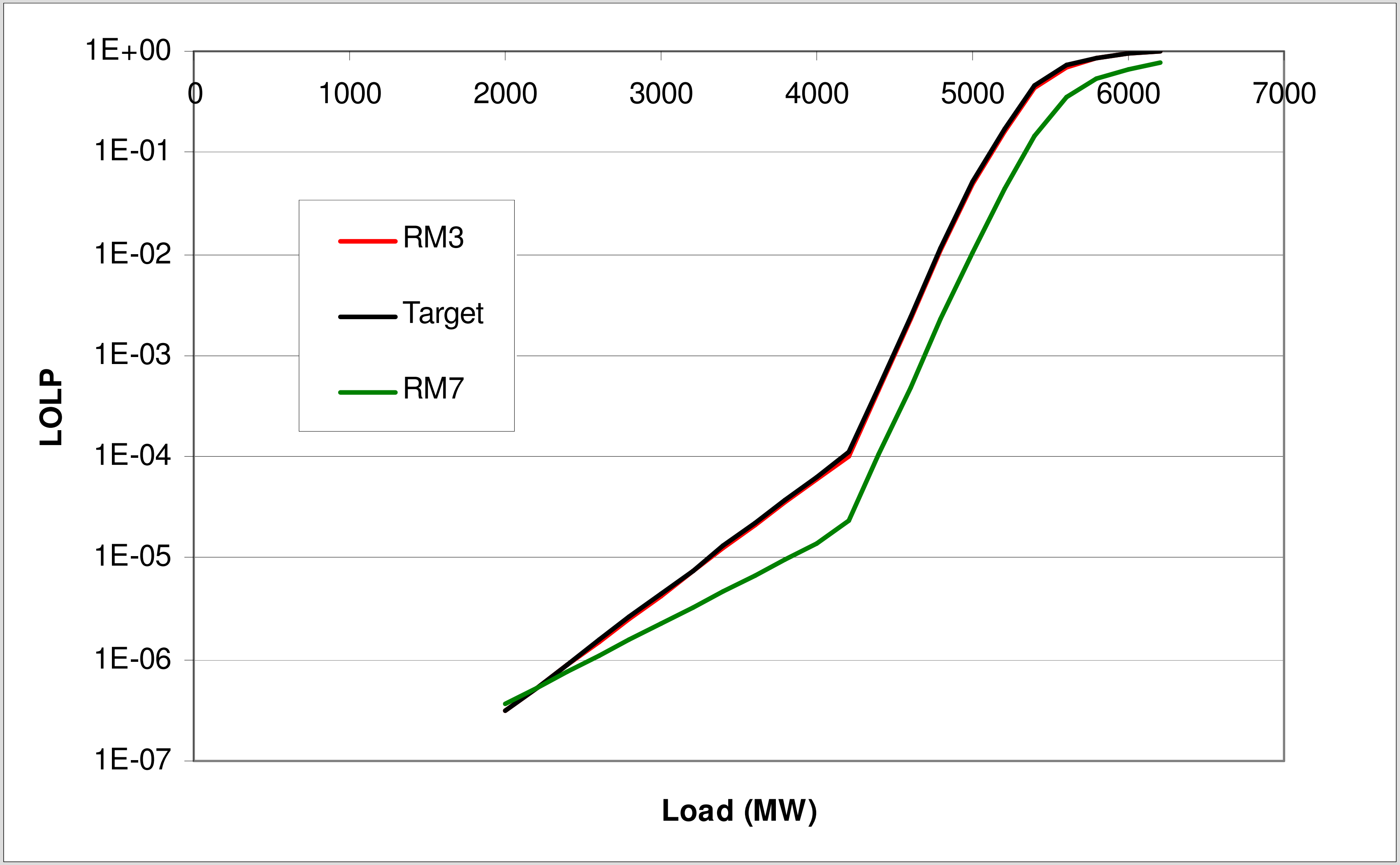
Develop a simple function

- Seasonality is not material for moderate levels of scheduled maintenance

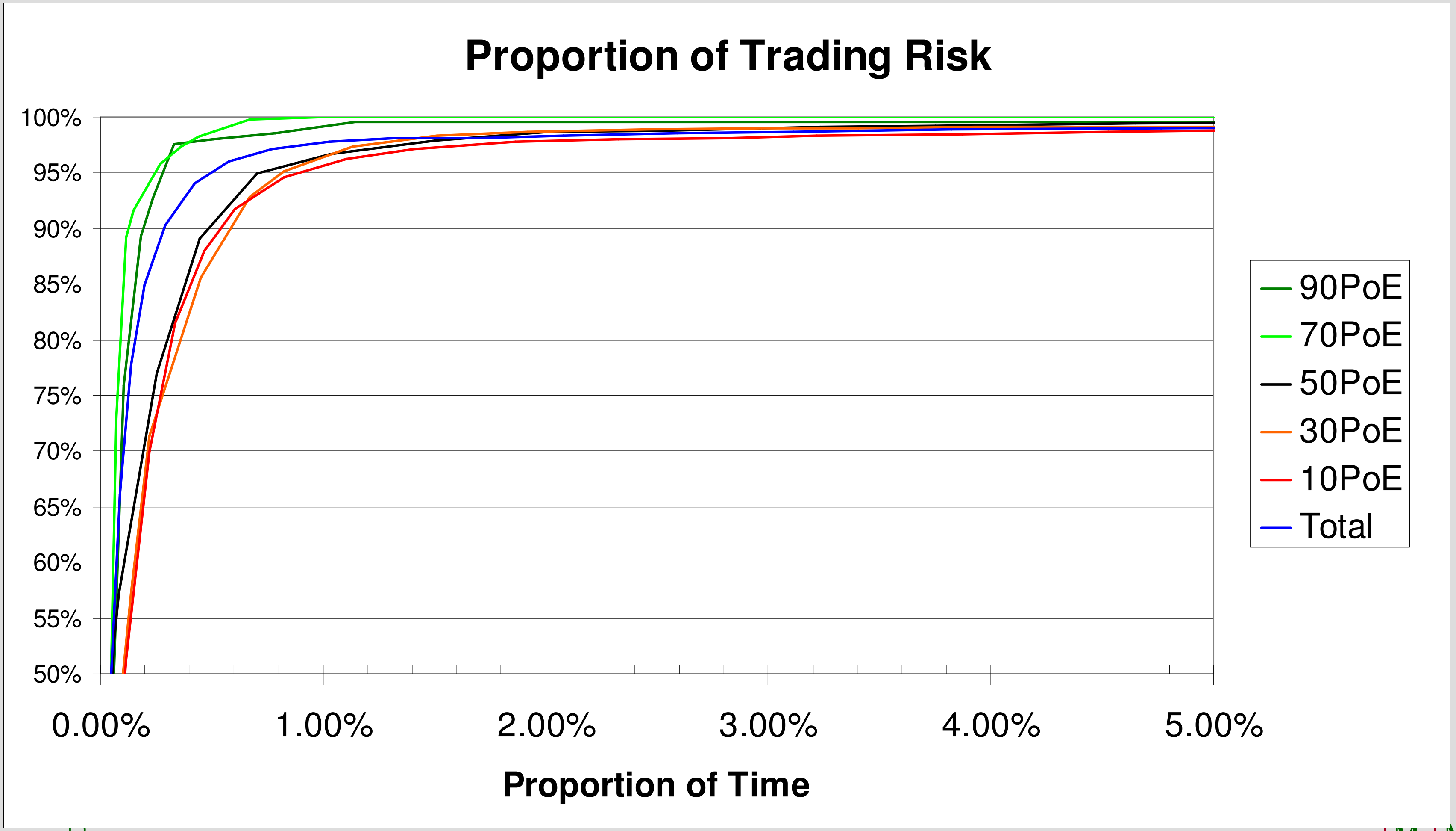


Two reference and one interpolated function



Duration of Risk based on LOLP

- Duration of risk is quite short: 98% in 1% of the time



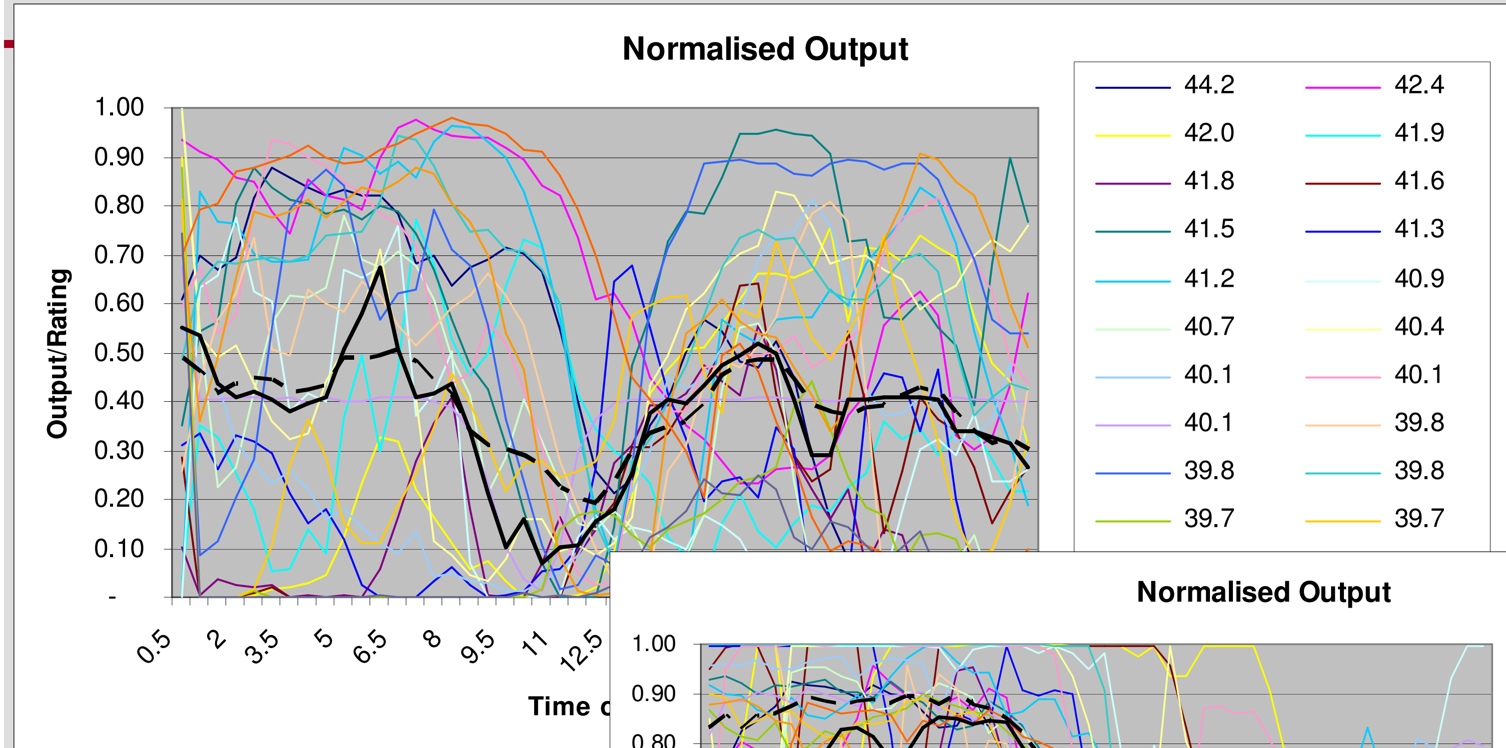
Uncertainty

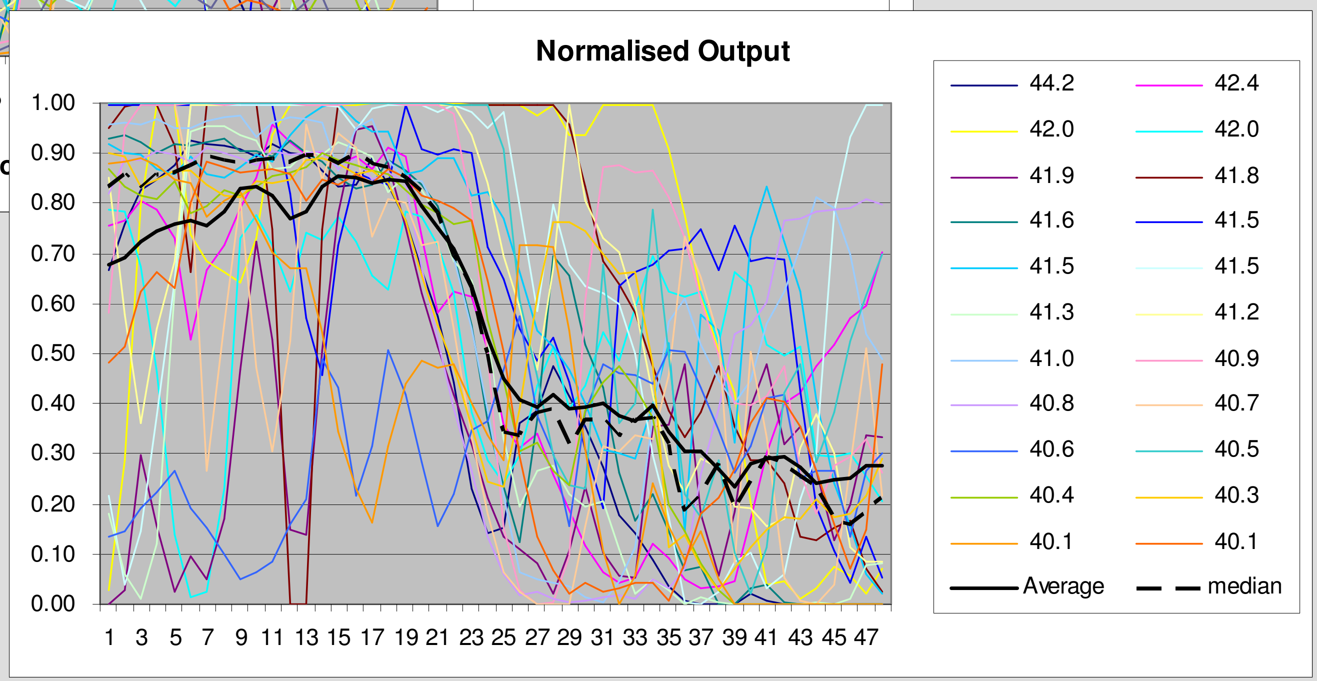
- **The analysis is affected by uncertainty in plant output at times of high demand due to the exposure to only about 80 hours per year**
- **Doesn’t matter how you do it, there is still volatility in the measure**
- **Measures that use more load data or weight it more evenly have lower volatility**
