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Methods to Model and Calculate Capacity Contributions of Variable Generation for Resource Adequacy Planning (IVGTF1-2): Additional Discussion

Composite photo created by NREL

NERC Loss of Load Expectation Working Group

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Report Link and Comment Instructions

The IVGTF Team 1-2 report *Methods to Model and Calculate Capacity Contributions of Variable Generation for Resource Adequacy Planning* is at http://www.nerc.com/docs/pc/ivgtf/IVGTF1-2_DRAFT_11.22.pdf.

Provide feedback by January 30, 2010 to michael.milligan@nrel.gov.

Scope & Objectives

– Consistent and accurate methods are needed to calculate capacity values attributable to variable generation.

– Technical considerations for integrating variable resources into the bulk power system

Scope & Objectives (continued)

Specific actions, practices and requirements, including enhancements to existing or development of new reliability standards

- Calculations and metrics, including definitions and their applications used to determine capacity contribution and reserve adequacy.
- Contribution of variable generation to system capacity for high-risk hours, estimating resource contribution using historical data.
- Probabilistic planning techniques and approaches needed to support study of bulk system designs to accommodate large amounts of variable generation.

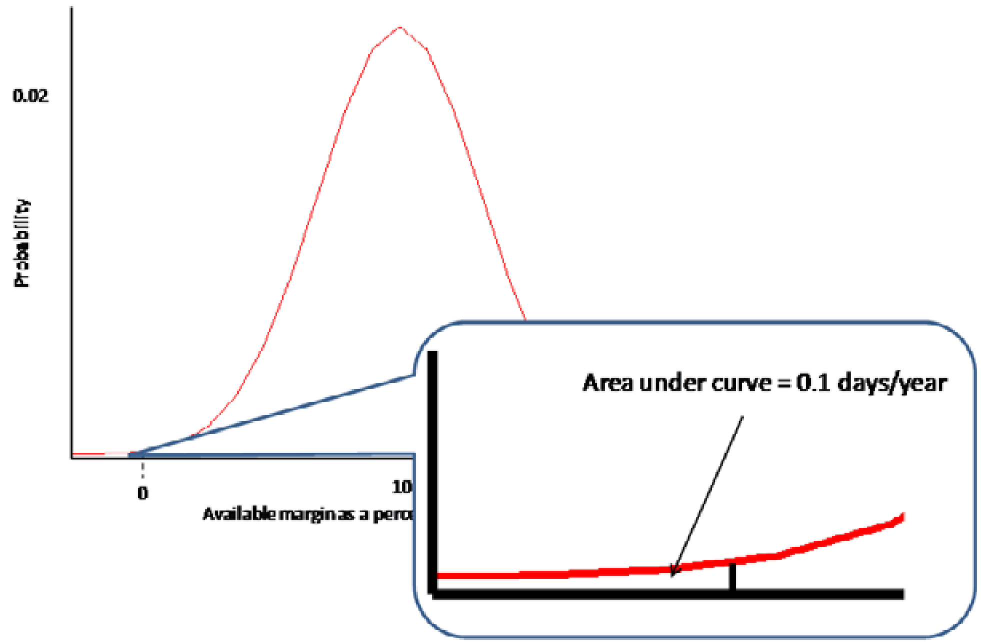
Report Outline

- Introduction
- Traditional Resource Adequacy Planning
- Data Limitations
- Approximation Methods
- Ongoing Variable Generation Actions
- Conclusion and Recommendation

Traditional Resource Adequacy Planning

Loss of Load Probability, LOLP

– LOLP analysis is typically performed, calculations can be done hourly or daily on a system to determine the amount of capacity that needs to be installed to meet the desired reliability target. Commonly expressed as an expected value (loss of load expectation, LOLE) of 0.1 days/year or similar target.



Traditional Resource Adequacy Planning

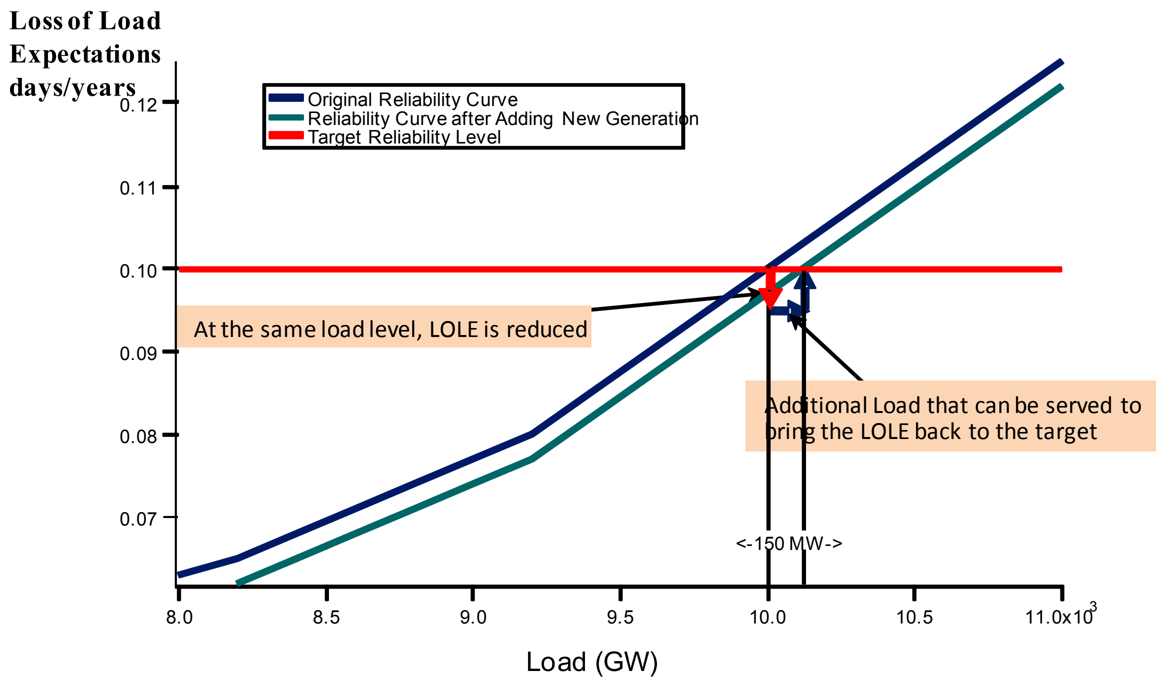
Loss of Load Hours, LOLH

LOLH by contrast, is concerned only with the number of hours of shortfall, and does not include any dimension for persistence of an outage event and therefore there is no quantification about how many days the outage is spread over.

Traditional Resource Adequacy Planning (continued)

Effective Load Carrying Capability, ELCC

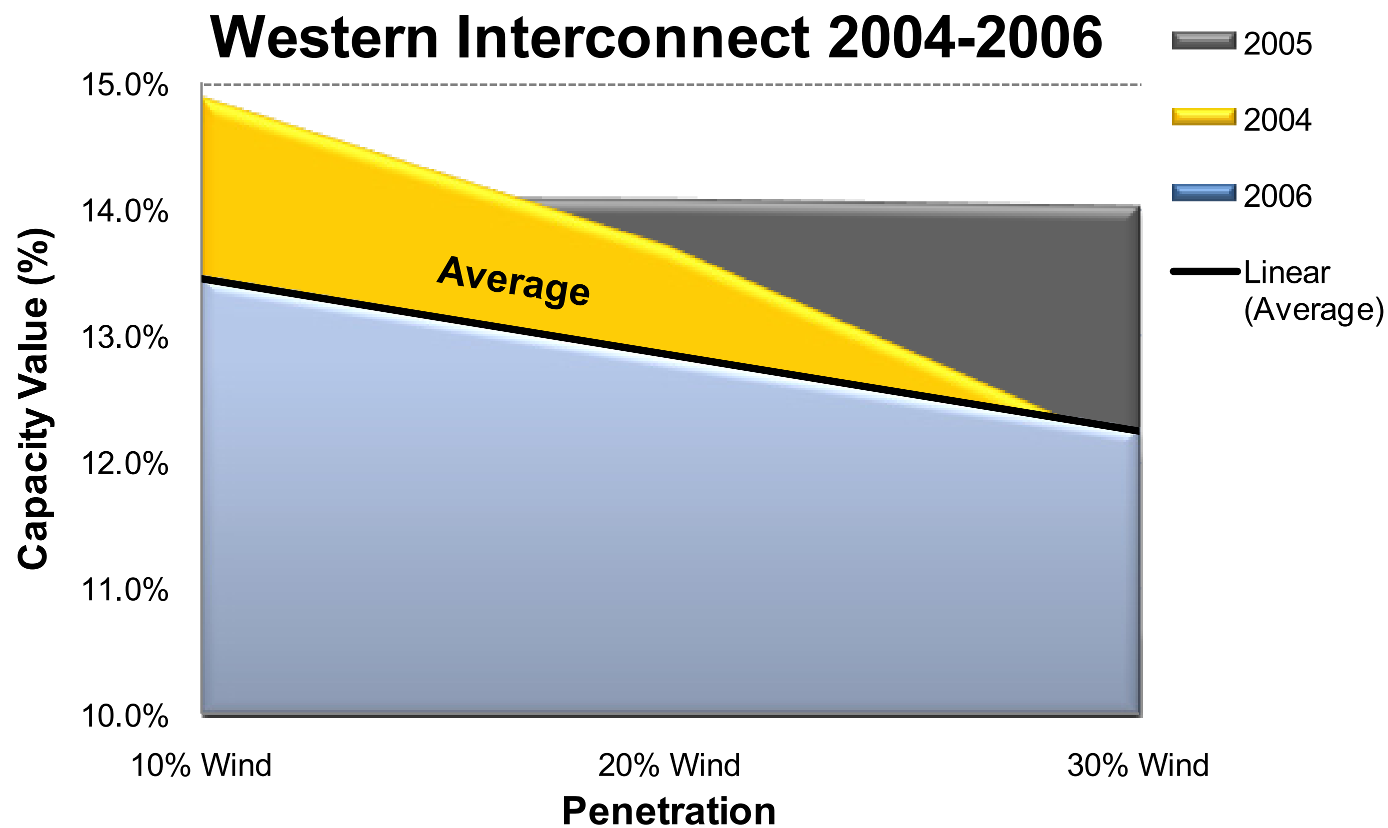
ELCC essentially decomposes the contribution that an individual generator (or group of generators) makes to overall resource adequacy. A generator contributes to resource adequacy if it reduces the LOLP in some or all hours or days. Conventional generators' contribution to adequacy is typically a function of the unit's capacity and forced outage rate.



