Estimating Capacity Value of Intermittent Generation

Dr Ross Gawler

McLennan Magasanik Associates

29 October 2009

|M |M |A|

Outline

- Structure of capacity and energy market
- What constitutes capacity value?
- What about intermittent generation?
- Alternative methods
- Methodology
- Quantitative analysis
- Likely issues needing resolution
- Discussion

Structure of Capacity and Energy Market

- The WEM is a capacity and energy net market based on bilateral contracting
- Net energy is traded through Day Ahead market (STEM) and the balancing mechanism in real time
- Energy bids are required to be based on SRMC in recognition of access to a capacity payment based on open cycle gas turbines with liquid fuel
- Capacity payment supports system reliability through a reserve margin requirement

Cost Recovery for Generation

- At all times bilateral contracts plus balancing trade are an alternative to substantial exposure to the net market
- Peaking capacity is supported by the capacity payment plus recovery of SRMC through the energy trading
- Uncontracted base load capacity with capacity cost greater than OCGT would be expected to top up revenue from the difference between market price and their lower SRMC

Capacity Value

- **Reliability is achieved by having capacity in reserve at times of peak demand to maintain load following for frequency control and cover the risk of plant outages**
- **What constitutes capacity value?**
  - For controllable generation it is the output available at 41ºC to match peak demand conditions on hot summer day
  - The contribution from intermittent generation is not obvious because the capacity available at 41ºC is not predictable: depends on wind/solar energy resource at the time

What is the most accurate value of capacity?

- **The most accurate value is based on reliability equalisation principle:**
  - It is the capacity of a reliable thermal generator which could replace the resource to be valued whilst leaving the reliability of supply unchanged
- **This is complicated by:**
  - Choice of reliability standard (loss of load hours, expected unserved energy, loss of load expectation)
  - Equivalent unit size with many small units is lower than with fewer larger equivalent units
  - Data on the correlation between generation and load may be is insufficient for accurate analysis, particularly for new projects
  - Planned maintenance and seasonal load shape cause complicating interactions that vary over time
  - The marginal value of capacity is not the same as the average capacity value for a fleet of similar technologies due to scale effects
  - The cost and complexity of the reliability analysis with alternative assumptions about future market resources.
- **So simpler methods are preferred**

Capacity Value of Intermittent Generation - 1

- **Currently capacity value is based on average power over all trading intervals in the last three years up to the last Hot Season (4.11.3A(a)) for incumbents**
  - Or projections of average power output for future plants based on a production model
- **Disadvantages**
  - Has the potential to over-value wind energy unless the average power matches the average output over the high load periods
  - Has the potential to under-value solar thermal and photovoltaic resources which have a high correlation between output and system summer peak demand
  - May provide inefficient price signals to renewable energy sources generally depending on their peak period performance

Capacity Value of Intermittent Generation - 2

- **Advantages of current method**
  - Relatively easy to understand and apply
  - Provides incentive for renewable energy as a mitigation measure for adverse climate change
    - seen as a positive by those who perceive that renewable energy is otherwise disadvantaged
- **Accuracy**
  - Capacity payment only represents about 10% - 15% of revenue for renewable energy sources so a highly accurate method is not critical for efficiency of project development
  - Ability to achieve high accuracy is limited by sufficiency of data on the relationship between intermittent generation output and system load.

Methods of Capacity Valuation - 1

- **Average power over all trading intervals – the current method**
  - Easy to understand and apply
  - Over-estimates wind and under-estimates solar power
- **Average output over a defined peak period based on a time period (work days in a peak season)**
  - A more volatile and less optimistic method for wind power, better for solar power
- **Percentile output over a defined time period to make it closer to the concept of a firm capacity (e.g. 90% POE capacity)**
  - A more conservative approach which does not consider diversity of resources or relationship to system reliability
- **Average output over defined peak period based on high values of actual system load (e.g. top 250 trading intervals)**
  - Can only be assessed in retrospect and tends to be volatile but more realistically so than average power over all periods or a defined peak season
  - More accurate that average power method as it focuses on the critical loading period
- **Percentile output over a defined peak period based on high values of actual system load to make it closer to the concept of a firm capacity (top 250 trading intervals in pre 2005 method)**
  - A very conservative approach which under values the capacity at other than these peak times and which does not necessarily relate well to system reliability impact
  - Unsuitable as a measure for solar thermal generation as many peak period days may have low solar output