  - But not necessarily more accurate
- **No robust models of wind farm output uncertainty with available data**
  - Have developed some simple models of correlation of outputs to obtain an initial assessment
  - Quantification of uncertainty is not an exact science

Correlation of wind farm energy outputs (Oct-Mar)

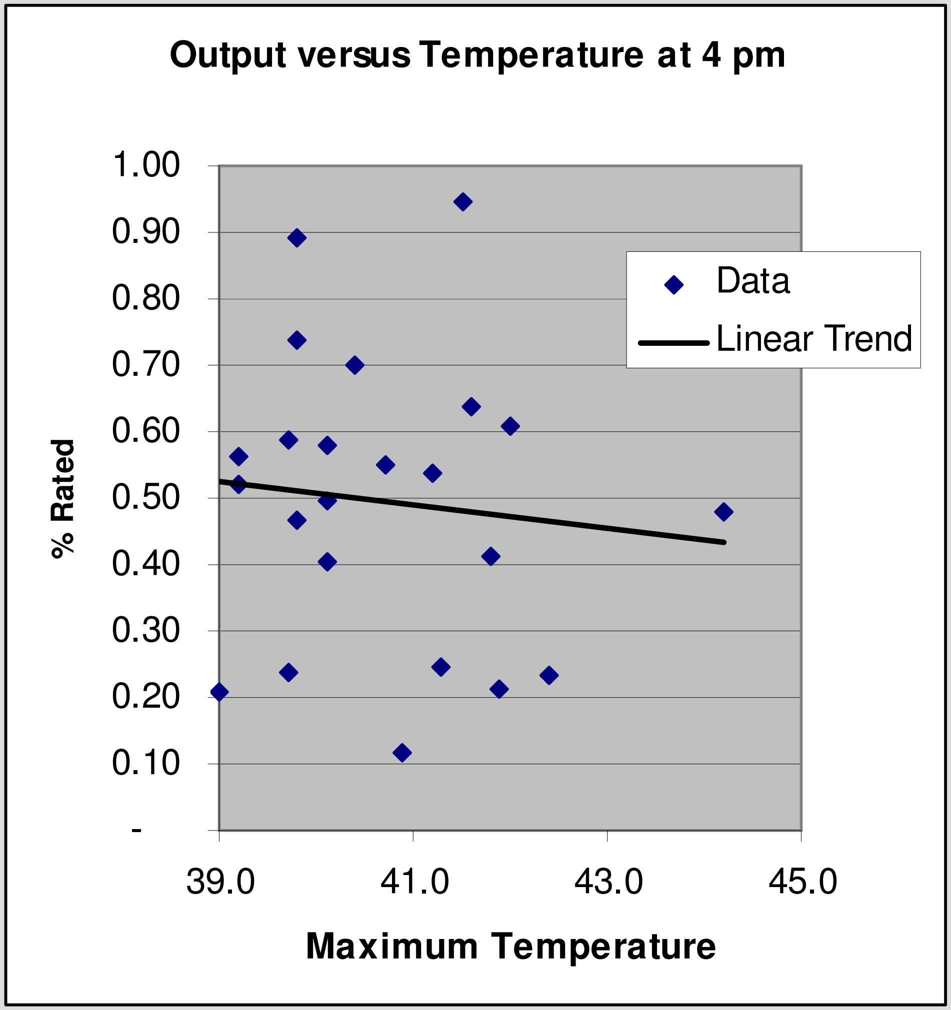
From	WF1	WF2	WF3	POE
To	WF2	WF3	WF1	
2002	0.041	0.375	0.116	
2003	-0.008	0.487	0.049	50%
2004	-0.021	0.430	0.047	10%
2005	0.054	0.472	0.135	30%
2006	-0.036	0.377	-0.035	
2007	0.036	0.611	0.174	70%
2008	-0.012	0.579	0.092	
2009	0.020	0.573	0.055	90%
Average	0.009	0.488	0.079	

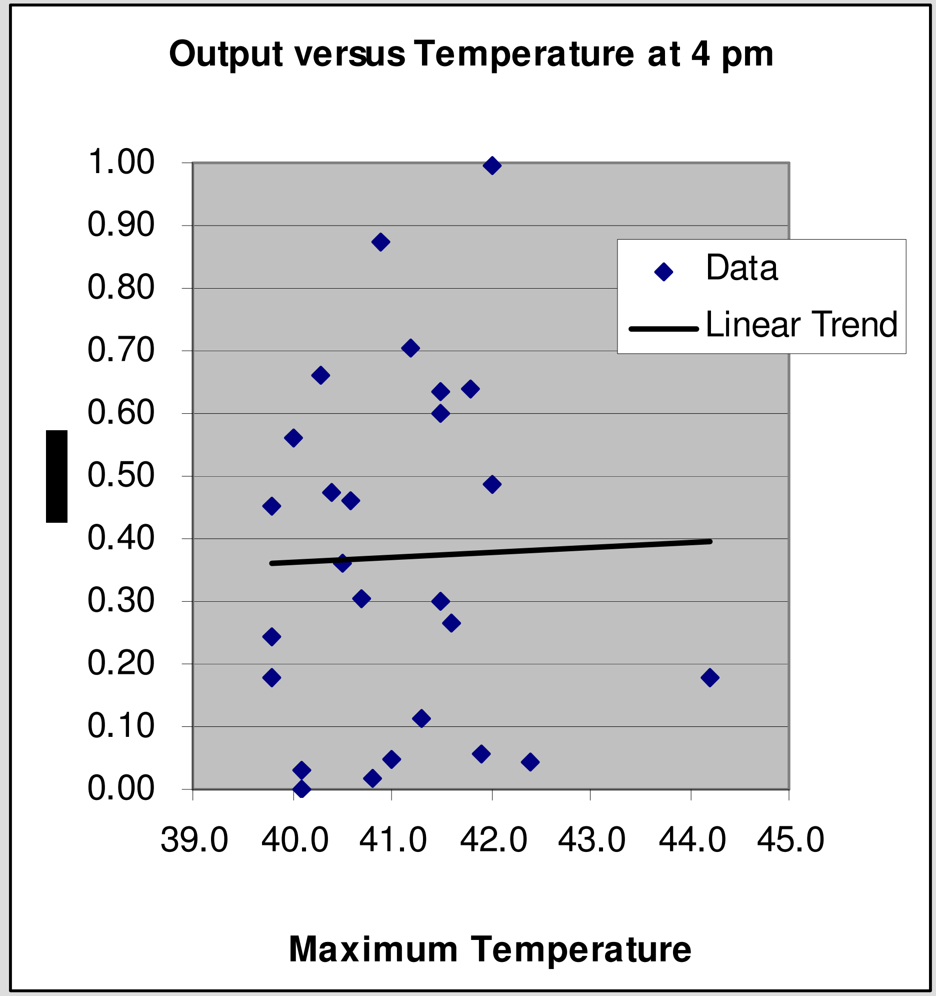
Hot day responses (above 39ºC)