ELCC Variation

Wind ELCC declines with penetration

Inter-annual variation implies need for many years of data (as with conventional generation)



Approximation Methods

Approximations are less than ideal and often do not take LOLP or risk into account

Approximation to Reliability Analysis:

R' = Exp{-[(P-L)/m]}

Where:

P = annual peak load,

L = load for the hour in question,

R = the risk approximation (LOLP), measured in relative terms (peak hour risk = 1)

Time Period Methods

- **Define the relevant time period to use**
- **Calculate the mean output of the variable generation over that period; or alternatively calculate a percentile or exceedence level of the variable generation over the period**

Data Limitations

- Data
  - Thermal Generation does exist
    - Long-term forced outage rates
    - GADS
  - Wind and Hydro does not have sufficient long term data
- Need for data from variable generation
  - Collected by NERC's GADS
  - Currently does not satisfy requirements for capacity valuation of variable generation

Conclusions and Recommendations

- *Additional research to equate traditional reliability targets (such as 0.1day/year) to alternative metrics is recommended. As adequacy studies are performed, we also recommend comparisons of results based on these alternative metrics.*

- *Alternative approaches and assumptions regarding the treatment of interconnected systems should be transparent to the analysis, and the development one or more common approaches for handling the impact of interconnected systems in the reliability assessments will be useful.*

- *Planning Reserve Margin levels should be benchmarked with, or derived from, an LOLP or related approach to resource adequacy. This should be done periodically to ensure that any correlation between a 0.1days/year target (or other adopted target) and a given Planning Reserve Margin do not change as a result of an evolving resource mix.*

Conclusions and Recommendations (continued)

Simplified approaches should be benchmarked and calibrated to the rigorous ELCC calculations to ensure the validity of the approximation.

NERC should design and implement a way to collect high-quality variable generation data that would help inform calculations of capacity value. The development of such a database should consider defining relevant time periods for the variable generation data.

Conclusions and Recommendations (continued)

NERC should request that government agencies like the DOE, working with NOAA/NCAR develop annual high-resolution, modeled wind power and solar power data on 10-minute time scales (or faster, as technology allows) and 2 km (or smaller) geographic grids. NERC should consider collecting 10-minute load data to support reliability and other analyses.

NERC should facilitate the dissemination of information on how LOLP-related reliability and adequacy calculations perform and what they measure.

End of NERC PC Presentation

Additional Topics

ELCC vs. PRM

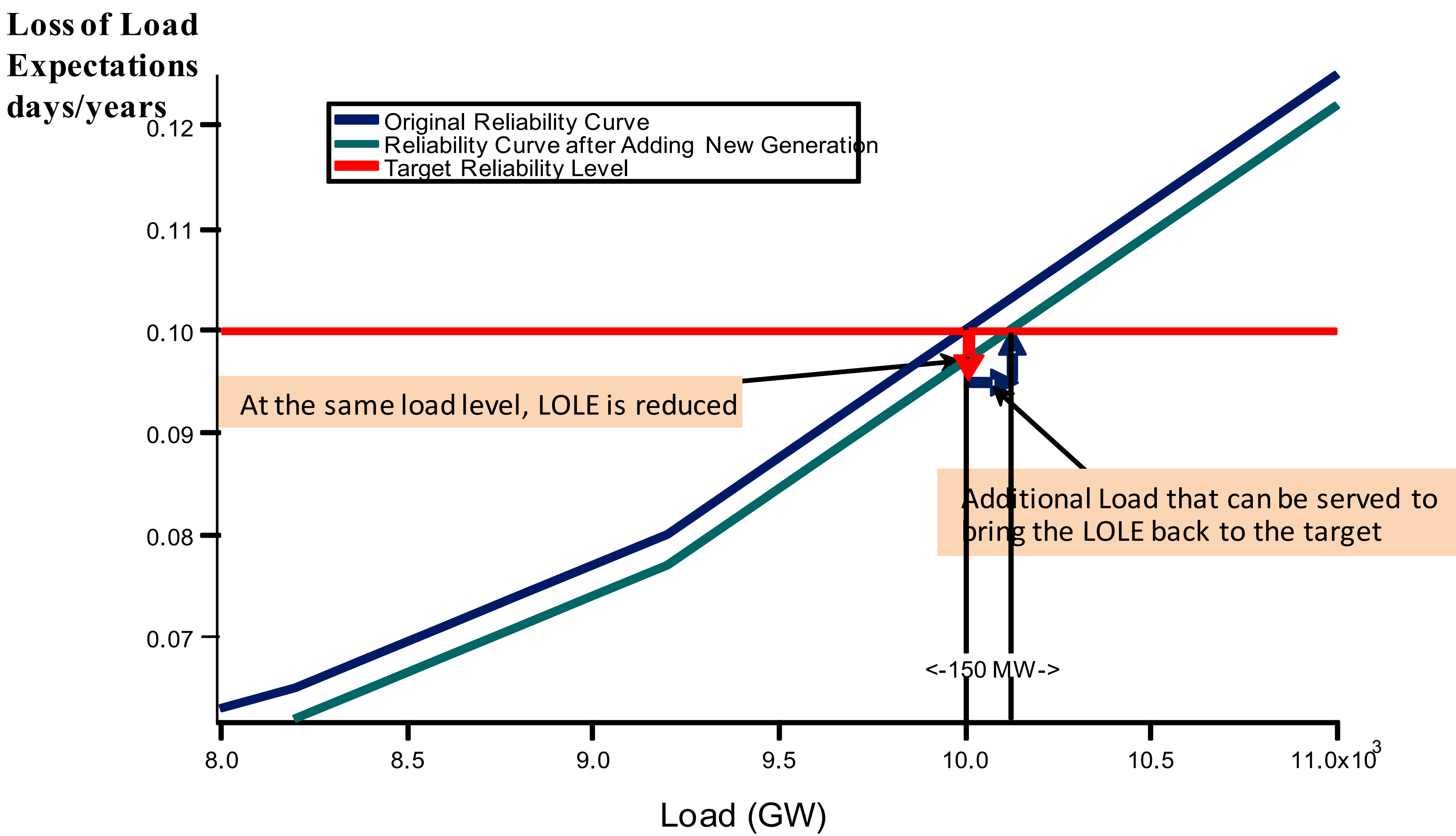
Alternative LOLP-related metrics: LOLP, LOLH, LOLE, EUE…

Calculation Approaches

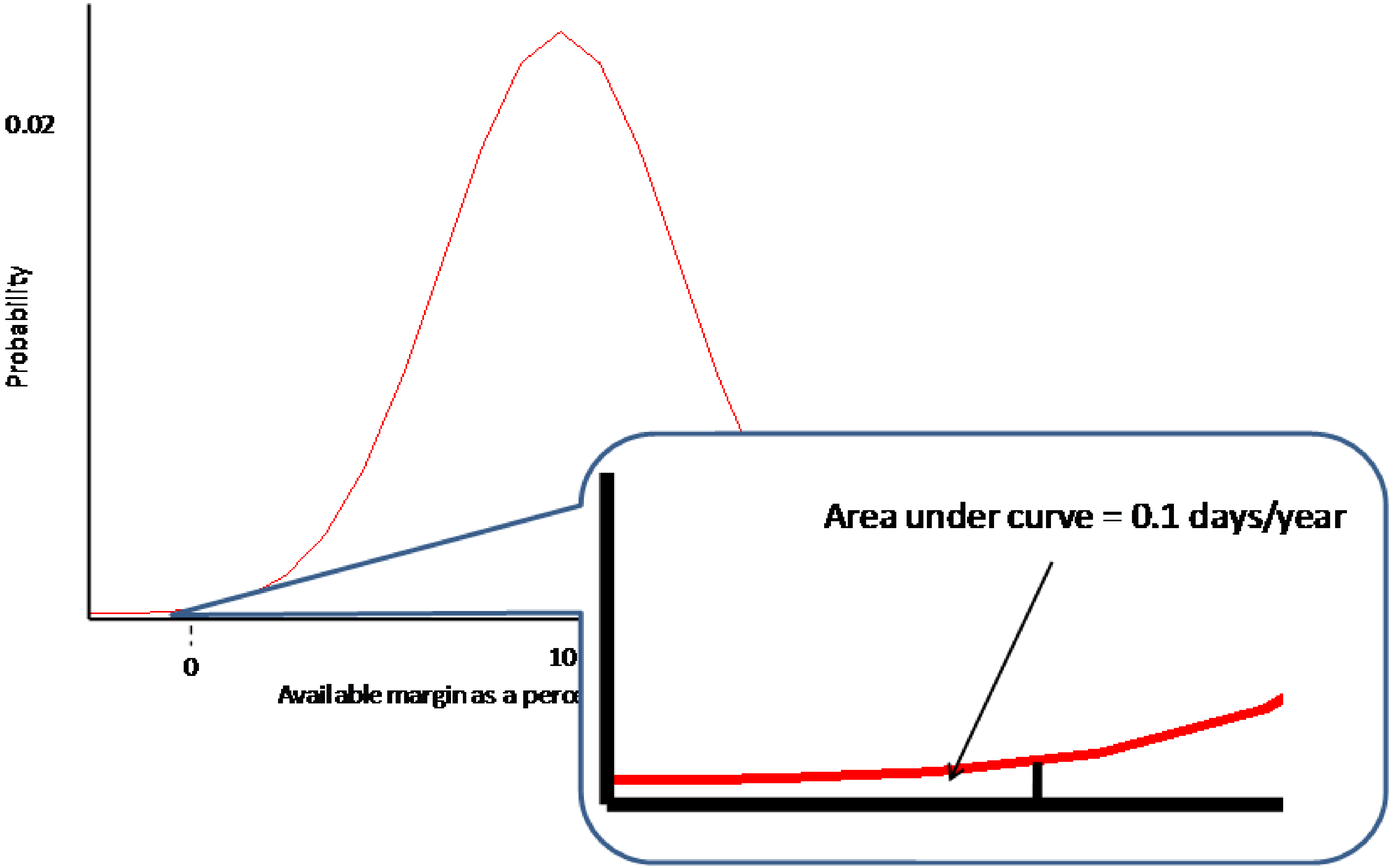
Data and LOLP techniques

Note: most work has been done on wind but other forms of VG can be analyzed using these methods