Methods of Capacity Valuation - 2

- **Average output as a share of a fleet of similar technologies to allow for diversity of contribution**
  - Provides a more accurate and less conservative assessment that percentile assessment based on individual plants
  - Less volatile as a measure
- **Percentile output over a defined time period of a fleet of projects of similar technology**
  - Less conservative than percentile assessment on an individual project basis
  - May still under-estimate capacity value for solar technologies
- **Reliability equalisation used to model a replacement controllable resource to achieve the same reliability**
  - Requires complex and costly analysis
  - Provides a less volatile and more accurate value providing that sufficient data are available and the market conditions are changing slowly
- **Output based on time period weightings according to the Capacity Refund Table in the Market Rules**
  - Probably provides a better measure of capacity than average over just the peak period.
- **Senergy has provided an analysis of these techniques for the Office of Energy in a recent report (October 2009)**
  - Highlighted that analysis of reliability analysis yet needed to be undertaken

Senergy Conclusions in Brief - 1

- **Limited time period selection results in a more volatile measure**
- **Average based calculations for one year are within ±15% of multi-year assessments**
- **10% percentile methods over long time periods do not work where output is positively correlated to system peak demand**
  - They work better at a fleet level
- **Coastal wind farms have higher than average output at peak times by up to 1.2 - 1.4 times**
- **For solar thermal the current method allocates 60%-70% of the capacity allocated from peak periods only.**