Sensitivity to temperature at 4pm





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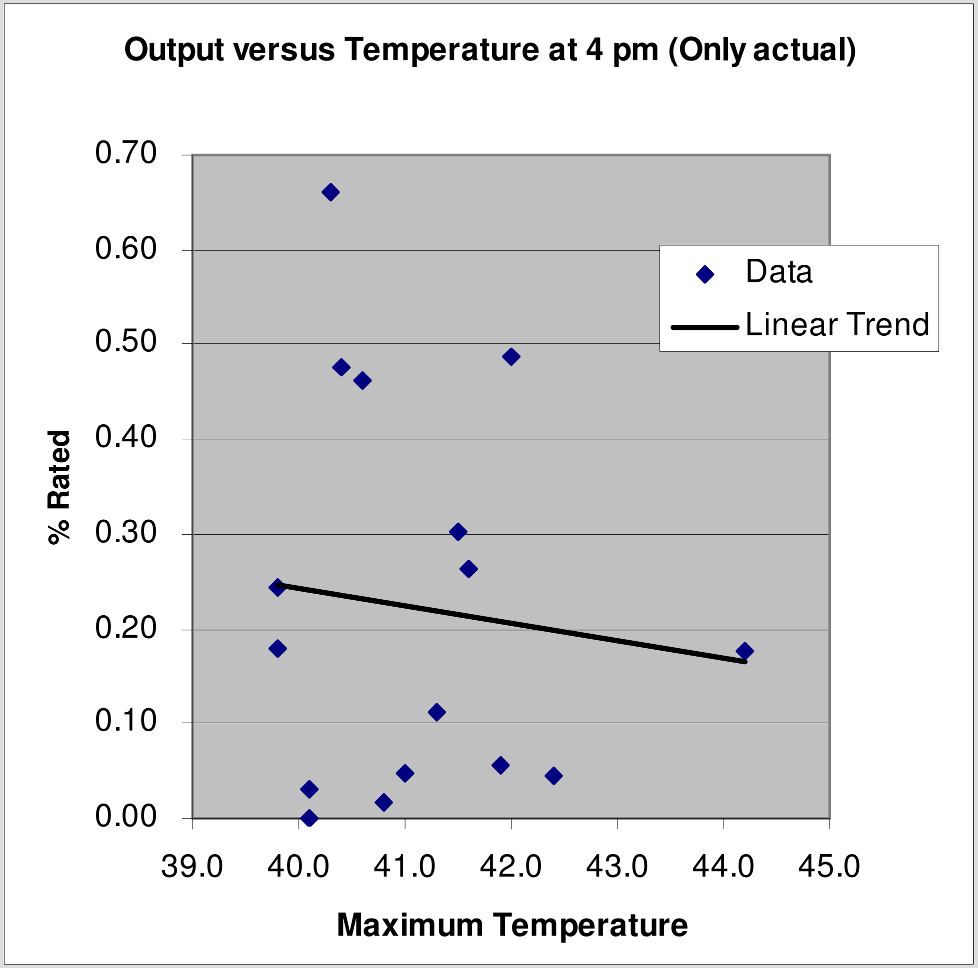
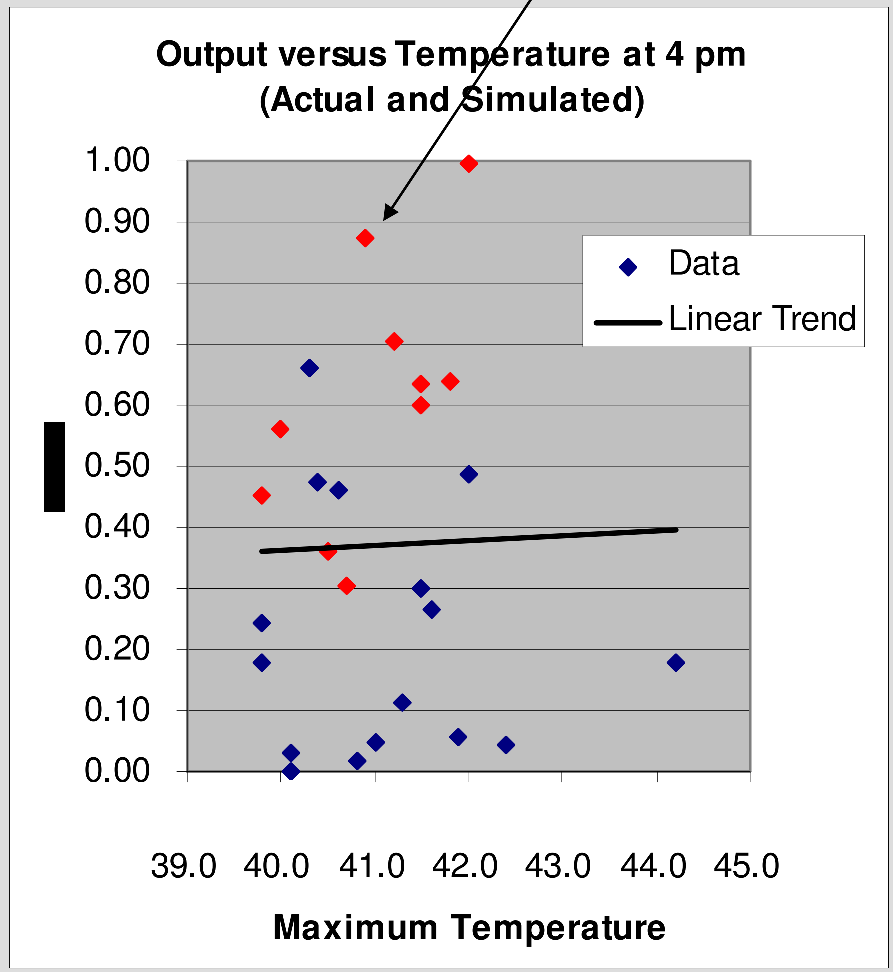
Simulated or measured data?

Simulated based on wind speeds





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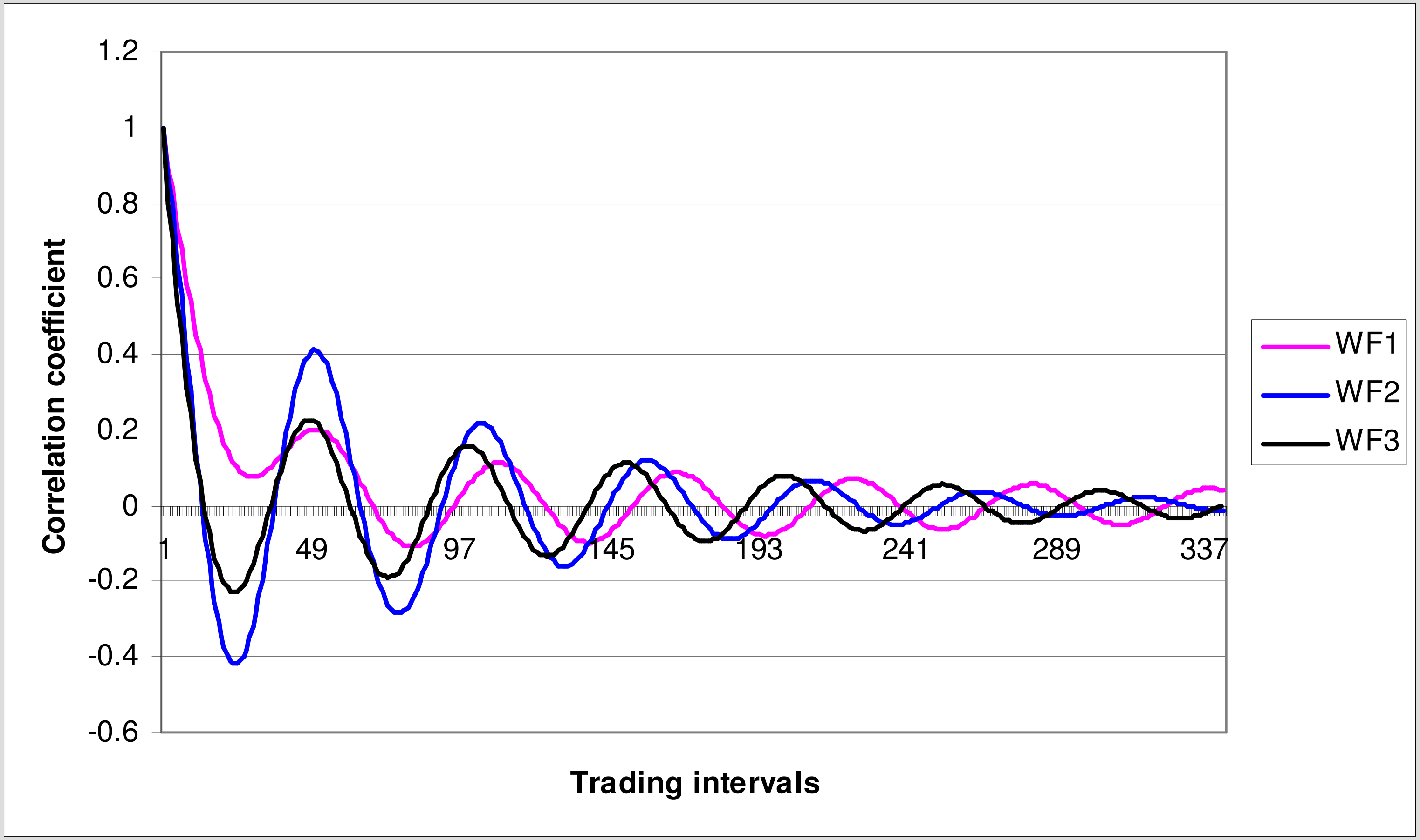
Impact of simulated data

- **Evidence is that simulated data may be too optimistic**
  - Wind speed only not sufficient to predict output of available plant?
- **Careful attention will be needed to identify any temperature effects that derate plant below energy resource capability**

Assessing volatility of measures

Trading interval correlation

- **Wind farms**



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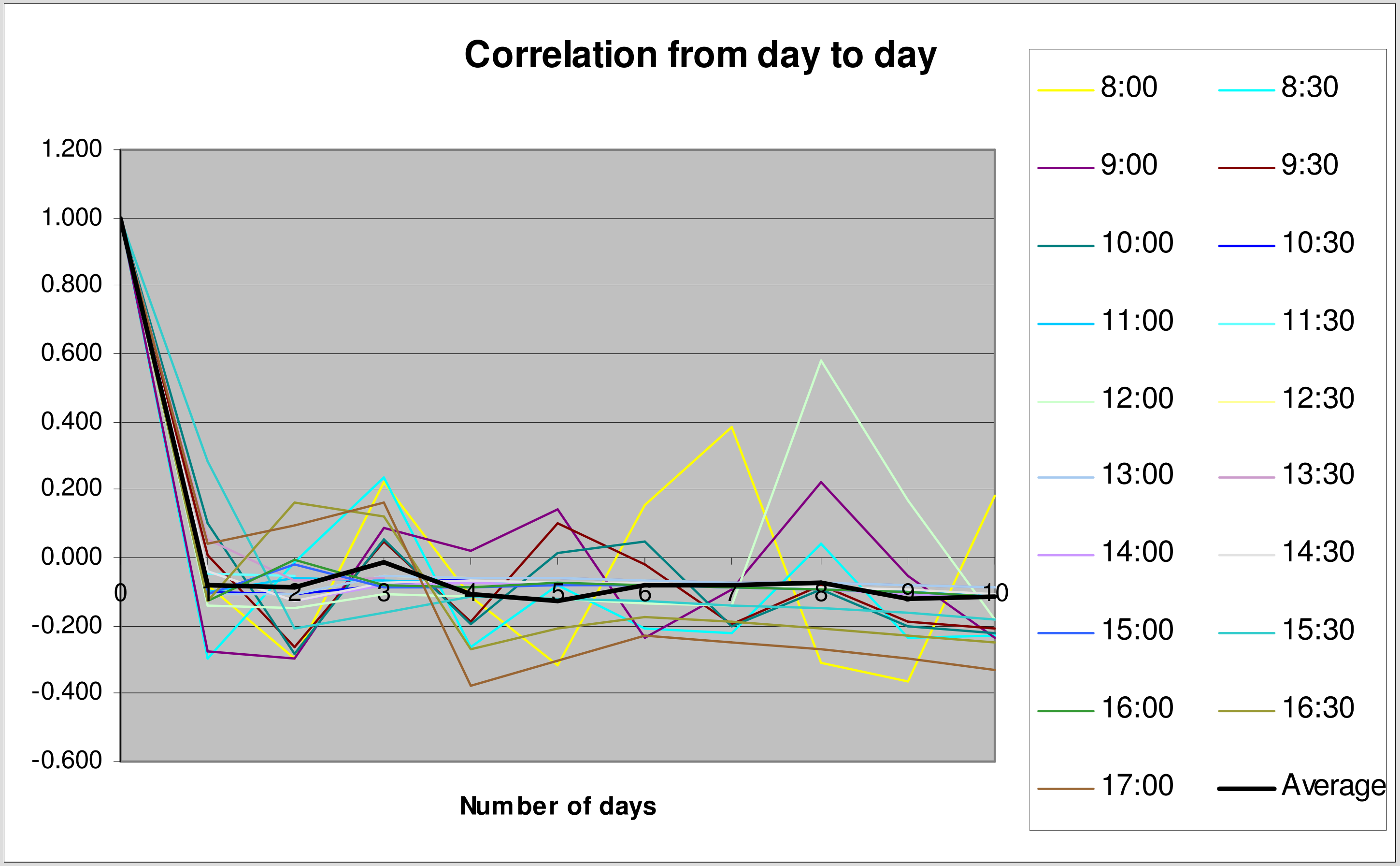
Solar thermal correlation from day to day