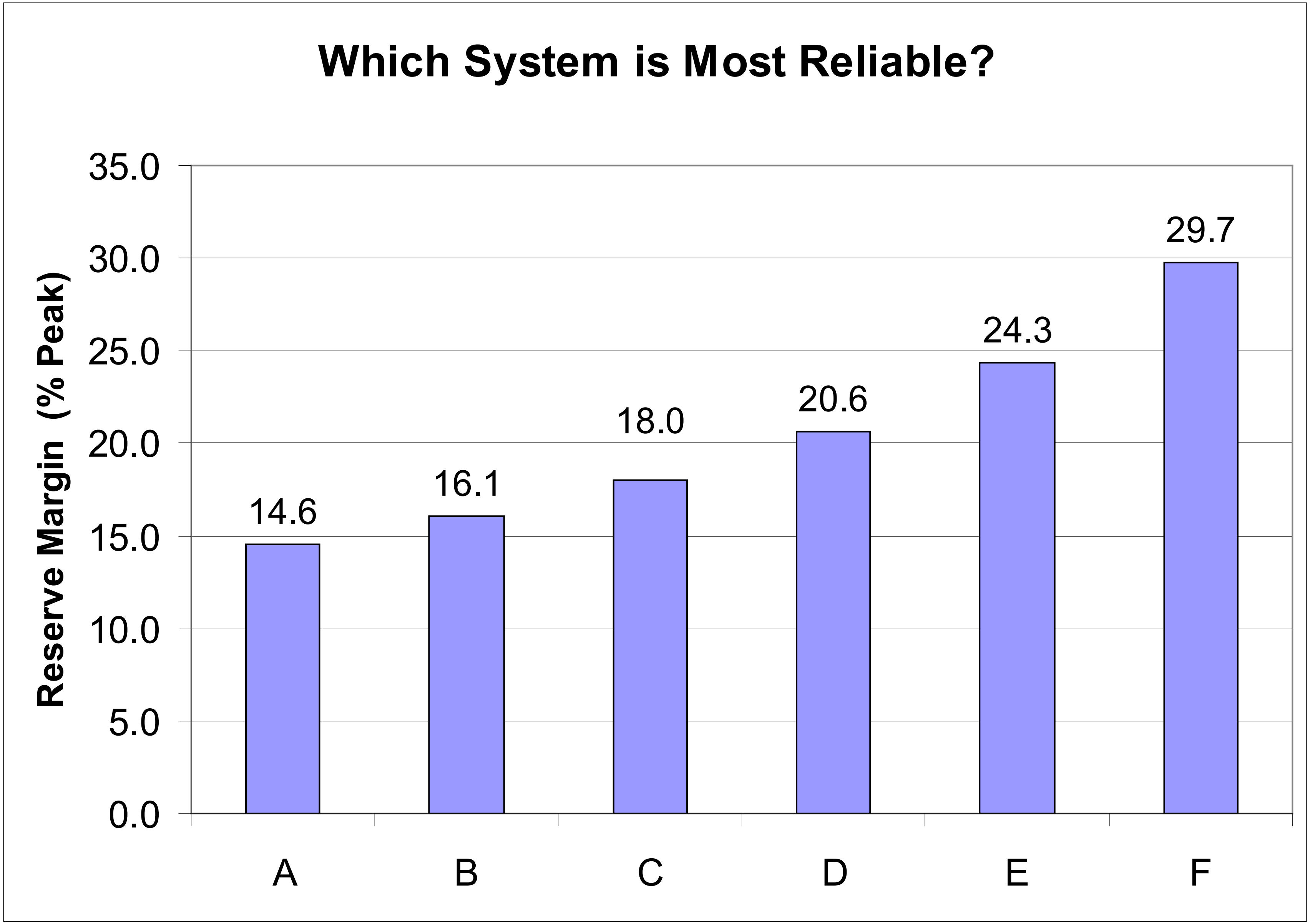
Effective load carrying capability



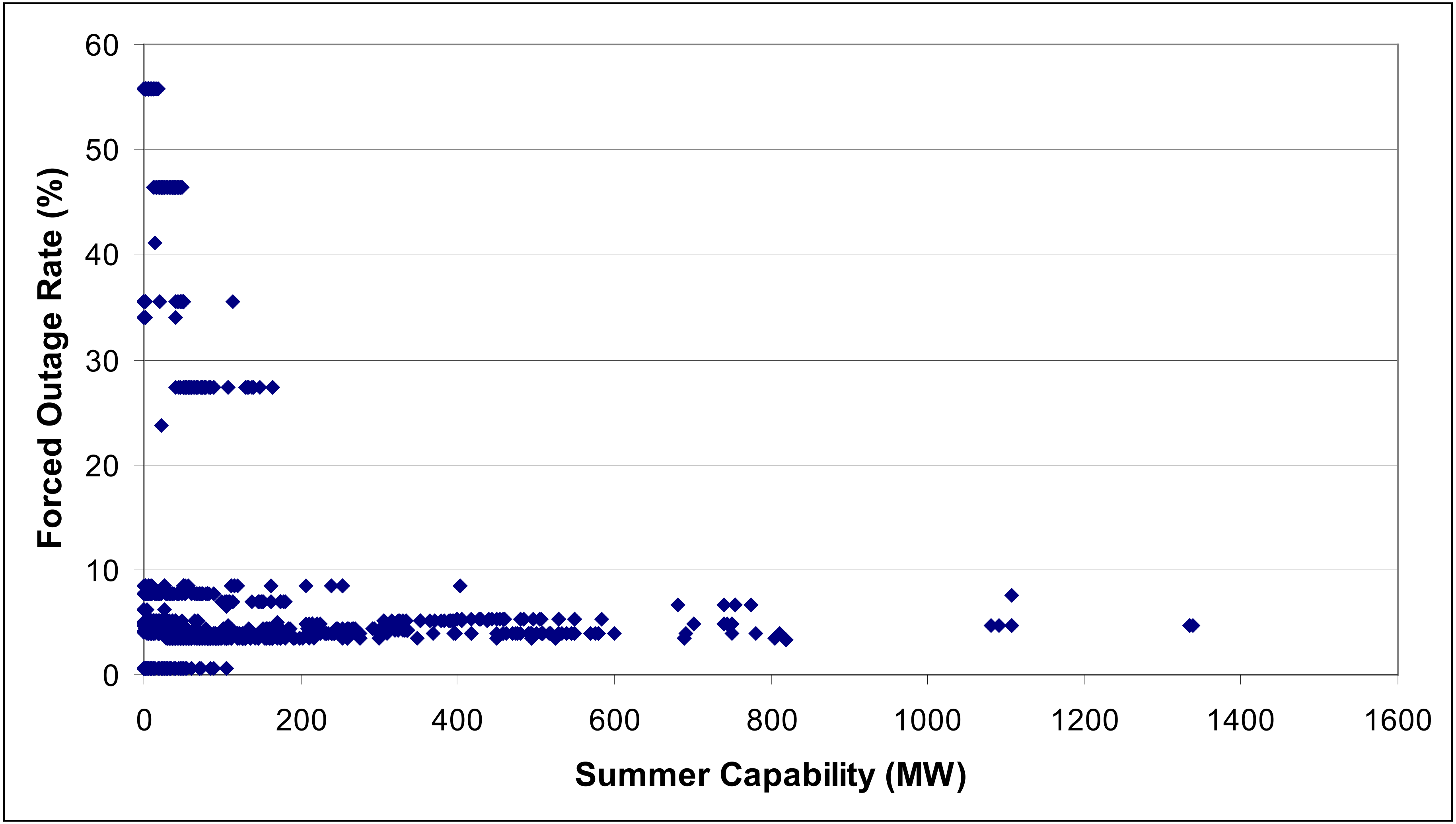
Another view of ELCC



Planning reserve as % of peak is not a good metric

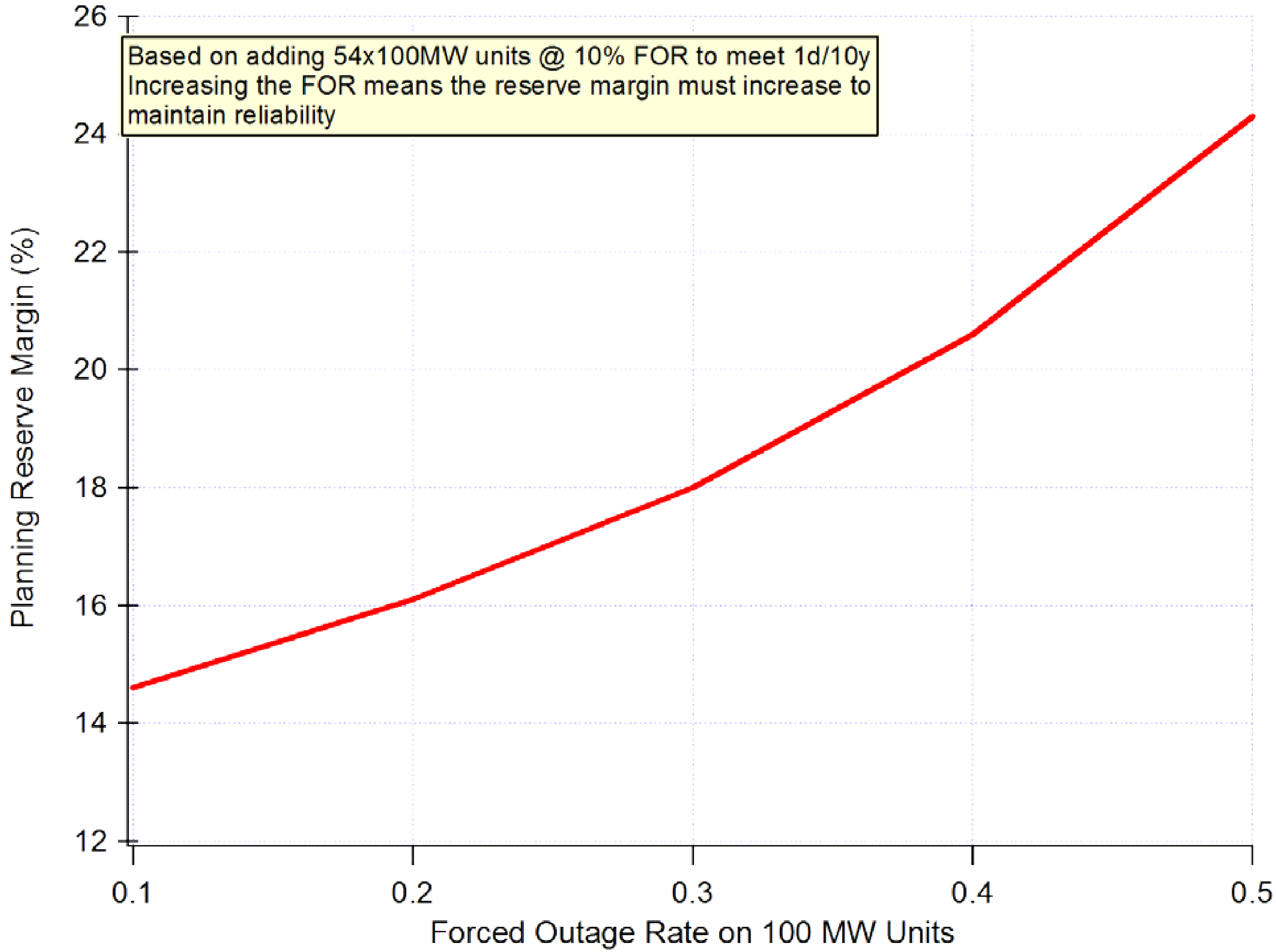


WECC Data



60
50
40
30
20
10
0
Forced Outage Rate (%)
0
200
400
600
800
1000
1200
1400
1600
Summer Capability (MW)