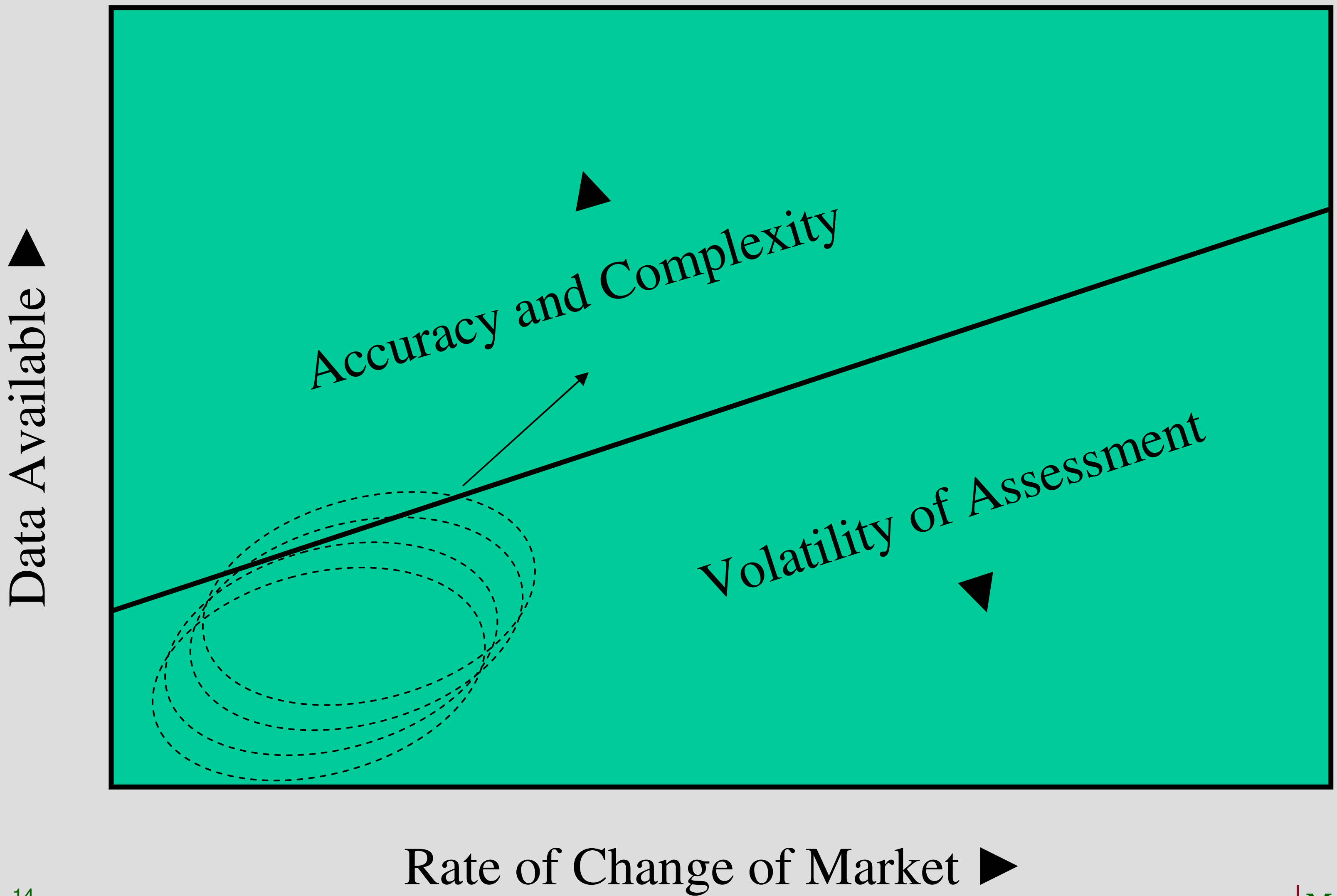
Senergy Conclusions in Brief - 2

- Solar thermal output and system load tend to both be higher at times of higher insolation and this is not recognised in current and alternative methods considered
- Thermal storage could make solar thermal capacity more reliable in meet early evening peak loads and mitigating the effect of cloud cover during the day
- Diversity of wind resources has the potential to raise the 90% probability of exceedance generation level of total wind power as a proportion of installed capacity

Issues - 1

- **Methods can only be less volatile if:**
  - The amount of data concerning system load and intermittent generation increases to reduce the statistical sampling error in defining reliability based models
  - The calculation method and data used are changed less frequently
- **There is a trade-off between volatility of analysis and accuracy**
  - with limited data and changing market conditions

Volatility and Accuracy



|M |M |A|

Issues - 2

- More data becoming available but market is also changing with RET and CPRS
- We have an opportunity to develop a reliability equalisation based approach to more accurately assess emerging new technologies
- However **simplicity and stability** in application remains an important objective to encourage investment and to reflect the quality of data available
- A user ought to be able to make a self-assessment without complex analysis