- Negligible by next day – conservative to ignore when it is negative



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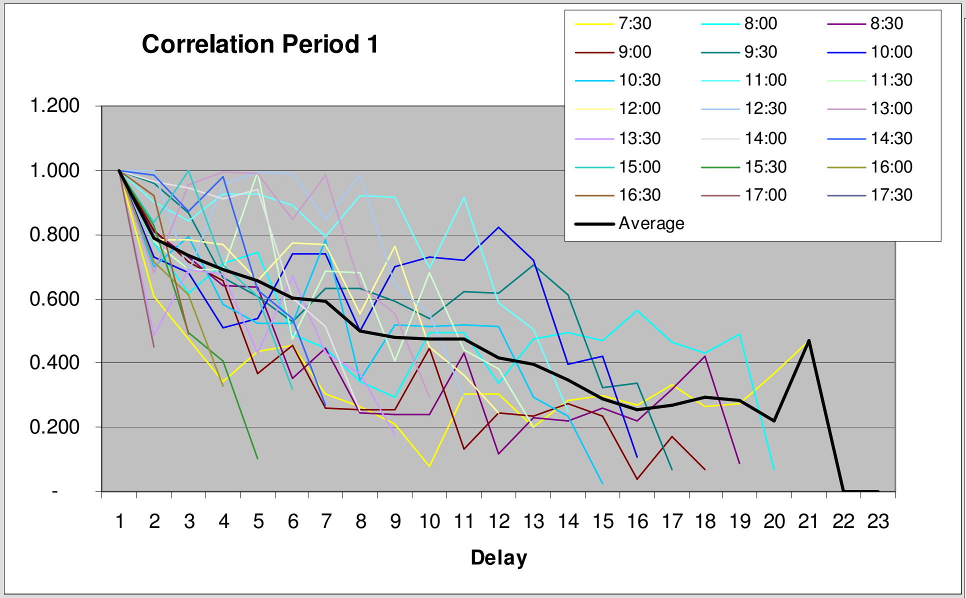
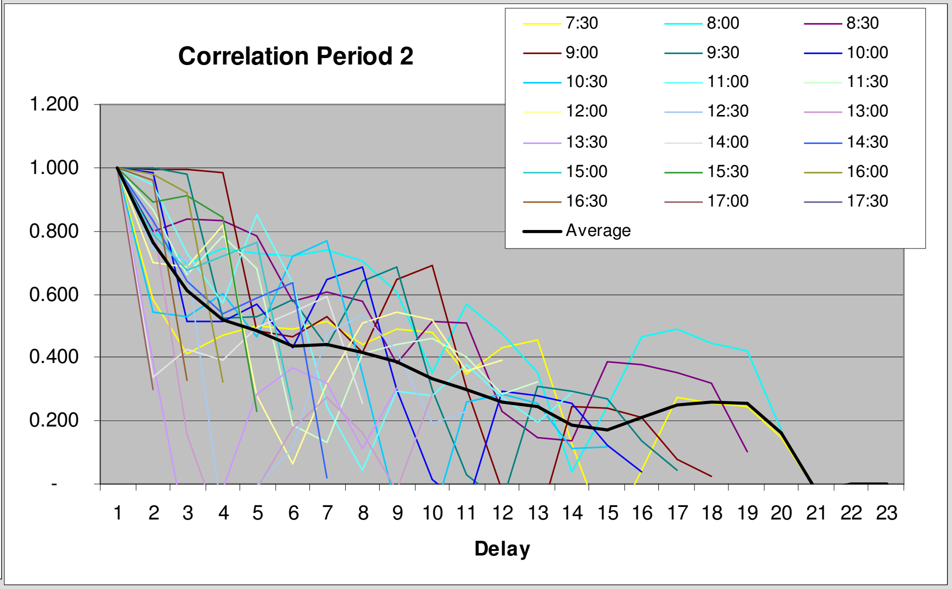
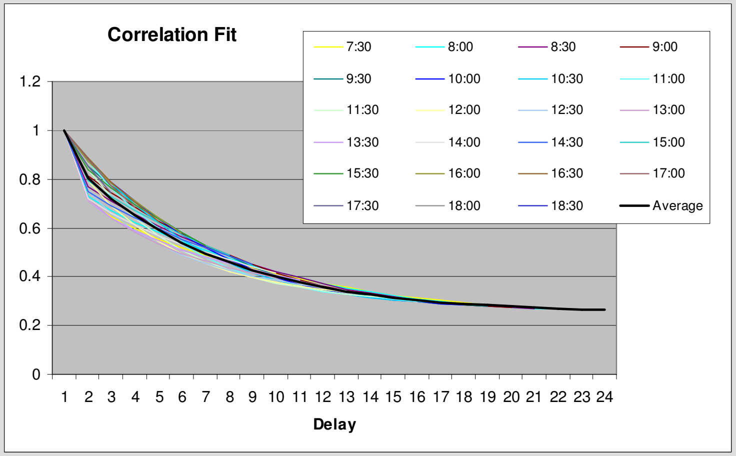
Trading interval correlation within the day

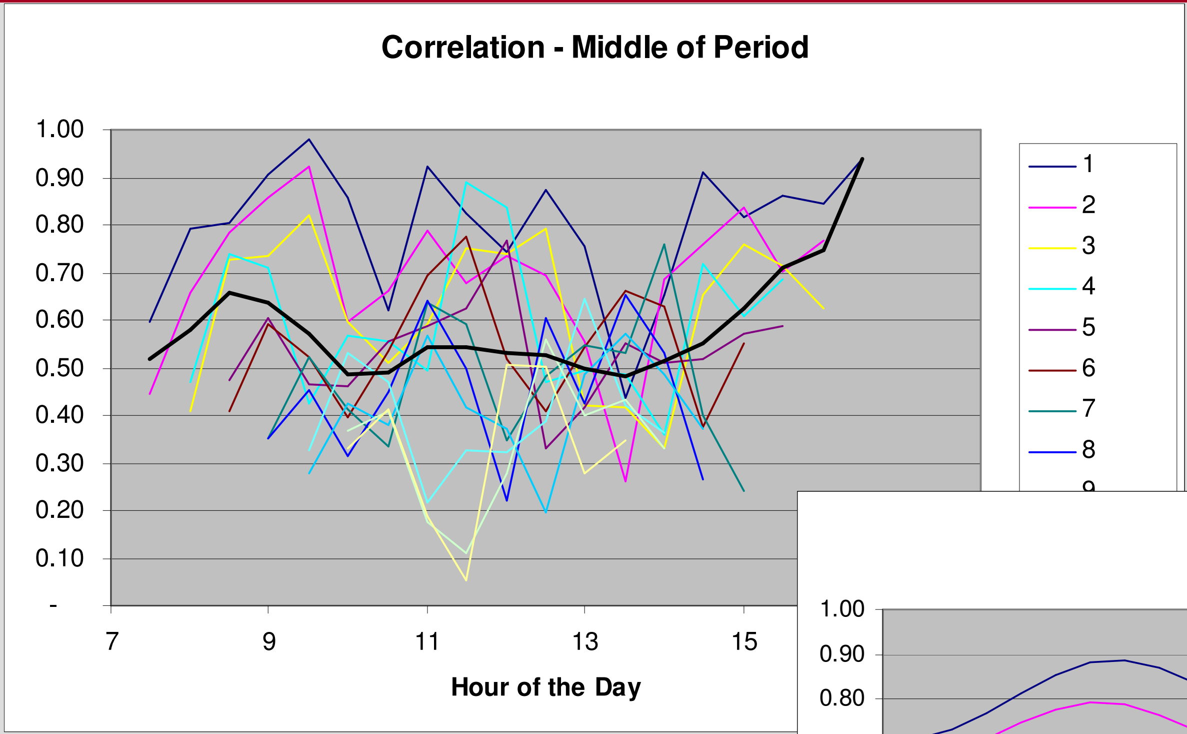
- Solar resources between 8 am and 4 pm

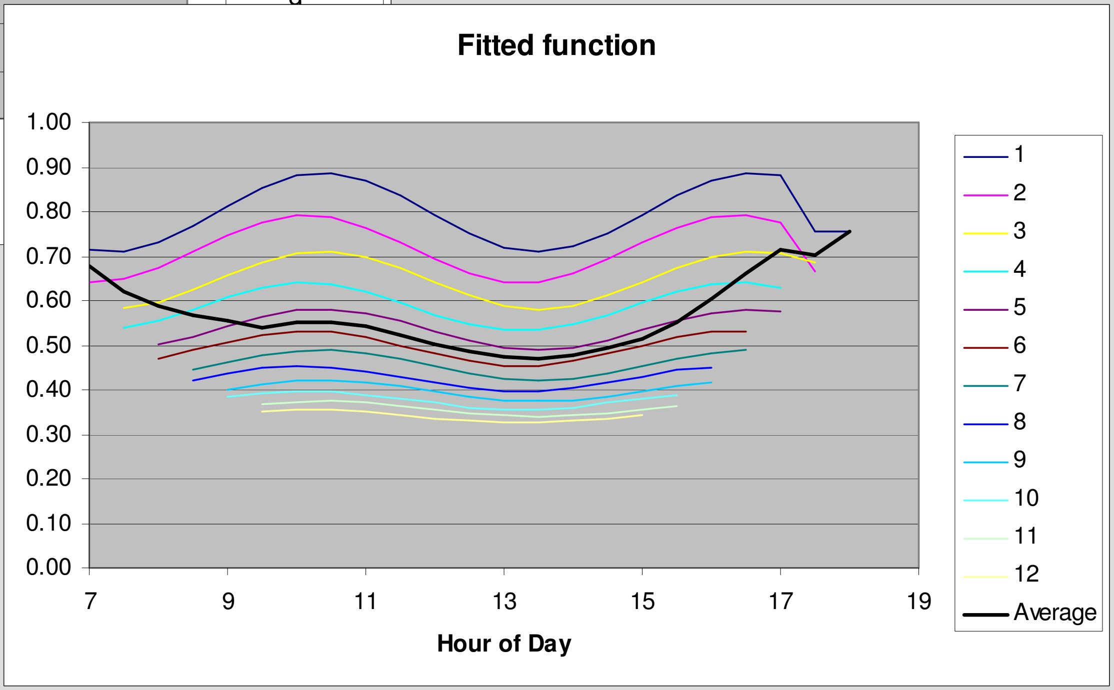






Correlation by time of day





Uncertainty

- Wind farm correlation after two days is negligible
- Solar thermal correlation after one day is negligible, conservative to ignore
- These functions were used to estimate the error in the various measures based on the measured outputs and the variance and correlation factor between time periods
- A standard method would need to consistently assess the basis for correlation across time periods