Reserve Margins Don't Directly Address System Adequacy



Alternative underlying reliability metrics

ELCC can be based on

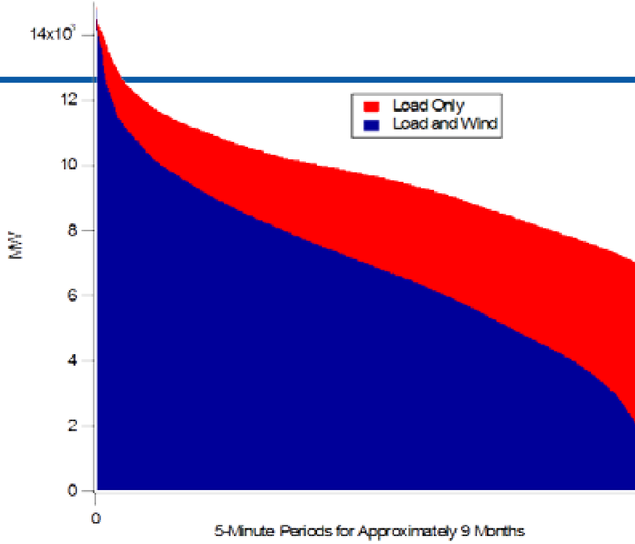
- LOLP/LOLE – daily
- LOLH (hourly LOLP)
- EUE – expected unserved energy

LOLP/LOLE measures count time periods but ignore the energy risk

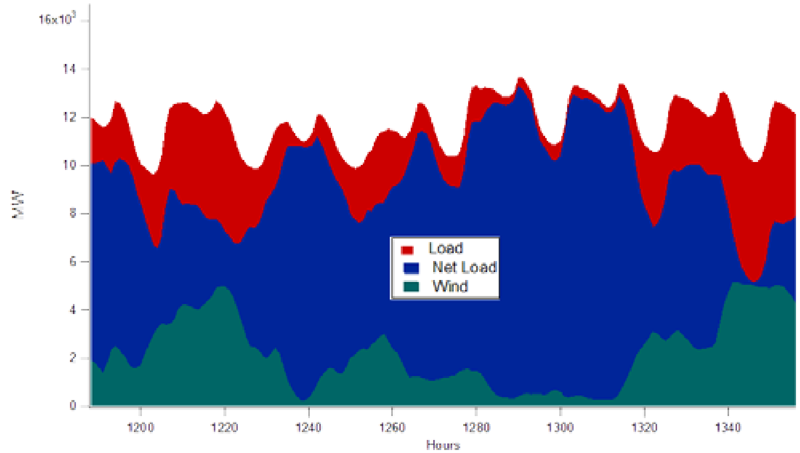
EUE does not count, but aggregates energy risk

Types of assessments

Frequency distribution/duration curves for load and wind (fewer computation requirements but can't be easily justified



Chronological simulation: best approach



Simplified approaches: use with caution; benchmark with ELCC required

Data required

Hourly load and wind/solar (VG), ***synchronized***

Generation capacities, forced outage rates

PIX 16799

PIX 02368

Representations of VG in reliability models

Hourly VG production (real or simulated)

Time-synchronized with load

This captures the actual variability in VG output

Multiple years (just like thermal units)

Conventional Stochastic Approaches: Multiple-block Unit

Wind as a multiple-block generator

For each month, calculate several discrete generation levels and frequency of occurrence according to reliability model requirements

Partition by hour of day

Result: 24 distributions per month, each representing a given hour of the day

Does not preserve underlying "weather" of VG and load

Sequential Monte Carlo: Use with Care

Basic Approach

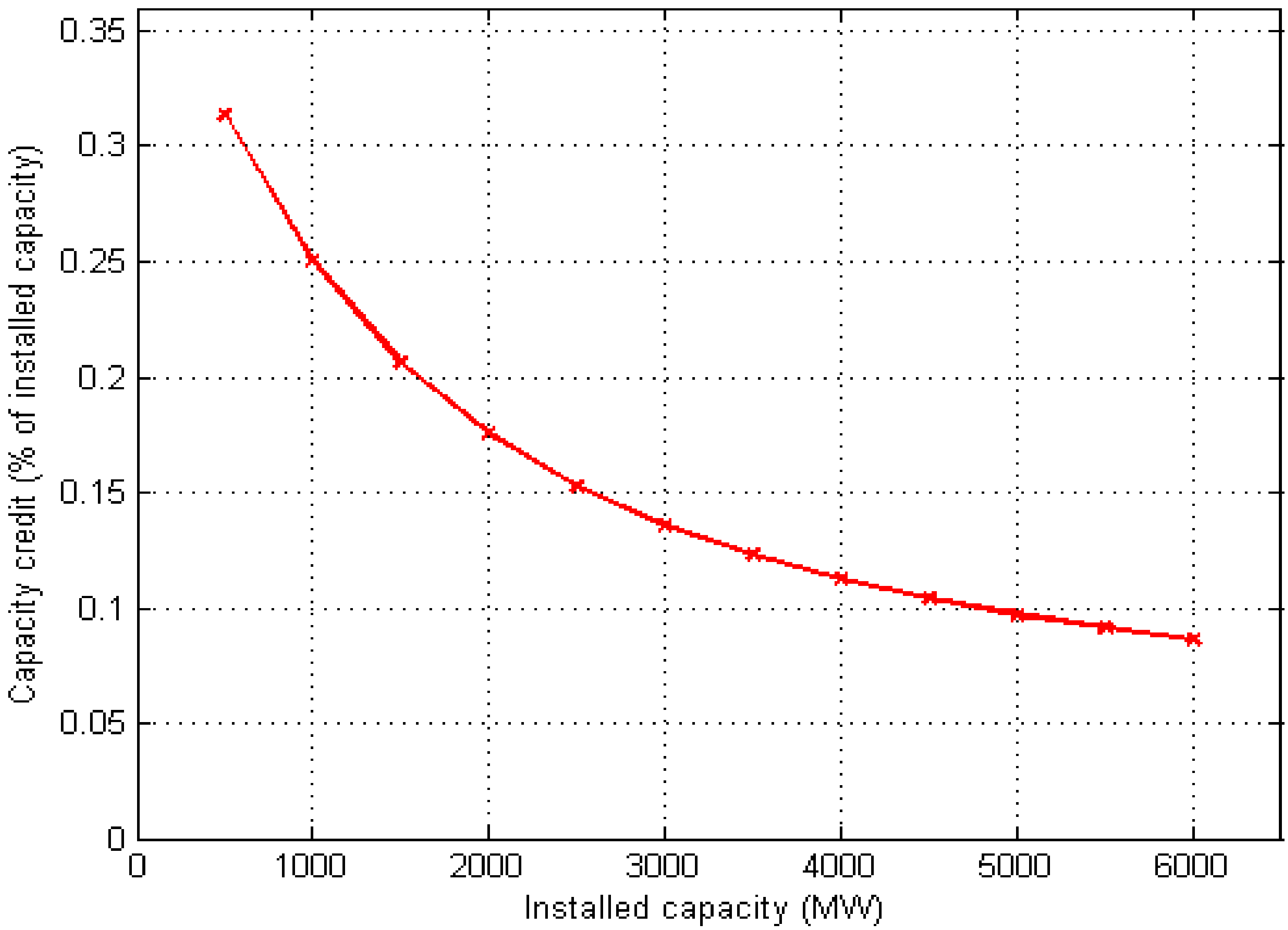
- Build probabilistic model of wind resource or wind generation
- Repeatedly sample from the family of distributions
- Run reliability model for each simulated year of wind data
- Collect results

Computationally expensive

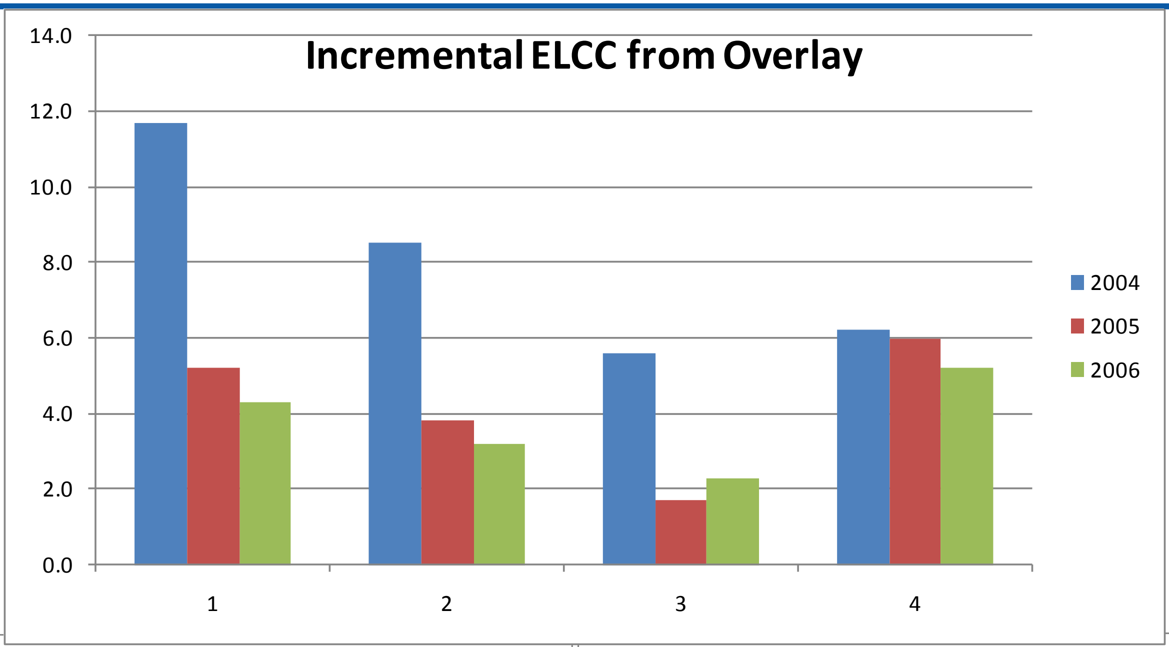
- ***May not adequately capture wind-load synergies***
- Can be difficult to obtain synthetic time series that adequately represent the complex correlation and auto-correlation structure in the real wind generation patterns