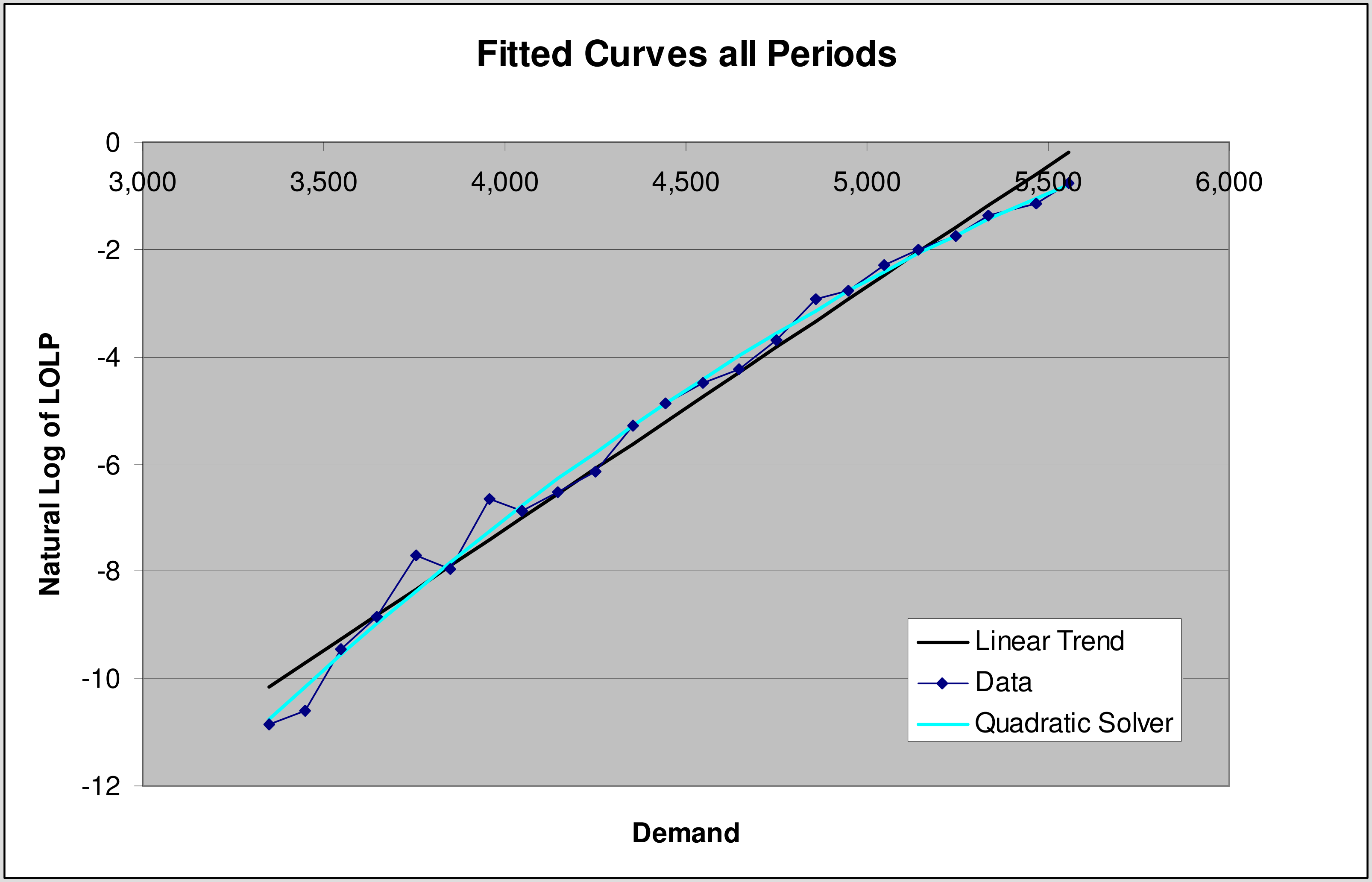
Proposed Approach - 1

- **Develop a full reliability model from 2012/13 – 2016/17**
  - Assumptions report to be prepared
- **Include the existing intermittent resources as ½ hourly data matched to the corresponding historical system load profiles**
- **Adjust the installed capacity or peak load and energy to meet the 8.2% capacity reserve margin and the unserved energy at 0.002% in each year**
  - 0.002% using a mix of 50% and 10% POE peak load values
- **From the historical data identify a set of historical years representing various load extremes and derive LOLP versus system load for these weather years**
  - See if they are materially different functions (expected not as there is no energy storage technologies as yet in the WEM)

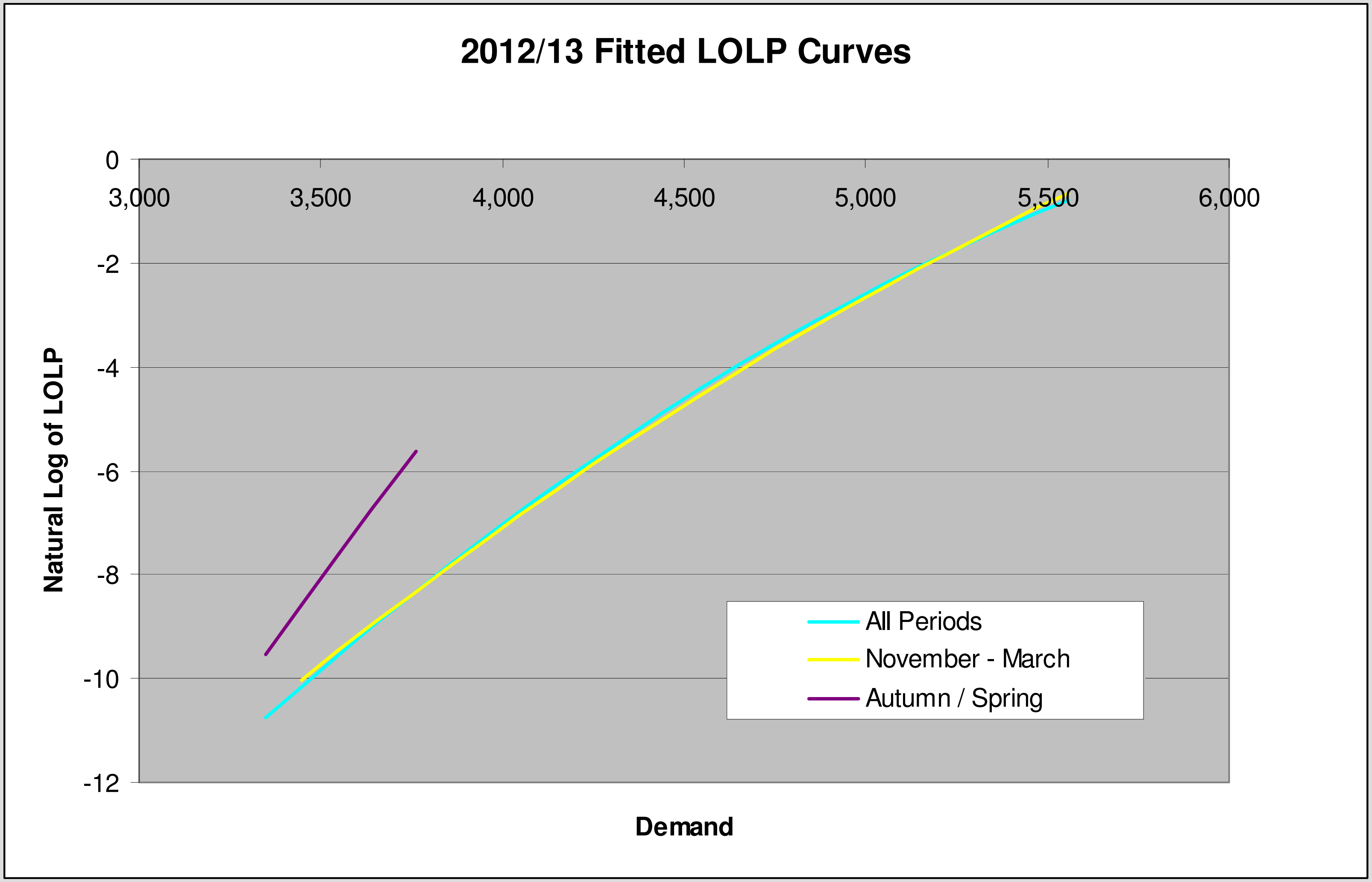
Preliminary Analysis for 2012/13 Contract Year