Comparison of measures

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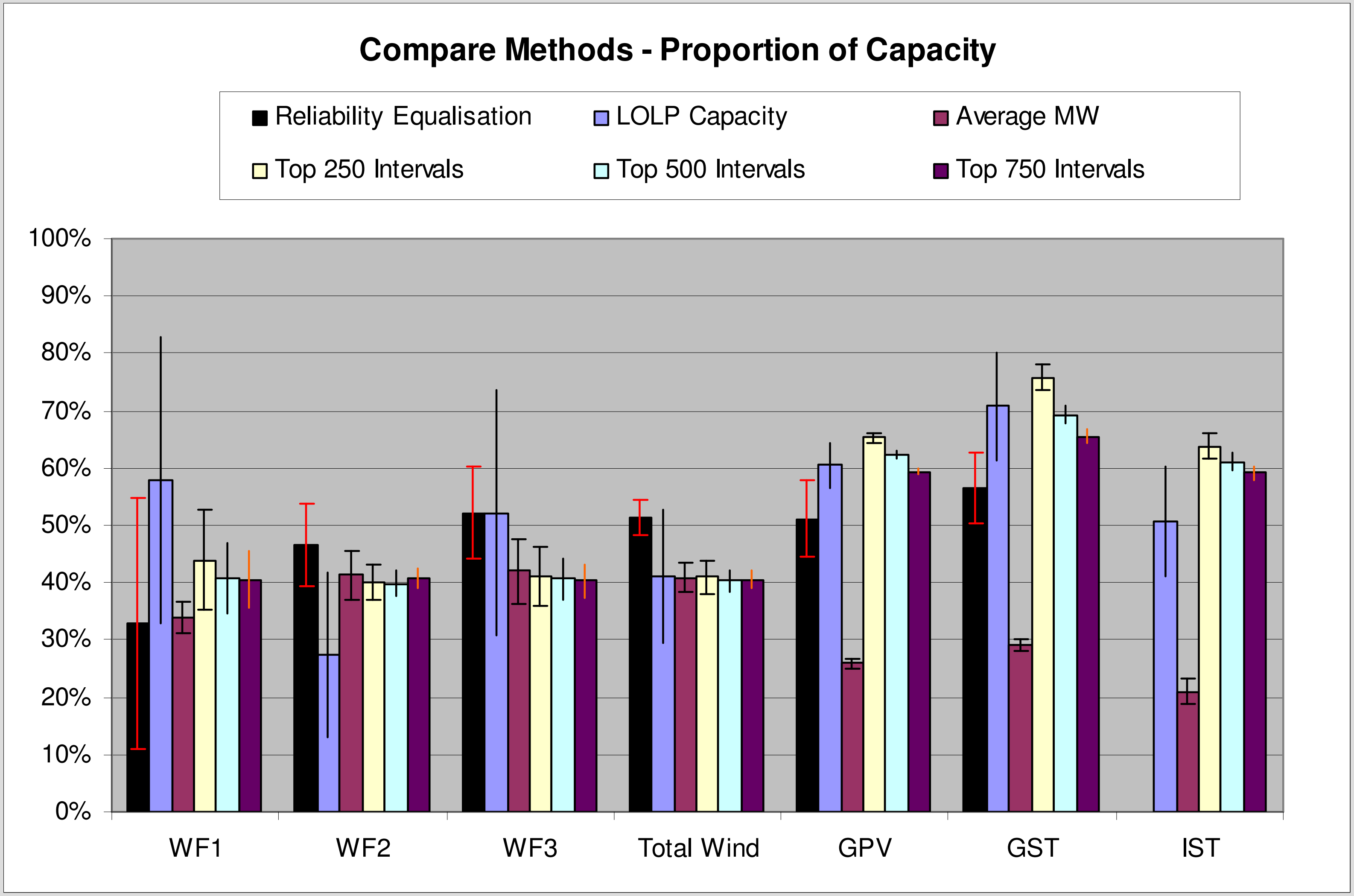
Results of various methods



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Observations

- **All measures except average power give similar results for wind and solar resources**
- **Reliability equalisation is quite volatile and needs about 1000 simulations to obtain a reasonable estimate**
  - Speed up is possible if the period of exposure is well defined (January to March)
- **LOLP measure is quite volatile due to the dependence on few periods**
  - LOLP method would work better at a fleet level to establish the overall level with less volatility
  - Allocation of fleet entitlement could be based on trading interval data
- **Trading interval methods are less volatile and give comparable results to LOLP method**
- **750 trading intervals provides a good fit to LOLP results at the fleet level and provides reduced volatility.**

Logic of direction

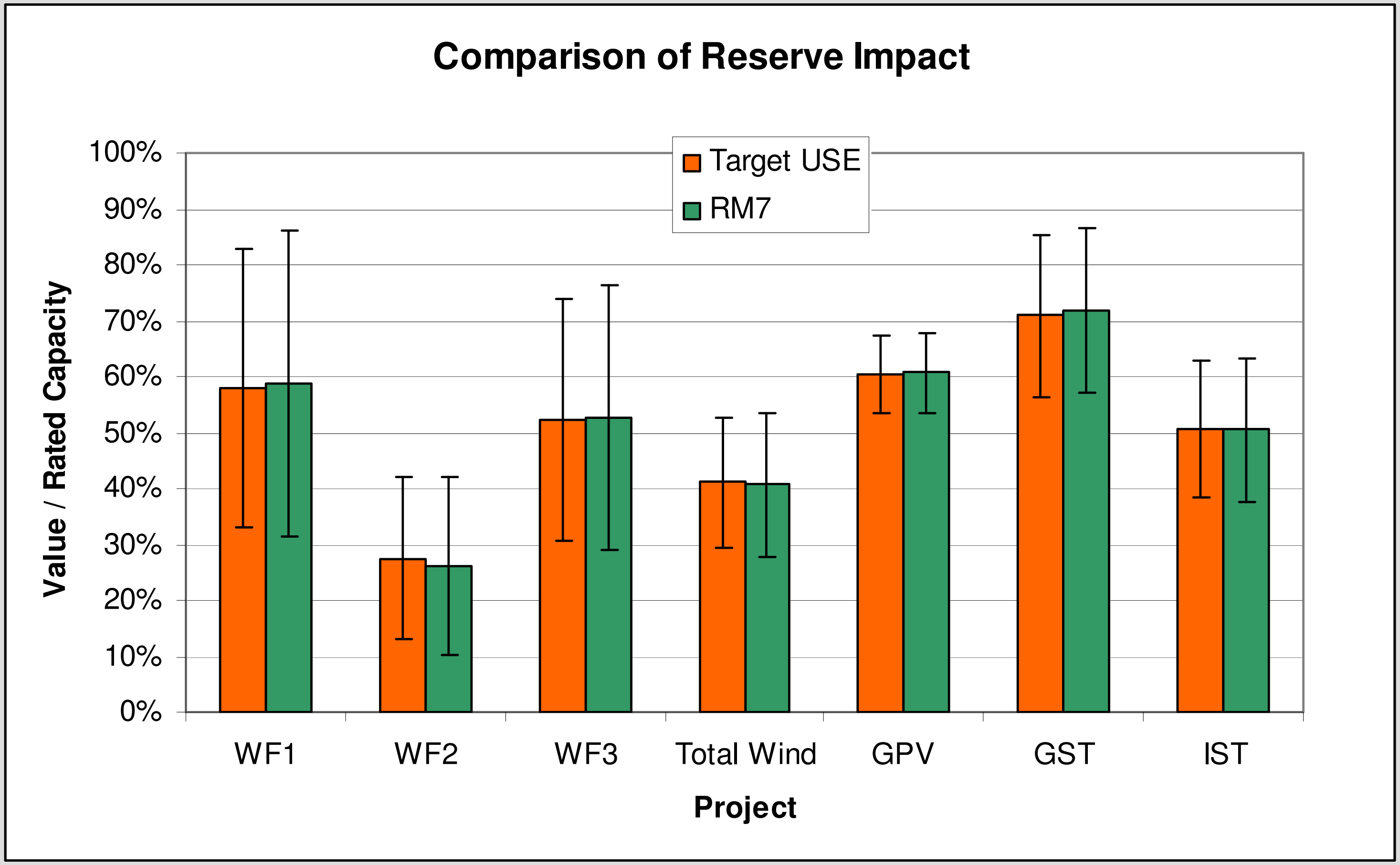
- International survey indicates that organisations move to more sophisticated methods based on reliability analysis as data becomes more extensive or there are multiple diverse resources
- Average power and trading interval measures are preferred initially when there are few projects and limited data
- Higher penetration of IG would justify the greater complexity of LOLP methods but we don’t need to do that as yet.

Other issues

- **Importance of penetration level: do we need to change the parameters as more IG is connected?**
  - Use LOLP versus load for scheduled generation
- **Does it matter at what level of unserved energy we apply the LOLP function?**
- **Does it vary according to supply conditions over time?**
- **Can we use shorter periods for averaging?**
- **What about impact of decommitment on thermal plant reliability?**

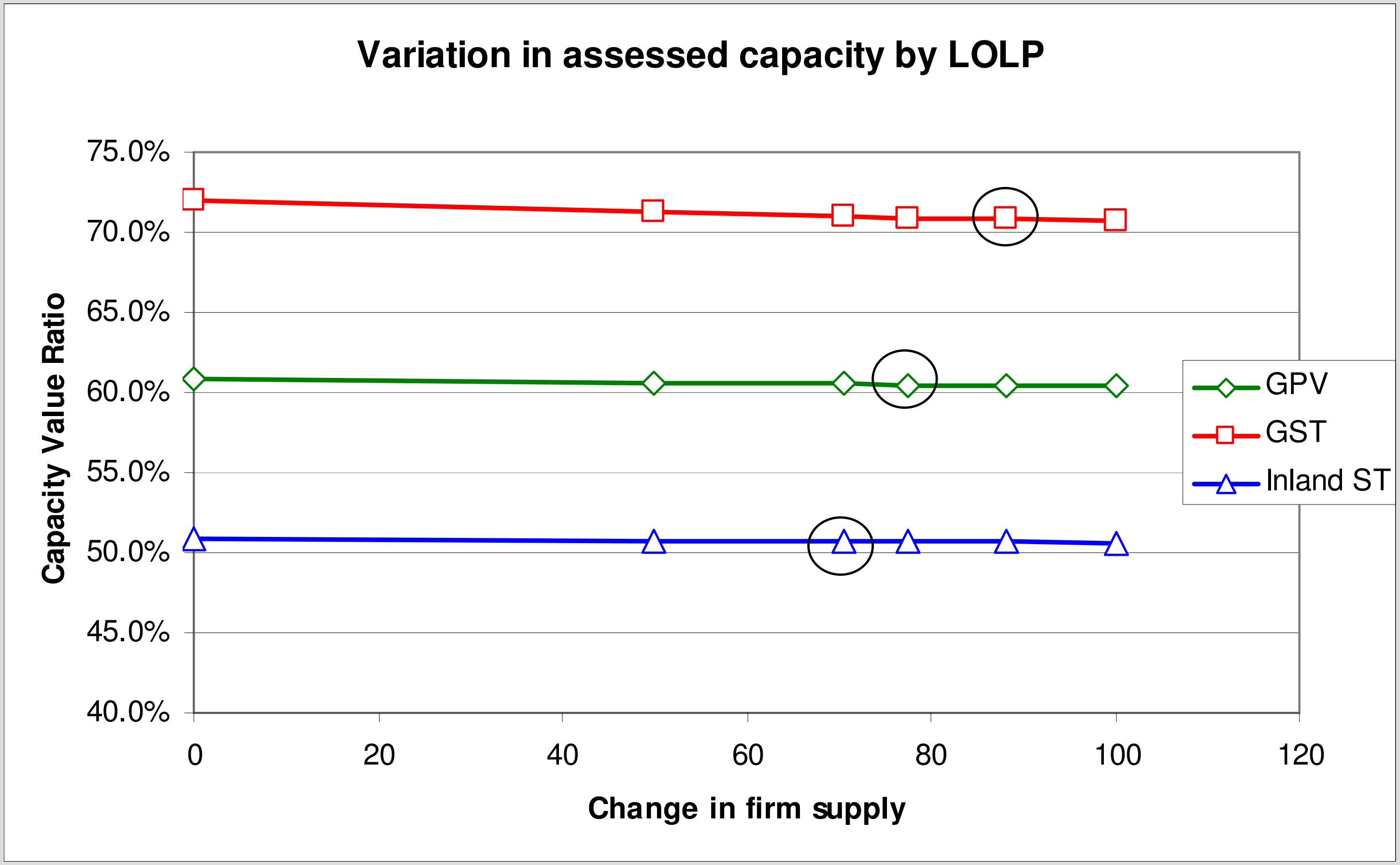
Reliability level for LOLP Analysis

- **It doesn't matter much at what reserve level you do the LOLP analysis**



Penetration

- The assessed level varied by 0.3% per 100 MW penetration for solar resources, so this is not immediately a critical issue.