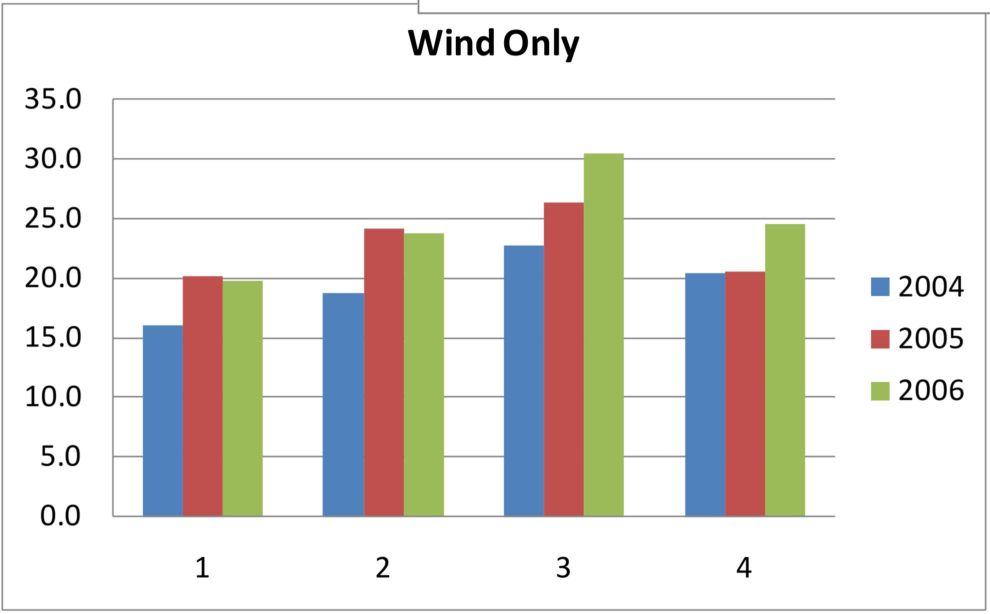
Characteristics and overview of findings

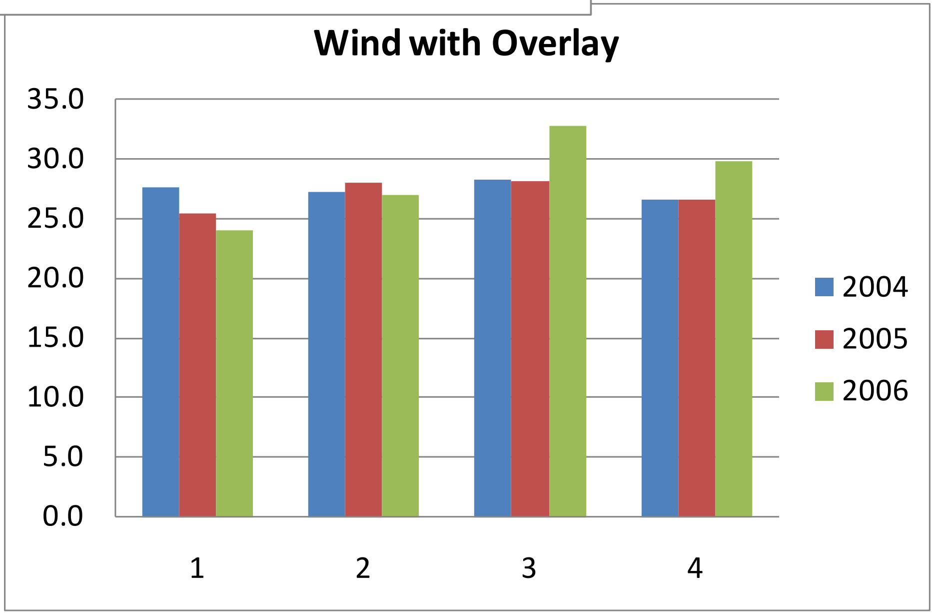
Capacity value declines with more wind



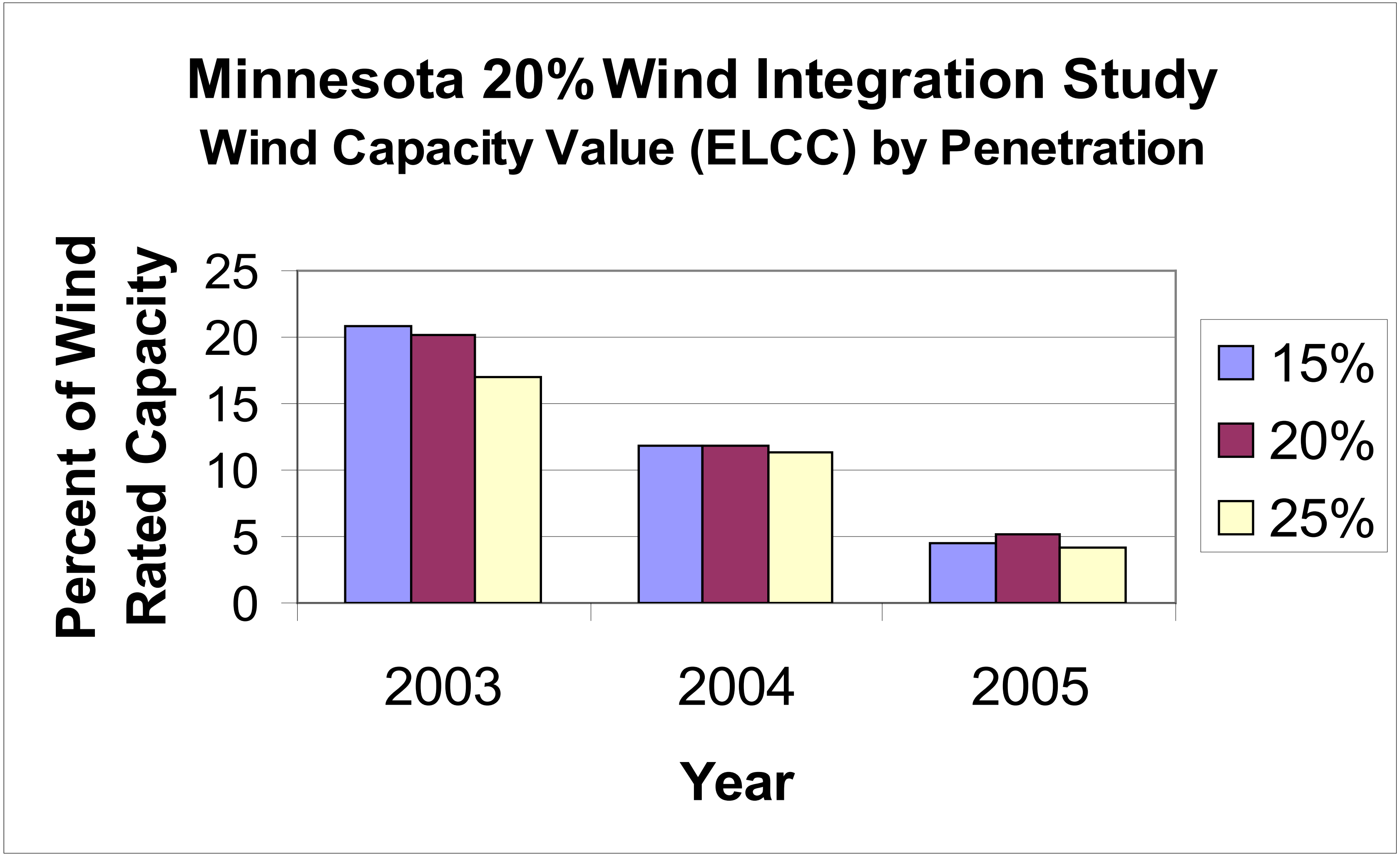
ELCC and LOLP depend on electrical footprint