- Evaluated LOLP versus load for 50% and 10% POE peak demand forecasts
- Checked that LOLP for winter is insignificant
- Higher in the mild seasons due to maintenance
- 90% of loss of load risk is in 3% of the time (525 trading intervals)
- 95% of loss of load risk is in 4% (700 intervals)
- Indicates that 250 is not enough

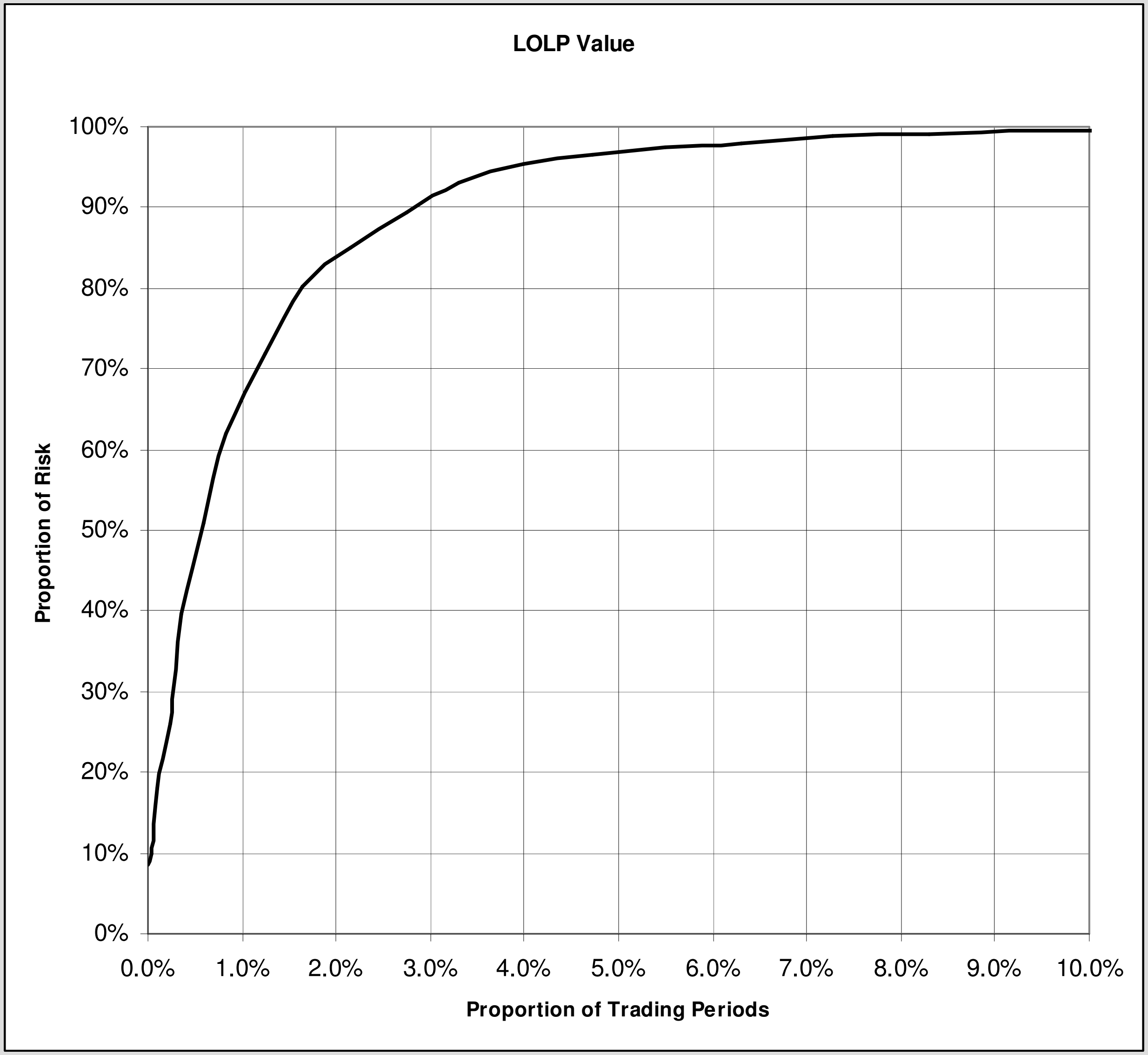
LOLP versus System Load (100 simulations)