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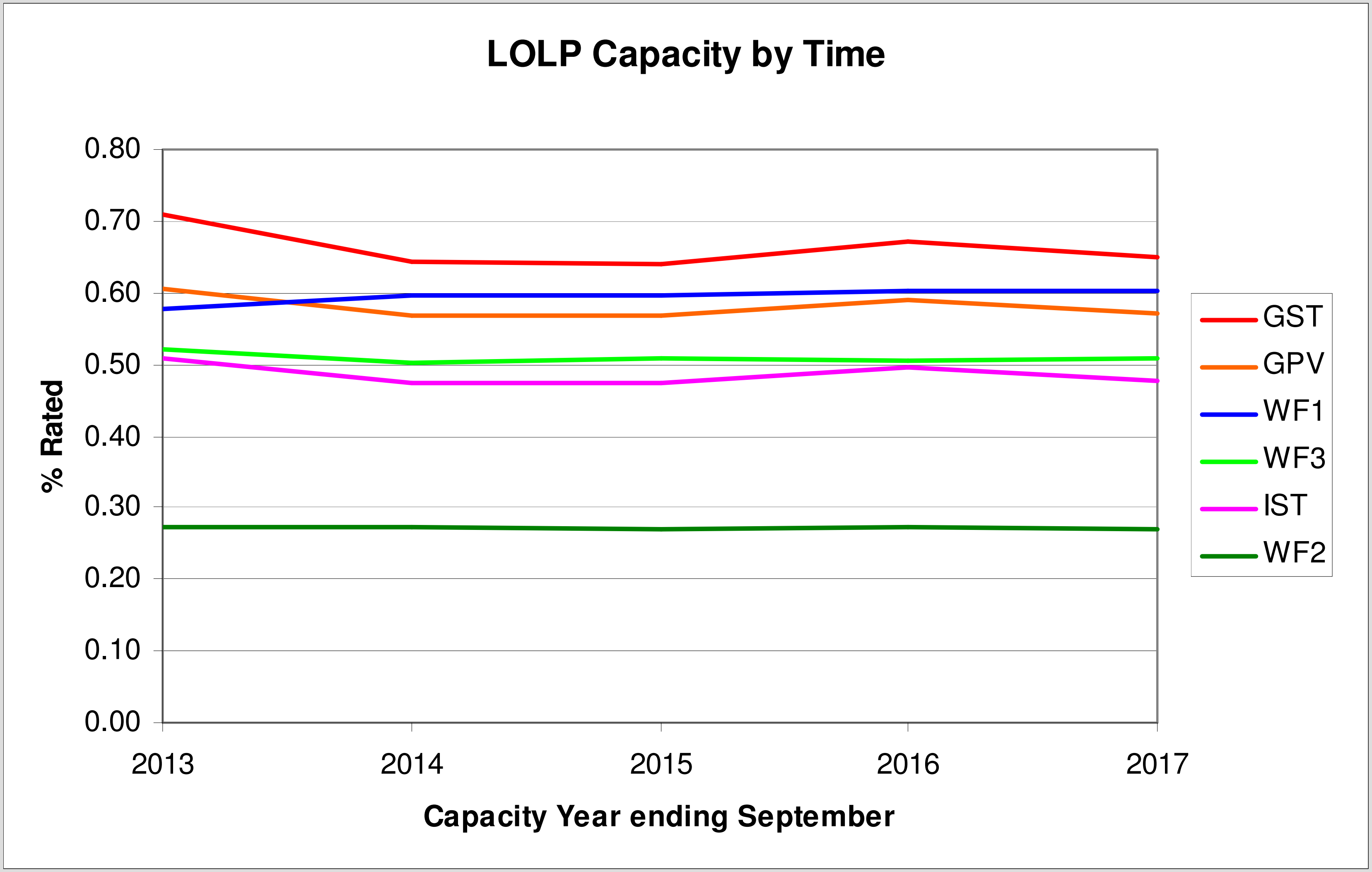
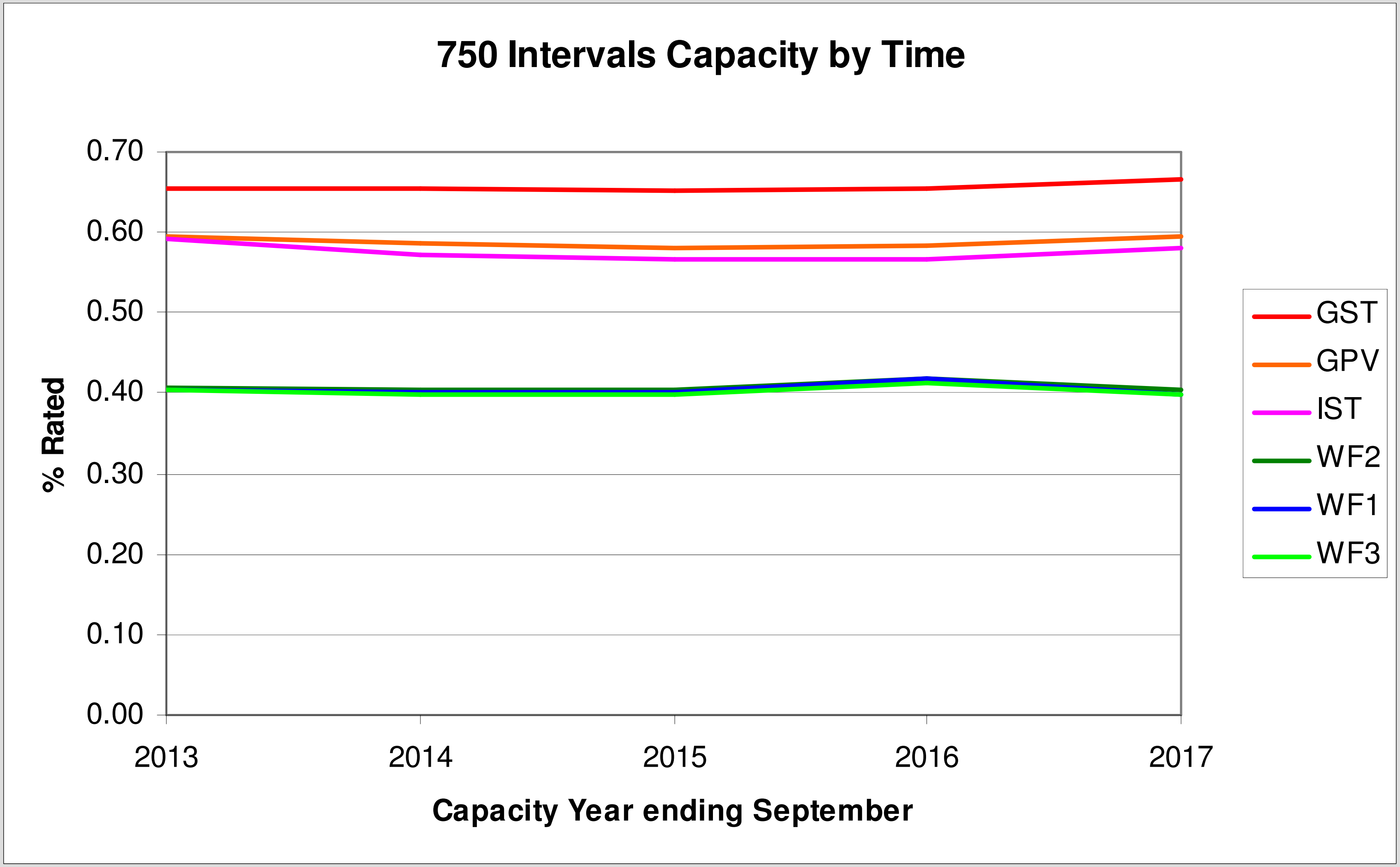
Multi-year valuations – LOLP Method



Multi-year valuations – 750 Trading Intervals



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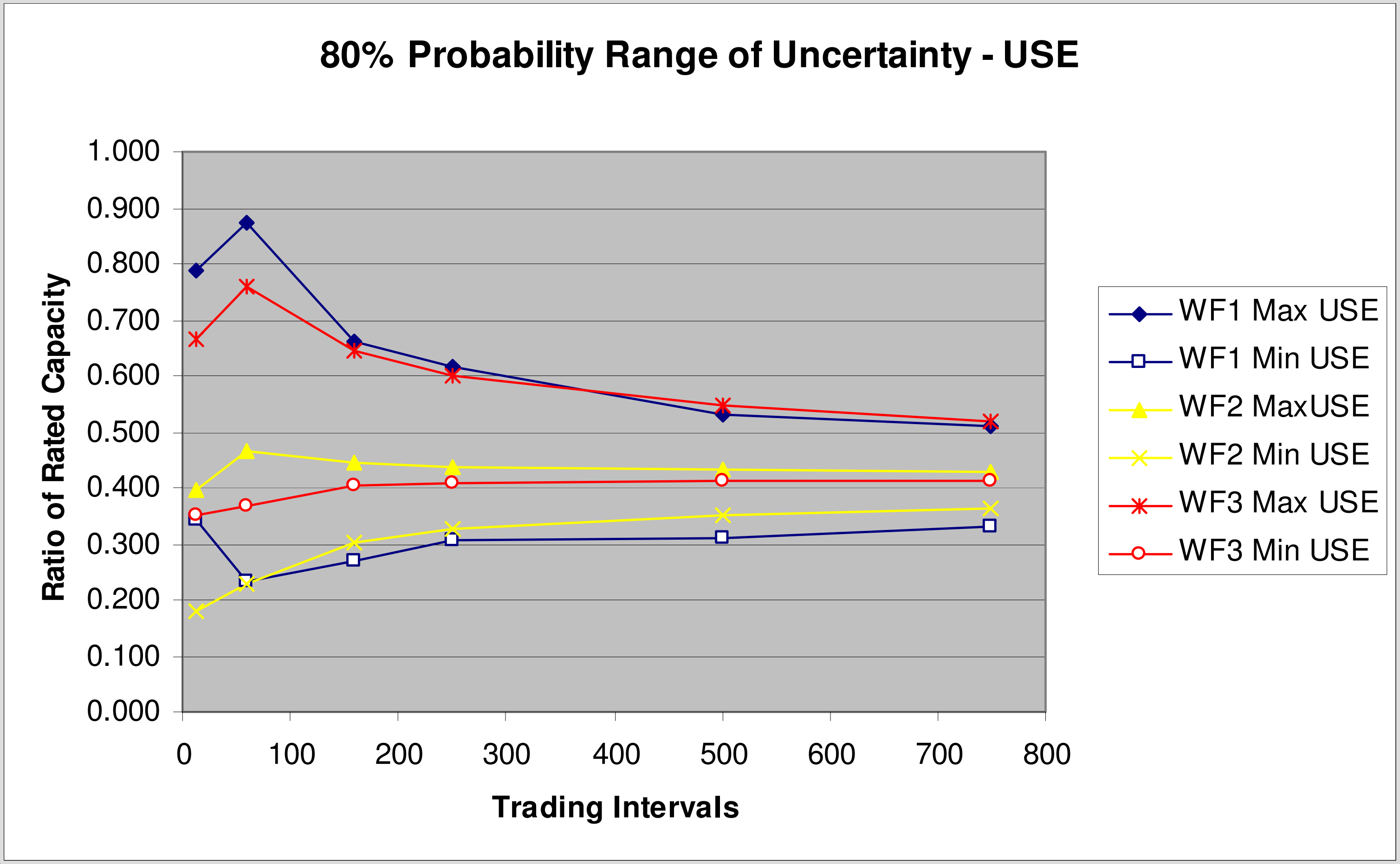
Using shorter periods