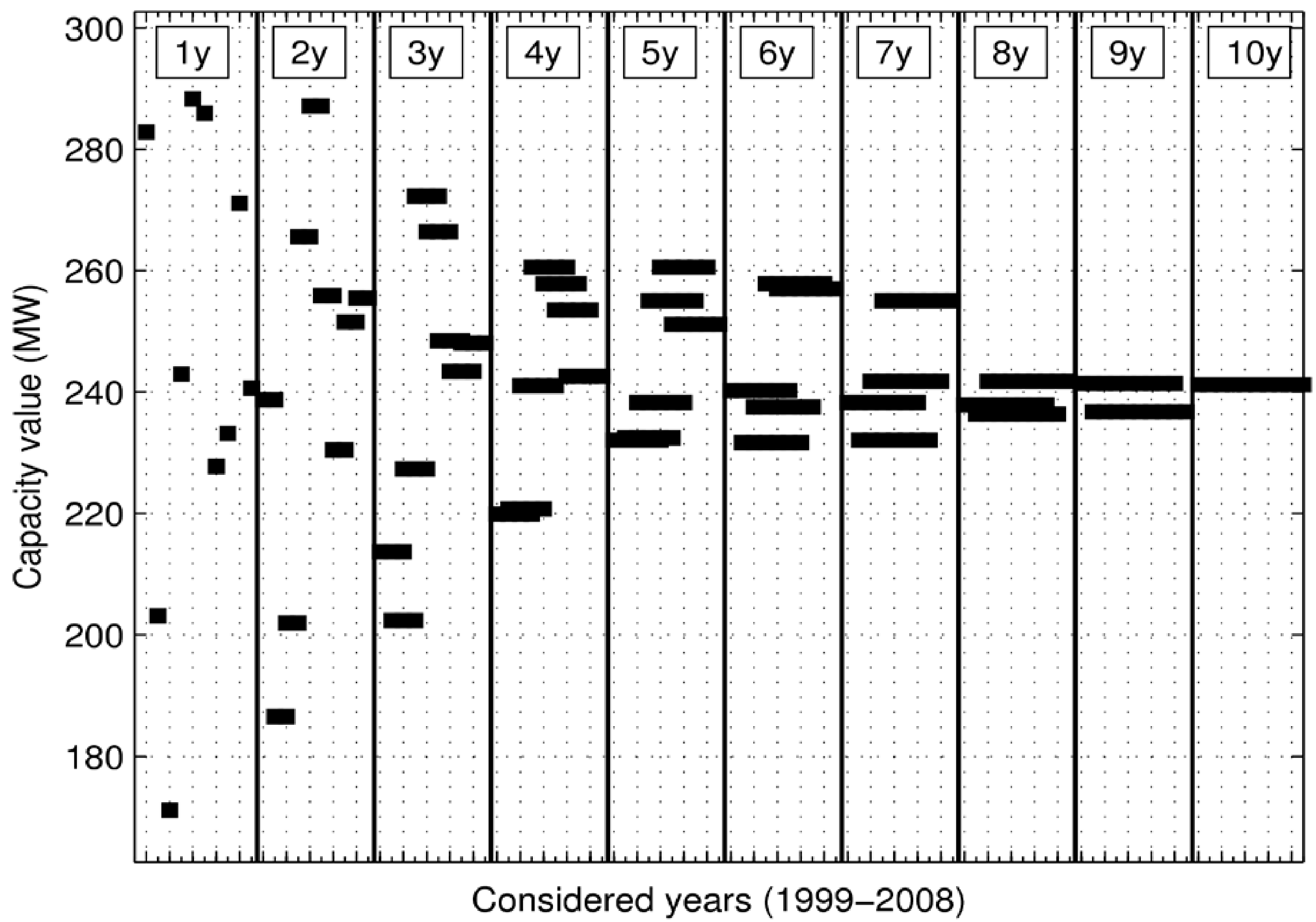




If you use one year of data you may be in trouble



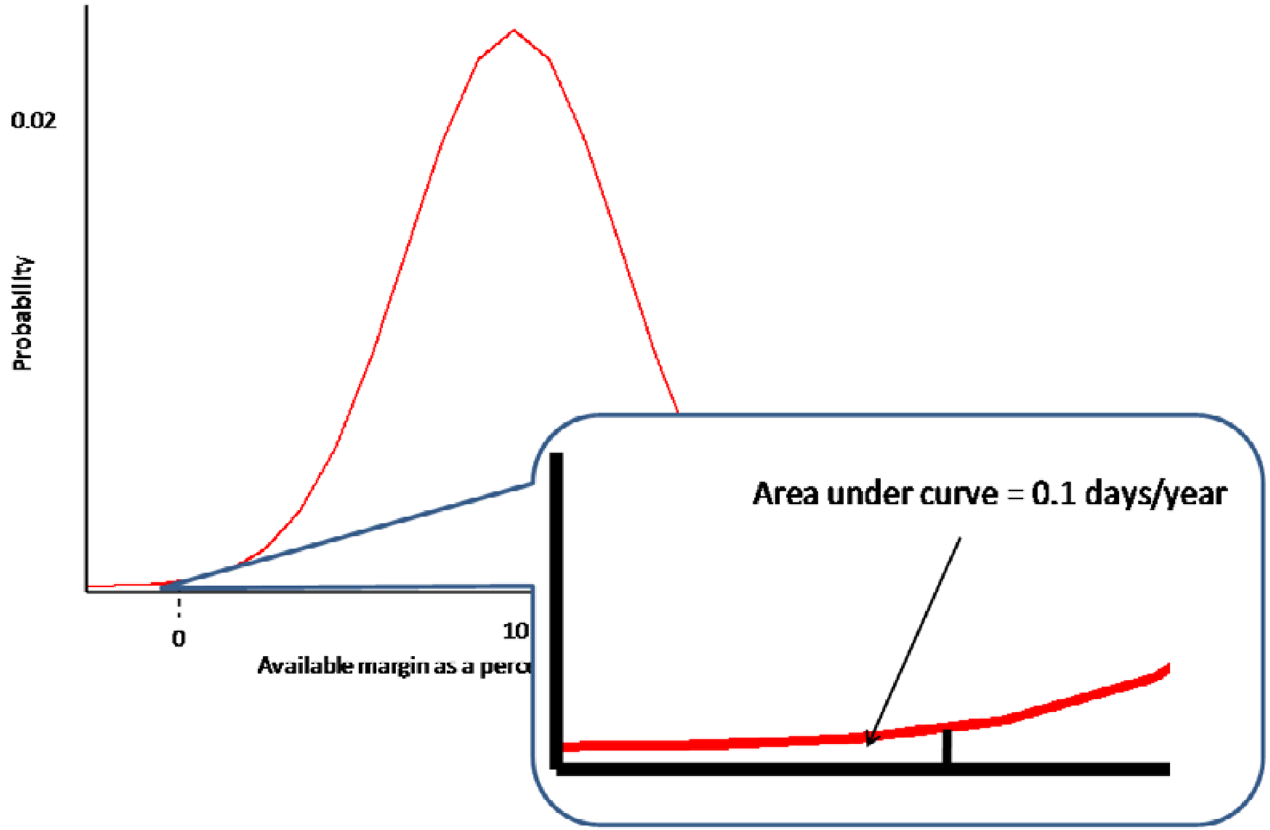
8 years of data appears safe (so far)