Seasonality 2012/13



Exposure to Risk of Loss of Load



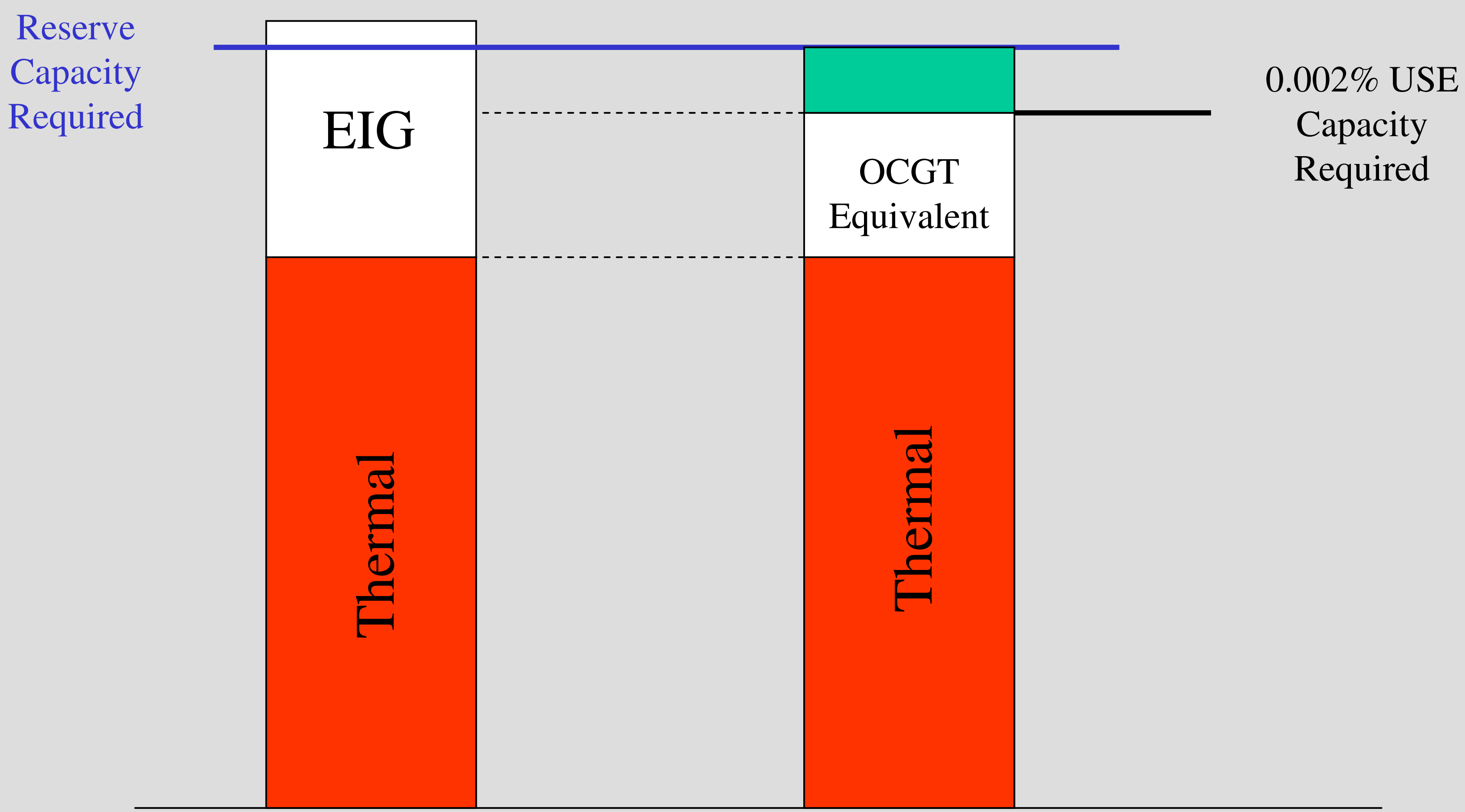
Proposed Approach - 1

- **Select suitable years as representative of mild, average and hot summers to capture variability of output in relation to peak demand**
  - 2003/04 close to 10% POE summer
  - 2004/05 close to 30% POE summer
  - 2006/07 close to 70% POE summer
  - 2008/09 close to 90% POE summer
- **More data with additional years could be used over time**