- Comparative analysis based on system peak or load for scheduled generation
- 12 intervals for individual reserve capacity assessment
- 60, 160, 250, 500 and 750 trading intervals
- Volatility decreases with more trading intervals but accuracy is less certain
- As trading period increases there is convergence for wind but not for solar
- Using load for scheduled generation is more conservative and addresses penetration level directly

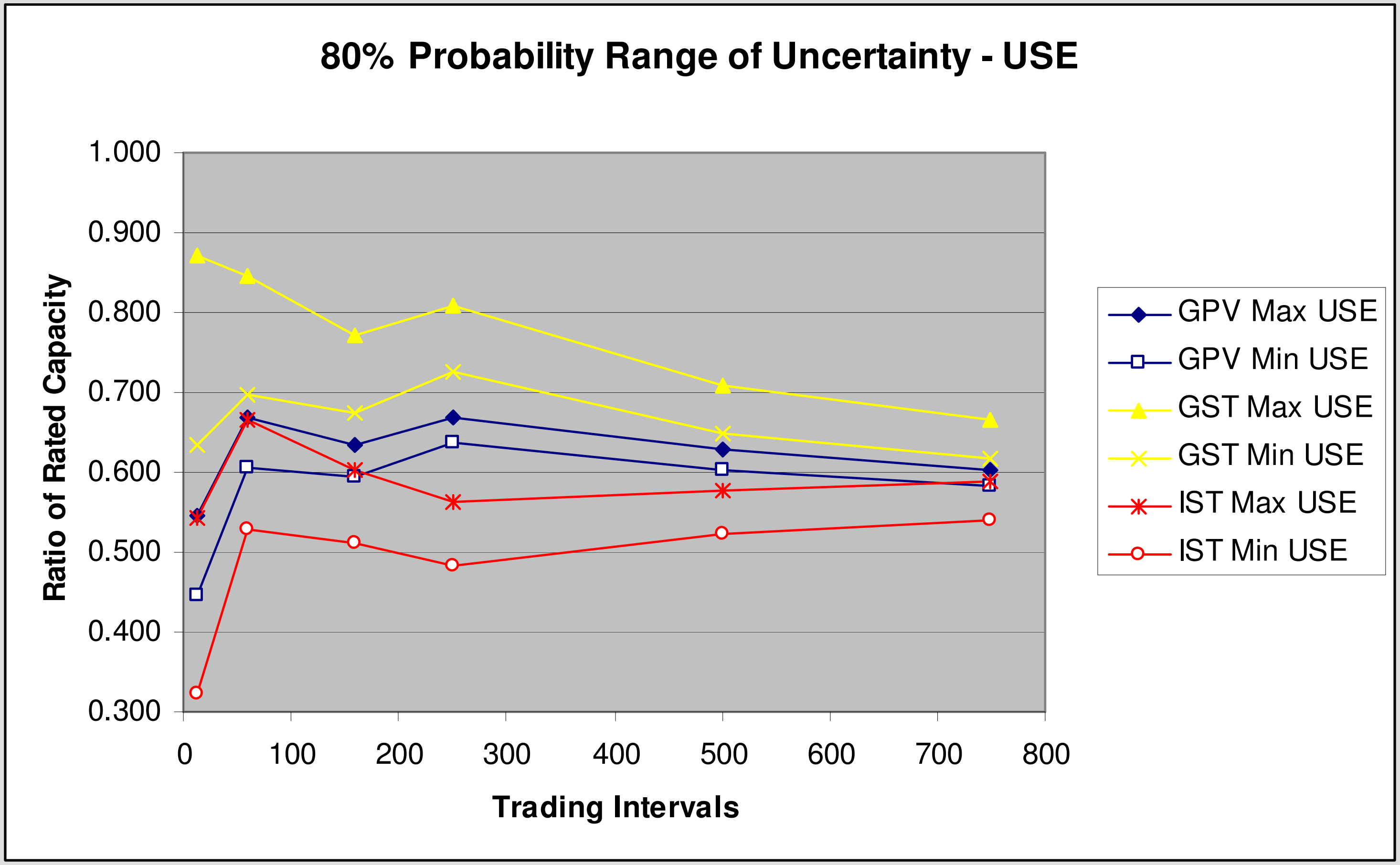
Shorter periods for averaging?

- Wind Farms - by peak load



Shorter periods for averaging?

- Solar thermal - by peak laod



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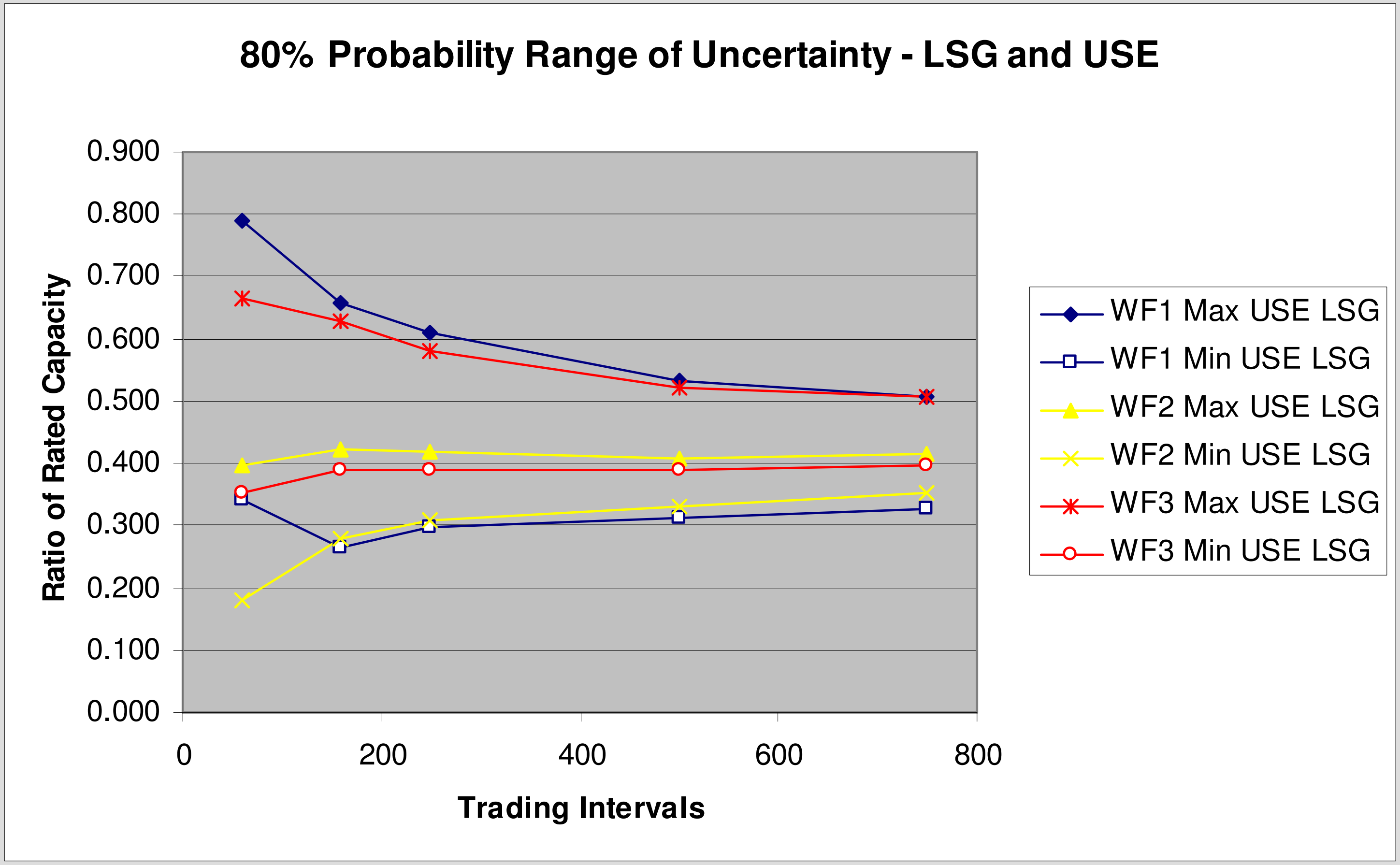
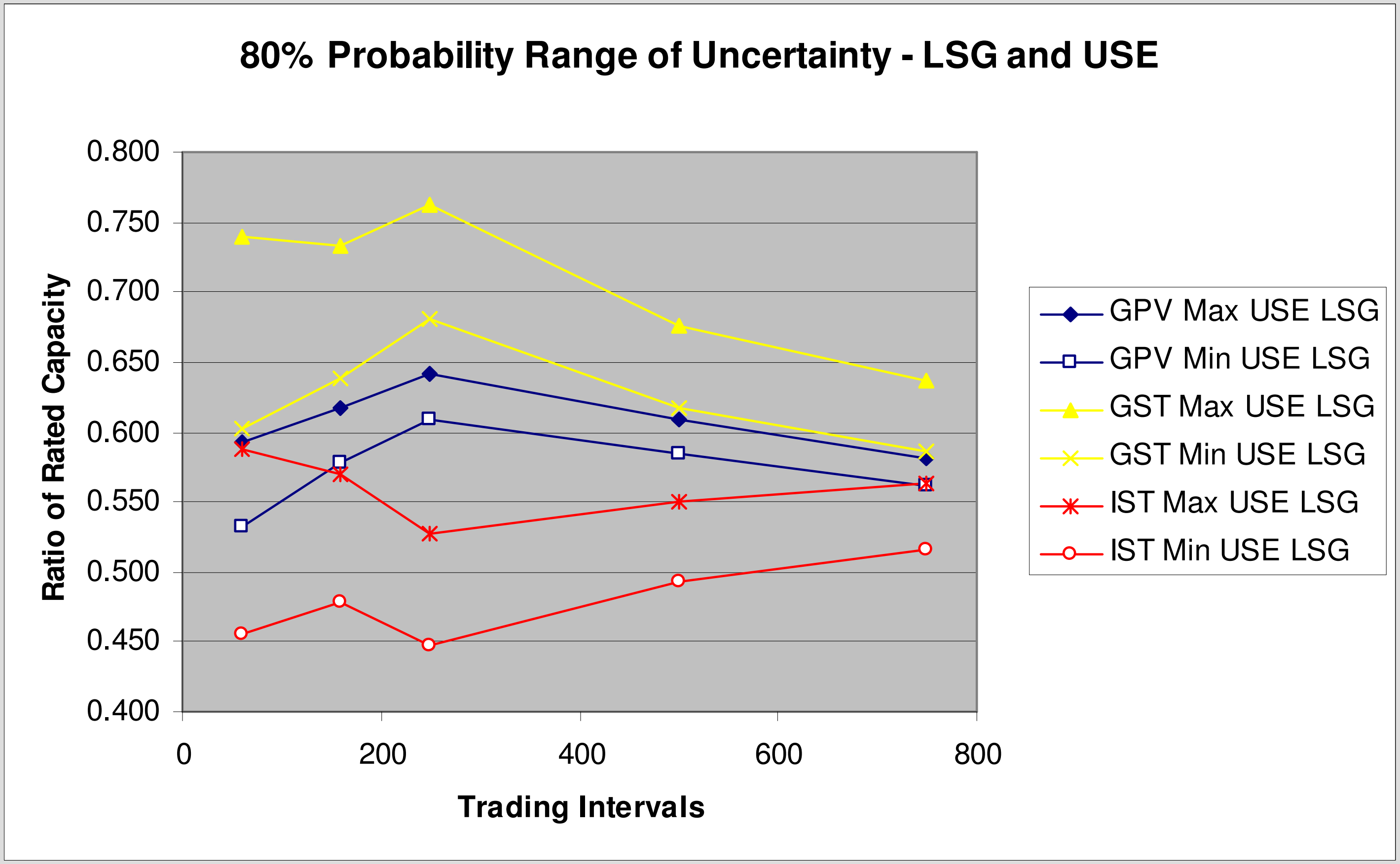
Shorter periods for averaging?