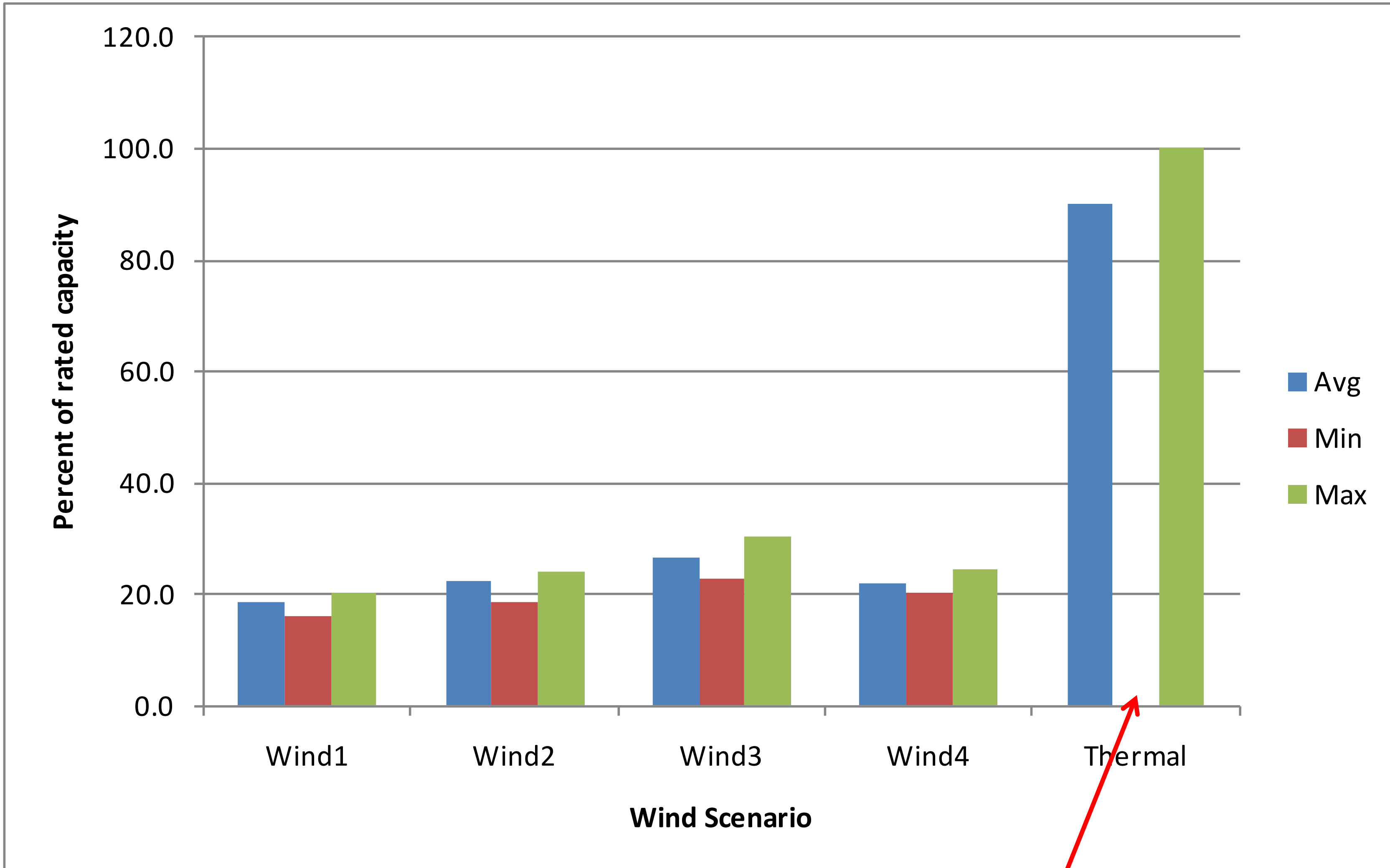
Observations

Concern regarding inter-annual variability of capacity value of wind

- Range of wind variation less than thermal units



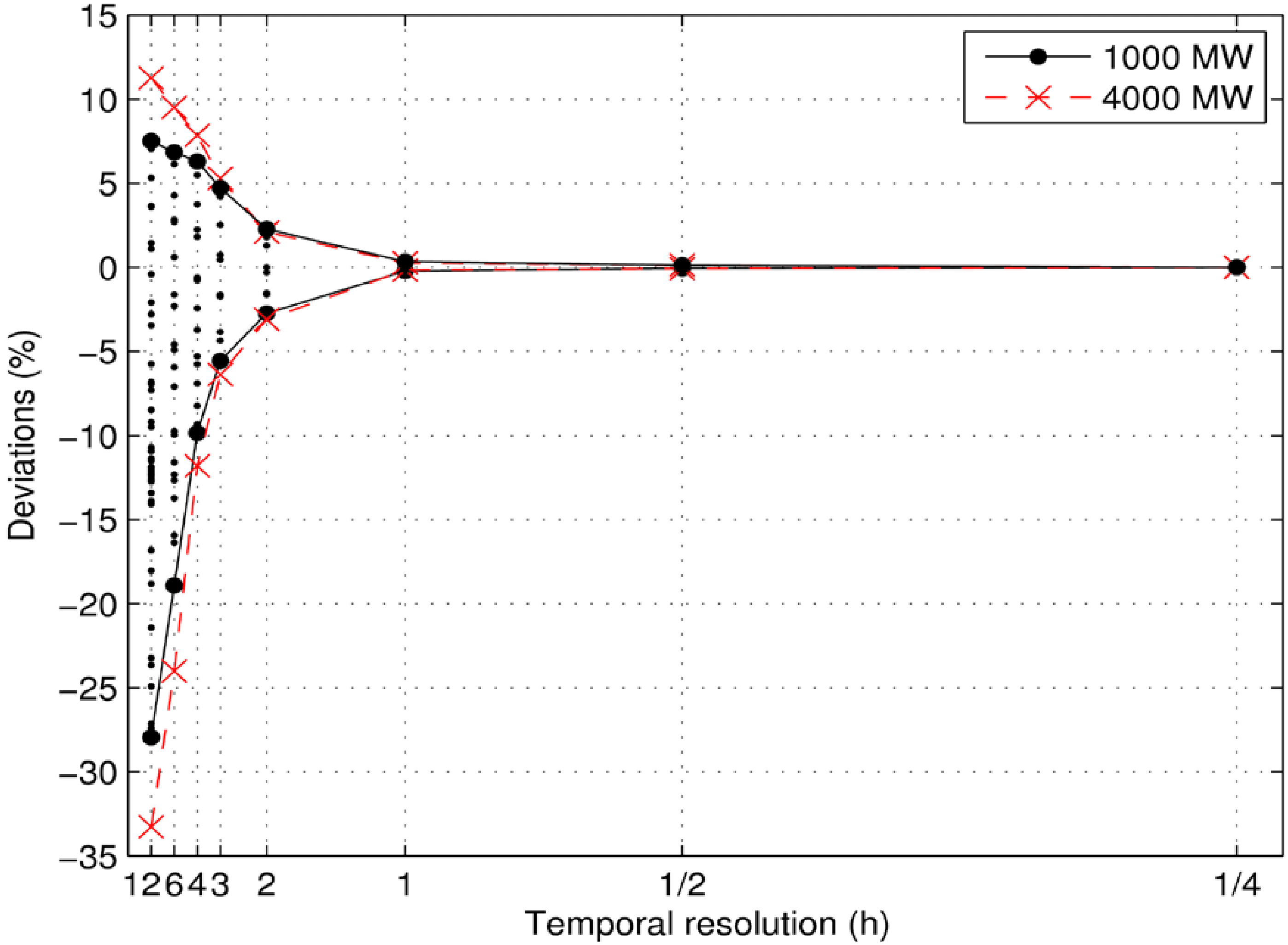
Range of capacity value (ELCC), EWITS



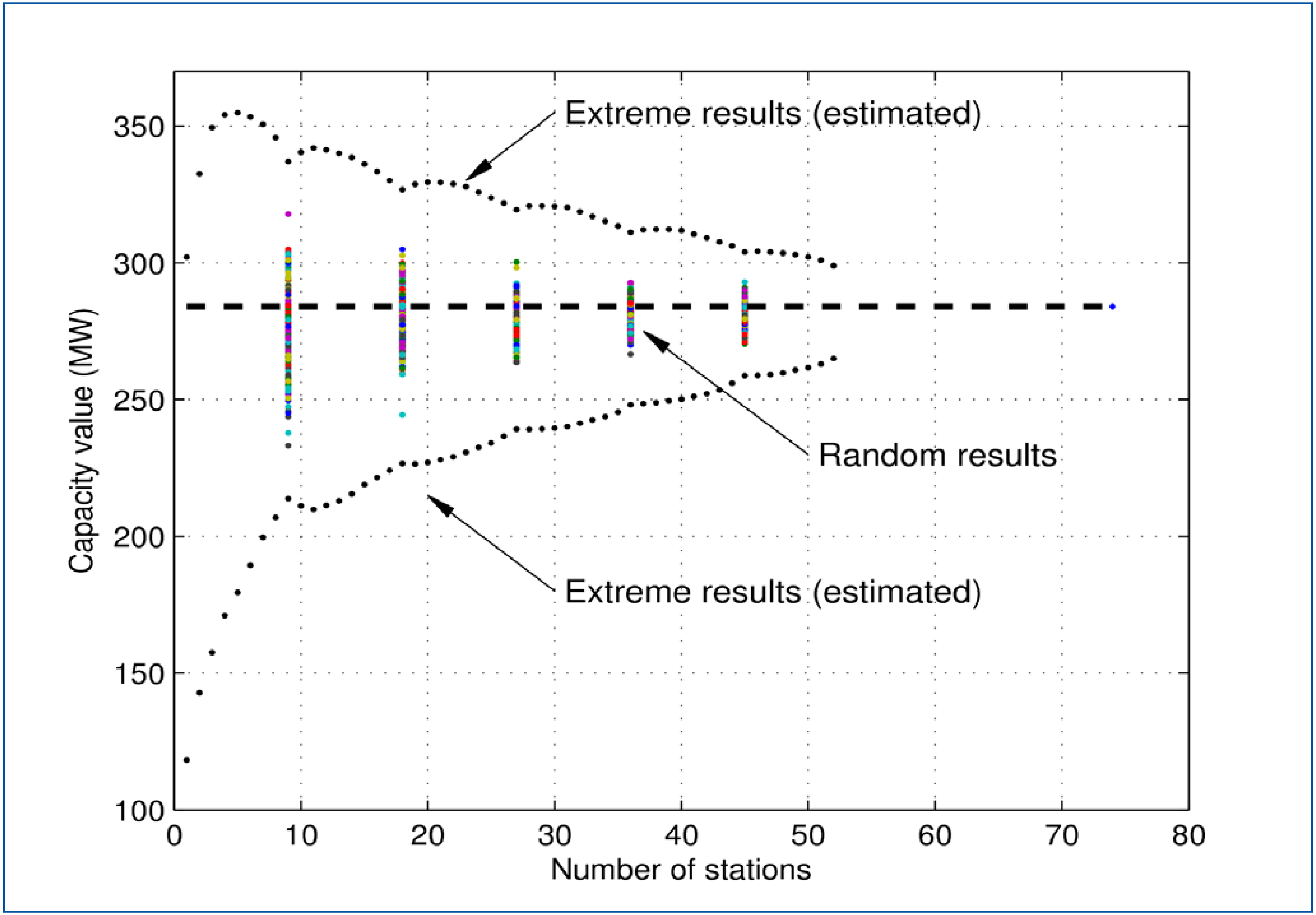
MW size also important!

Minimum = 0

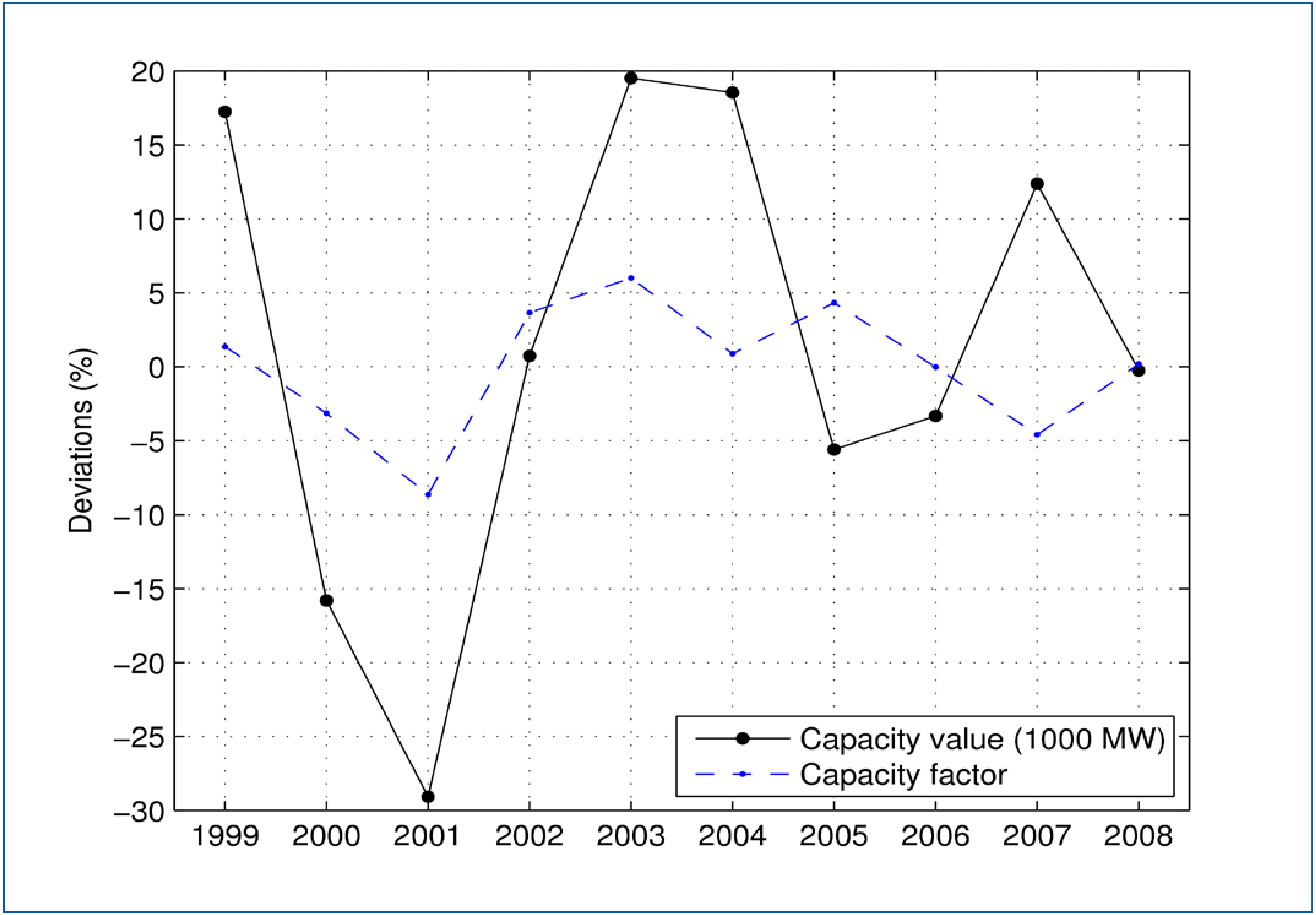
Hourly data (or faster) is required



For large penetrations you need data from multiple locations



ELCC is not just a function of capacity factor



Other (non-reliability) Approaches

Many entities use an approximation method

Common approximation is wind capacity factor over some defined peak period

Most have not compared the approximation to a reliability-based metric

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Approximations and different methods