Proposed Approach – Testing 2

- **Model the WEM with and without existing intermittent generation (EIG) so as to assess aggregate capacity value**
  - Model the WEM with projected supply, EIG and load that meets USE criteria (EIG generation profile matched to load)
  - Remove EIG, replace with OCGT (unit size 40- 120 -160 MW) to achieve the same reliability for USE (2 – 3 capacity cases with regression and interpolation)
  - Difference in capacity relative to USE gives a reliability equalisation measure of aggregate capacity value to meet USE
  - The simplified methods should achieve this result in aggregate
  - Same measure could be used for the reserve margin criterion if proven practicable.

Capacity Reference Value - EIG



Two cases with same unserved energy

Proposed Approach – Testing 3

- **Derive ½ hourly LOLP versus system load for both cases**
  - May need to decompose into seasonal functions depending on planned maintenance distribution
  - Higher LOLP at lower loads in winter season due to maintenance
  - Same function should apply for alternative weather years
- **Calculate the LOLP weighted system load as a reference index**
- **Calculate the LOLP weighted capacities of each of the EIG projects**
  - Compare the weighted capacities with the aggregate equivalent
  - Are they equivalent in aggregate and additive?
- **Calculate the capacity values according to the other methods and compare accuracy**
  - Are any of the simpler methods adequate?

Proposed Approach – Testing 4

- **Test individual EIG's relative to the case with all others present**
  - Does the equivalent capacity adequately match the value obtained from LOLP analysis?
  - Test the significance of the difference between marginal value and average value in the fleet
- **Add additional renewable energy resources to the EIG such as solar thermal and photovoltaic and test for average and marginal impacts**

Proposed Method for Capacity Value - 1

- **IMO confirms existing and committed IG (ECIG) for a capacity period (say 3 years from 2012/13)**
- **Build system model with and without ECIG as two reference cases**
  - Run with the reference year profiles to assess unserved energy
- **Conduct reliability equalisation study for ECIG cases to determine reliability equivalence of aggregate capacity over reference year loads and generation profiles**
  - Reference loads consider variation in weather effect on system demand as well as ECIG
  - The sum of the assessed capacities would sum to this value for the ECIG

Proposed Method for Capacity Value - 2

- **Develop a workbook that includes LOLP versus scheduled (thermal) generation for each forecast year and calculates an equivalent capacity for each ECIG resource over these periods for the weather profiles**
  - Weight these to obtain an equivalent capacity based on relative unserved energy level for the profiles
- **Derive a scale factor that would scale incremental capacity to add up to aggregate value based on reliability equalisation for ECIG projects as a fleet from the calibration analysis.**
- **This would provide the basis for assessed capacity over the evaluation period.**