- **Wind Farms - by load for sched. generation**



Shorter periods for averaging?

- Solar thermal - by load for sched. generation



Comparison of trading intervals and LOLP

Trading Intervals	12	60	160	250	500	750	LOLP	Best Fit
Peak								
WF1	0.474	0.475	0.442	0.440	0.408	0.405	0.578	60
WF2	0.374	0.371	0.397	0.401	0.399	0.408	0.274	60
WF3	0.427	0.404	0.420	0.411	0.406	0.403	0.522	12
GPV	0.646	0.677	0.647	0.653	0.623	0.594	0.605	750
GST	0.880	0.809	0.749	0.757	0.693	0.656	0.708	500
IST	0.681	0.685	0.662	0.638	0.610	0.592	0.507	750
USE								
WF1	0.565	0.553	0.465	0.461	0.421	0.421	0.578	12
WF2	0.289	0.346	0.373	0.382	0.392	0.395	0.274	12
WF3	0.509	0.564	0.525	0.505	0.481	0.465	0.522	160
GPV	0.496	0.638	0.615	0.653	0.616	0.592	0.605	160
GST	0.753	0.771	0.722	0.767	0.678	0.641	0.708	160
IST	0.434	0.598	0.558	0.523	0.550	0.563	0.507	250

Note: Based on system peak demand

Comparison of trading intervals and LOLP

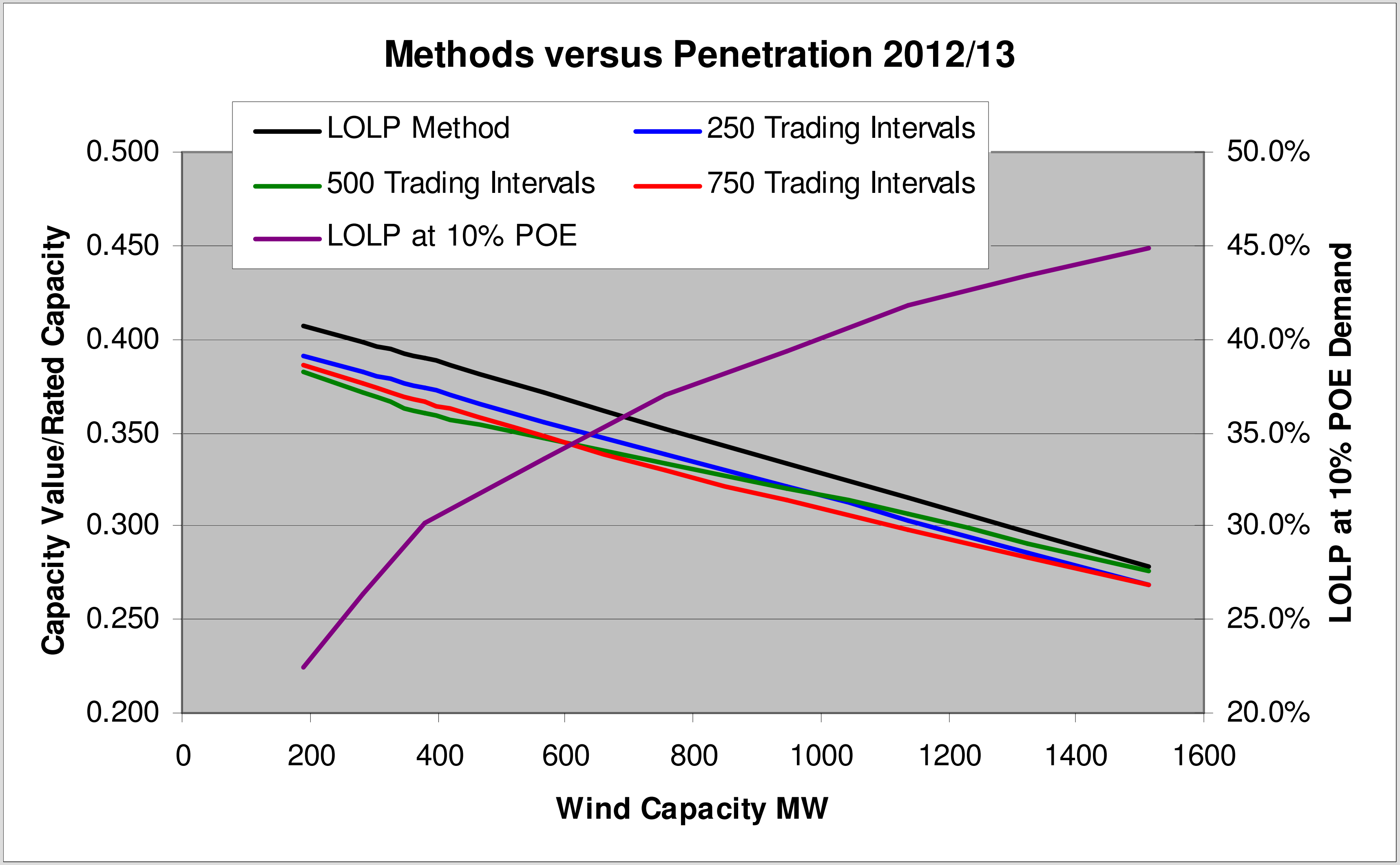
Trading Intervals	60	160	250	500	750	LOLP	Best Fit
Peak							
WF1	0.451	0.442	0.435	0.406	0.400	0.578	60
WF2	0.337	0.372	0.379	0.376	0.386	0.274	60
WF3	0.359	0.400	0.394	0.383	0.383	0.522	160
GPV	0.624	0.620	0.620	0.593	0.561	0.605	500
GST	0.730	0.692	0.702	0.646	0.602	0.708	250
IST	0.624	0.625	0.595	0.572	0.551	0.507	750
USE							
WF1	0.495	0.462	0.454	0.422	0.417	0.578	60
WF2	0.313	0.351	0.362	0.369	0.384	0.274	60
WF3	0.502	0.510	0.486	0.455	0.453	0.522	160
GPV	0.563	0.597	0.626	0.597	0.572	0.605	160
GST	0.672	0.686	0.722	0.646	0.612	0.708	250
IST	0.522	0.524	0.487	0.522	0.539	0.507	60

Note: Based on load for scheduled generation

Wind farm penetration

- Analysed increasing the size of existing wind farms assuming no diversity and basing the analysis on trading period averages selected according to maximum load for scheduled generation
- Also looked at the maximum LOLP assuming the unserved energy was 0.002% by adding to demand
- 750 trading intervals remains conservative for wind

Total capacity value versus penetration



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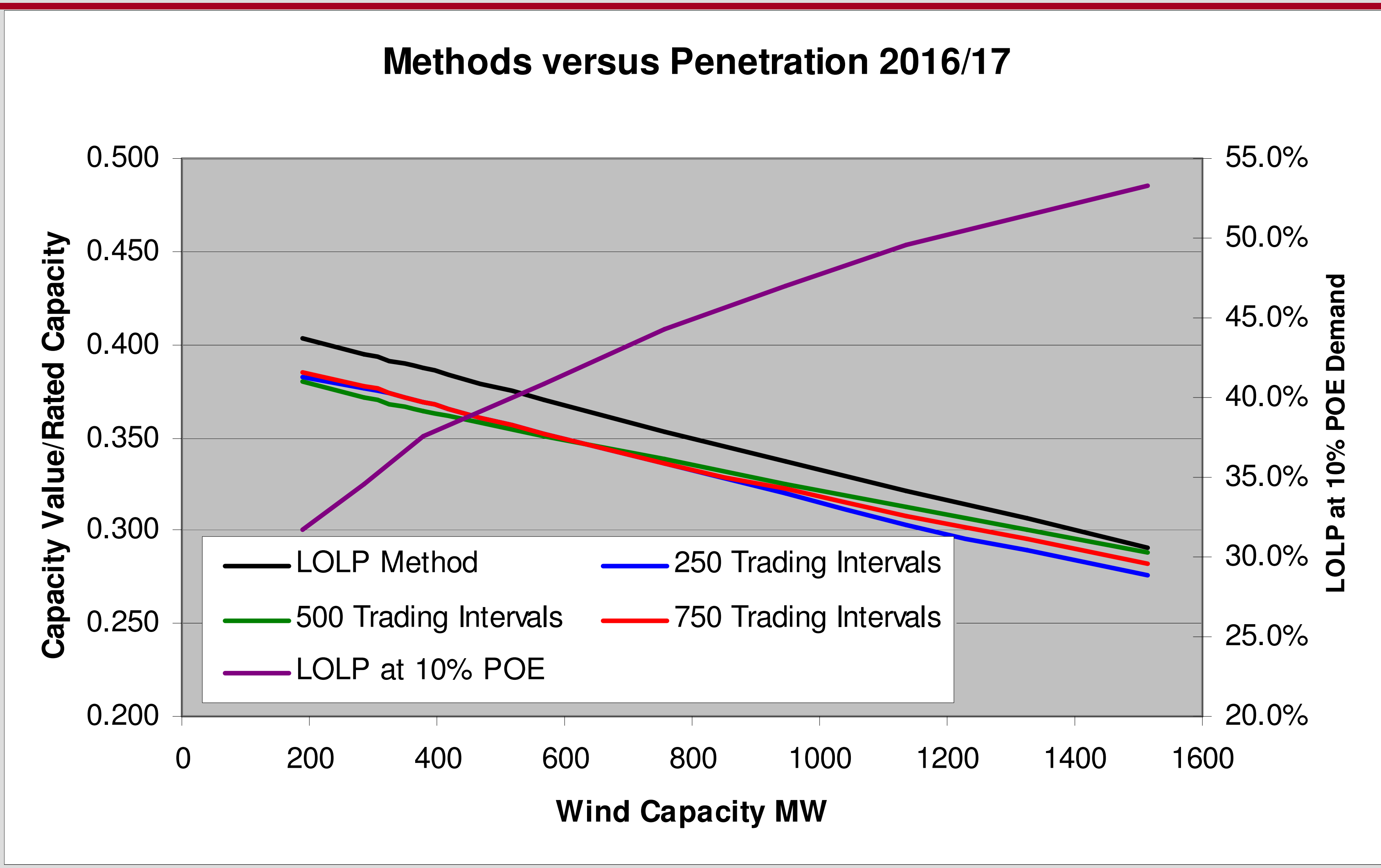
Total capacity value versus penetration



Scope for additional wind

- LOLP would not exceed 50% in any trading interval with 0.002% unserved energy up to about 1200 MW of wind power
- Capacity value would drop from ~ 37% to ~ 27%
- Propose that method be reviewed when wind capacity reaches 1200 MW or is projected to exceed 1500 MW
- Capacity valuation would be considered with next review of the reliability standard

Impact of increased decommitment

- No evidence available that increased decommitment has affected thermal plant reliability
- Capacity value would decrease if extra intermittent generation reduced the reliability of the thermal fleet
- Would need to work both ways: a storage device could get an extra capacity credit
- No precedent, too controversial, not needed, so not recommended

Stakeholder input

- **If stakeholders are not willing to go to LOLP methods for the long-term benefit and having regard to the volatility of the measure:**
  - Trading interval averages would be a viable next step to overcome the bias against solar resources with the current method
  - Trading intervals selected by load for scheduled generation is best to address penetration
  - Addition of another 500 MW or more of solar resources would not seem to present a major problem for a trading interval method (needs to be confirmed)
  - 1200 MW of wind could be accommodated using proposed valuation methods based on 750 trading intervals

Questions