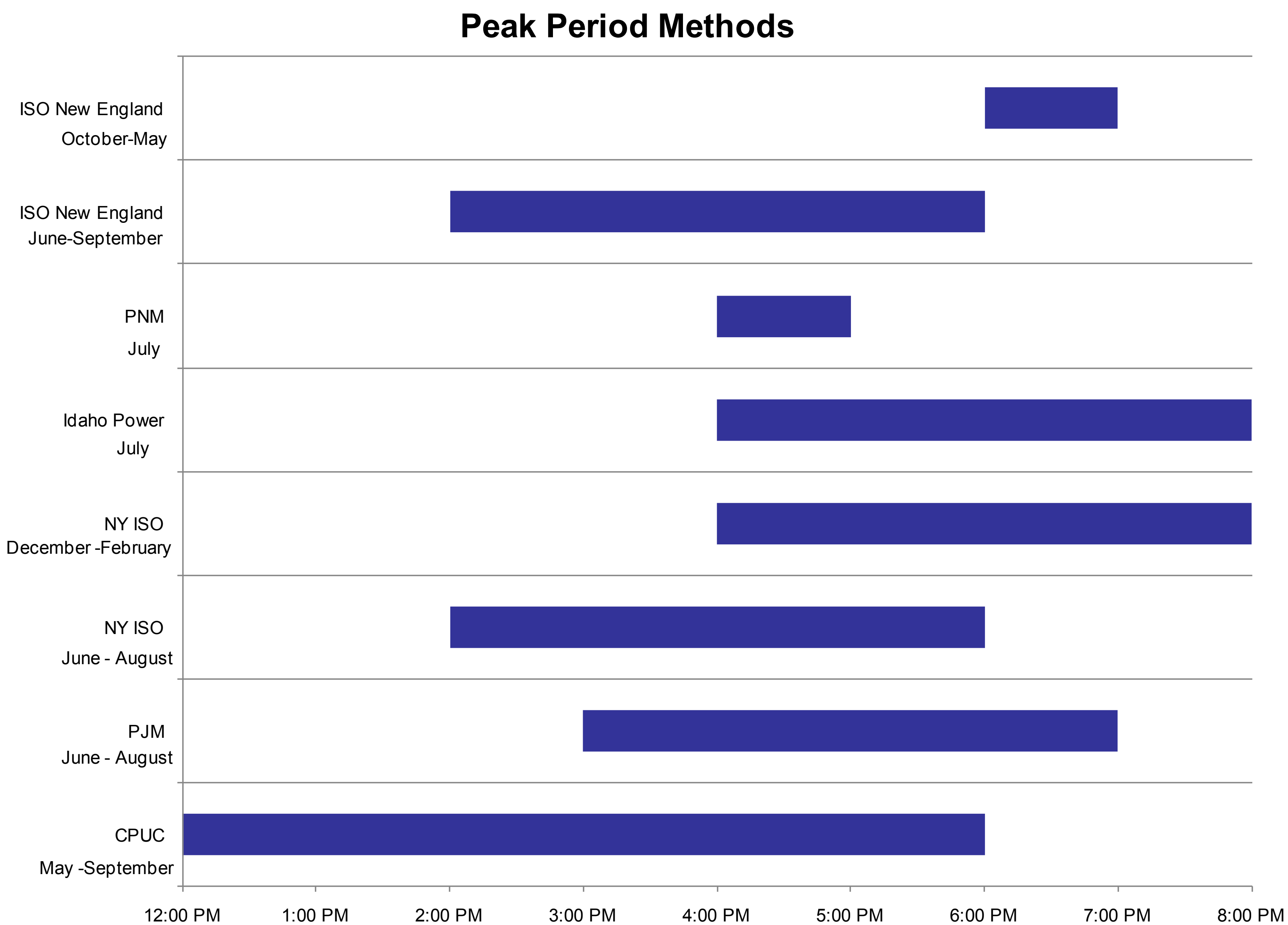
Approximations to ELCC

- Approximations may be needed due to lack of data
- Computational time is not a reason
- Approximations will have errors
- Important to establish reliability target

Different methods

- Not calculating capacity value
- Should not be compared (except to benchmark simple methods)

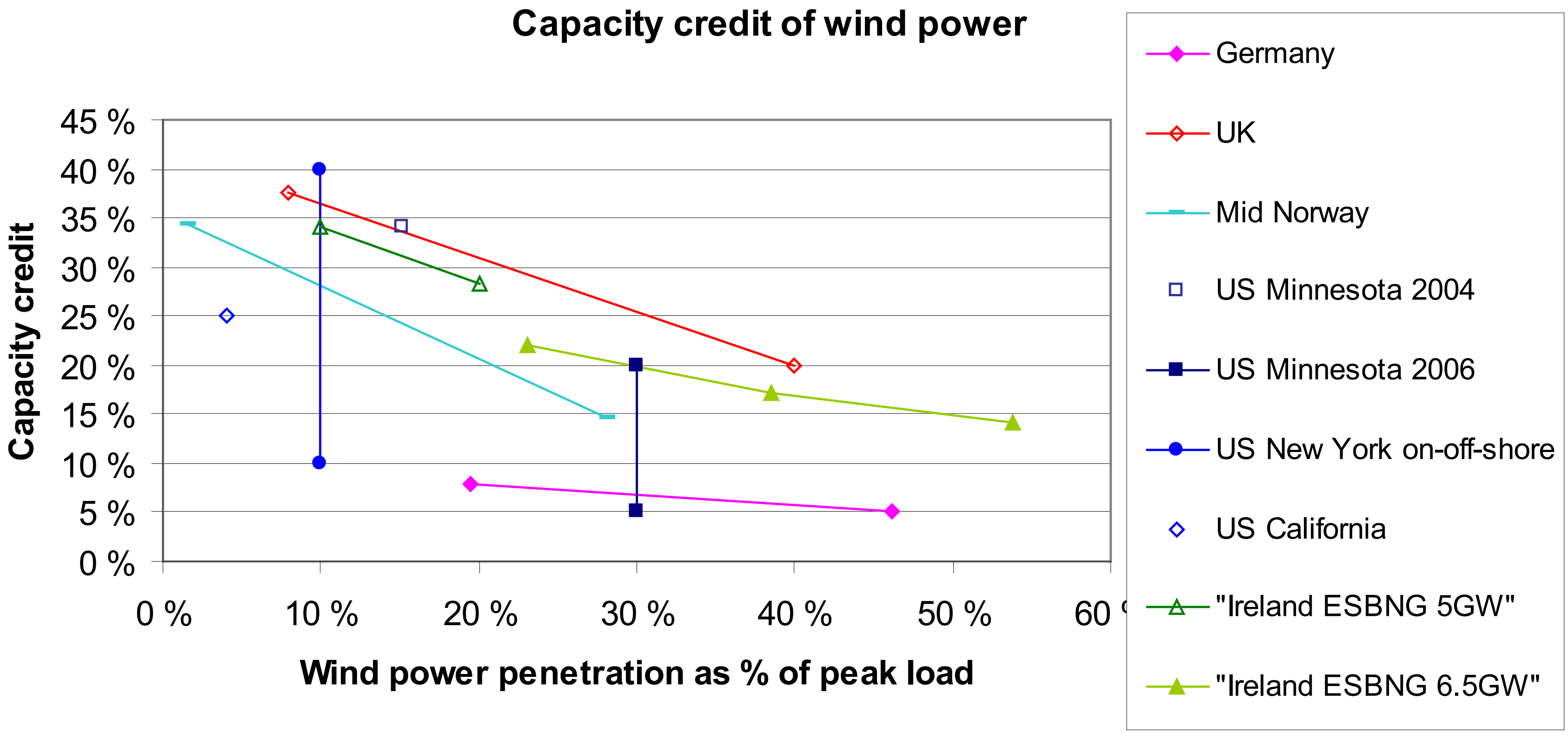
Peak period capacity factor simple approaches have not been benchmarked with ELCC



International Comparisons

Country values have wide range

…but that depends on methods, and real differences in wind-load correlations



Wind capacity value decreases at larger penetrations, faster for smaller areas.

Differences: wind resource at peak loads, reliability level, methodology

Common findings

Declining marginal contribution to planning reserves as a function of penetration

Capacity value increases with geographic diversity

Capacity value is relatively small fraction of wind installed capacity

Multiple years of data required – just like thermal units

IEEE Wind Capacity Value Task Force paper in press

Recommends ELCC

Discussion of alternative targets: 0.1 d/y ≠ 2.4h/y

Careful benchmarking of simple approaches to ELCC

Capacity Value of Wind Power

Task Force on the Capacity Value of Wind Power, IEEE Power and Energy Society

Andrew Keane, *Member, IEEE*, Michael Milligan *(Vice-Chairman)*, *Member, IEEE*, Chris Dent *Member, IEEE* , Bernhard Hasche, Claudine D'Annunzio, *Student Member, IEEE*, Ken Dragoon, Hannele Holttinen, Nader Samaan, *Member, IEEE* , Lennart Söder, *Member, IEEE*, and Mark O'Malley *(Chairman)*, *Fellow, IEEE*

***Abstract*-- Power systems are planned such that they have adequate generation capacity to meet the load, according to a defined reliability target. The increase in the penetration of wind generation in recent years has led to a number of challenges for the planning and operation of power systems. A key metric for generation system adequacy is the capacity value of generation. The capacity value of a generator is the contribution that a given generator makes to generation system adequacy. The variable and stochastic nature of wind sets it apart from conventional energy sources. As a result, the modeling of wind generation in the same manner as conventional generation for capacity value calculations is inappropriate. In this paper a preferred method**

lacks information on the importance and duration of the outage. LOLE is the expected number of hours or days, during which the load will not be met over a defined time period. The effective load carrying capability (ELCC) is the additional load which the system can support on addition of new generation, while maintaining the same LOLE level [3].

The topic of capacity value of wind power has been attracting attention in recent times with a number of publications dealing with this issue. In [4] methods for capacity value are described, and classified as either chronological or probabilistic. A range of methods for the calculation of capacity value are assessed in [5, 6]. A

Other references

Milligan and Porter, "Determining the Capacity Value of Wind: An Updated Survey of Methods and Implementation." Presented at WindPower 2008. Available at http://www.nrel.gov/docs/fy08osti/43433.pdf

Milligan and Porter, "Determining the Capacity Value of Wind: A Survey of Methods and Implementation." Presented at WindPower 2005. Available at http://www.nrel.gov/docs/fy05osti/38062.pdf

Billinton and Allan: Reliability Evaluation of Power Systems, 2nd Ed. Springer, 1996.

Questions/ Discussion?

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