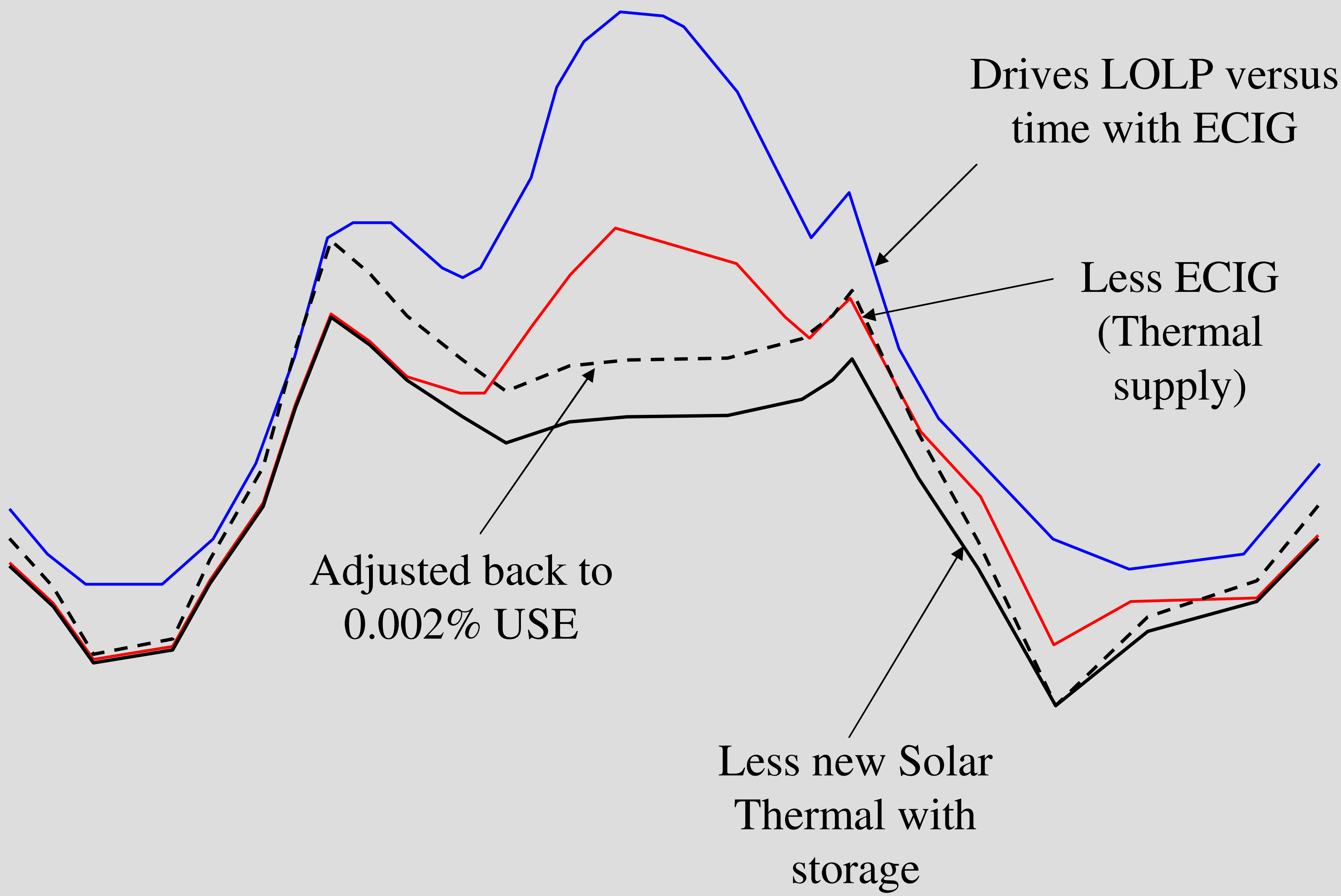
New Projects

- **To manage the diversity effects and scale effects, the pattern of new resources would potentially change the capacity value of the ECIG over time.**
  - Eg more solar thermal would progressively decrease the value of afternoon intermittent energy and increase the relative value of shoulder production
- **For new projects, provide a tool which assesses an individual project as incremental to the existing committed fleet**
  - Capacity weighting would be based on the revised net scheduled supply after deducting the incremental IG

Capturing the change in IG diversity

- **Model the change in net thermal profile and rescale the load shape to approximate 0.002% USE using a weighting index based on the LOLP weighted net thermal supply**
  - This is equivalent to varying the thermal mix in response to a change in the IG mix, which would happen over time
  - Without scaling, capacity value may be under-stated and scale-back of capacity payments would be double jeopardy
  - Scaling allows the potential capacity value to be identified assuming the market is balanced
  - Incumbents can then assess the risk of displacement by assets of similar profile

Illustration of mix adjustment



|M |M |A|

On Scale back

- **Model the change in net thermal supply profile and rescale the load shape to approximate 0.002% USE**
  - Without scaling, capacity value may be under-stated and scaled-back of capacity payments would be double jeopardy
  - Scaling allows potential surplus to be identified so that other suppliers may withdraw if their plants are marginally viable in the market (as may happen under CPRS)
- **We may be able to approximate the rescaling by using the LOLP weighted net load curve as an approximation to a load profile which delivers 0.002% unserved energy**

Some questions under consideration

- Are there enough data to avoid volatile assessments that have no real economic value?
- Can we develop statistical distributions that provide a less volatile assessment?
- Do we need to focus solely on 10% POE peak conditions?
- Does consideration of 70% - 30% POE conditions provide any value?

Issues for resolution

- **How many projects need to be tested at this stage**
  - Albany, Walkaway, Emu Downs
  - Solar thermal option
- **Is there any useful information on wave or tidal?**
  - Focus on wind and solar thermal as the near term resources that will influence the result
- **Use four years at estimated 10%, 30%, 70% and 90% POE (50% not readily available)**
- **May need to fill missing Albany data for 2005/06**
  - Base on days with matching temperature profile?
- **At what level of LOLP can data be neglected without loss of consistency or accuracy?**
- **Can IMO provide an aggregate ECIG profile without confidentiality issues?**

Discussion