sapere research group

Relevant level review

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5 November 2014

Agenda

- Introduction
- Background
- Current methodology – impact and performance
- Review of options
- Conclusion

Context

- Relevant level (**RL**) is the basis for the Capacity Credits awarded to intermittent generation facilities (**IGF**s) and other facilities
- The RL methodology was revised in 2012 based on recommendations set out in 2011 Board Report (by Richard Tooth of Sapere)
- IMO required to undertake a review of the methodology every three years.

Objective and scope of work

- **Objective:** Review the performance of the RL methodology introduced in 2012 and any proposed amendments to the methodology, including possible amendments to the Market Rules.
- Scope including
  - Review of international best practice
  - Consider impact and performance of methodology
  - Consideration of changes to the methodology
  - Update K and U values
  - Recommendations as to any amendments

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About capacity credits

- Value of a Capacity Credit – the contribution a facility makes to reliability

- Widely accepted measure of capacity value is Effective Load Carrying Capability (**ELCC**)

  the additional load that the system can supply with the particular generator of interest, with <u>no net change in reliability</u>

- Most stringent reliability criterion relates to system peak. Therefore measure reliability by loss of load probability (**LOLP**)

Estimating capacity value

- Can’t directly observe it. In effect, forecasting outcomes of a rare event in the future
- Approximation methods use output at trading intervals (**TIs**) as basis for estimating capacity value
  1. Time based methods
     - Taken from particular time (common in the US)
  2. Risk based methods
     - Taken from times of high LOLP
     - In effect, what we currently have
- Alternative is detailed simulation modelling but this requires good data and lacks transparency

Common approximation method

Probability theory predicts that

- ELCC $\approx \bar{I} - K\,\sigma_I^2$
  - $\bar{I}$ and σ_I^2 are the mean and variance of IGF output when surplus is zero, and
  - K is a constant

- Intuition for this
  - An IGF is like negative demand that affects the mean and distribution of the load to be met by other generators

The big challenge

- Basic formula of "*average – k*variance*" works when output at peaks is independent of demand* and IGF is small compared to demand (which it continues to be)
- Problem: it appears that at extreme peaks demand and IGF output are correlated
- In particular, IGF output is less at extremes
  - Extremes driven by high temperature
  - Low IG output at very high temperature days

* Or measured when surplus is zero

What's happening in other markets

- Most markets use simple approximation based methods
- Generally the complex numerical method used for estimating contribution of the fleet
- On the issue that output of IGFs correlated with demand
  - No applications found in practice that address this issue
  - Some research being underway in the UK and US

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Current methodology

RL	**=**	1. Average IGF output in peak TIs	***Less***	2. G x variance of IGF output during peak TIs

Where:

- G= K + U
  - K = 0.003 per MW^{-1}
  - U = 0.635/(average IGF output in peak TIs) per MW^{-1}
- Limit on the U-factor adjustment of 1/3 of average output
- Peak TIs are the top 12 TIs drawn from separate days over 5 years as determined by load for scheduled generation (**LSG**)
- LSG is (some qualification) system demand less IGF output
- Output measured in MW
- Estimated data used for IGFs not operational

In effect two components

1. Mean output at peak LSG less the K-factor adjustment

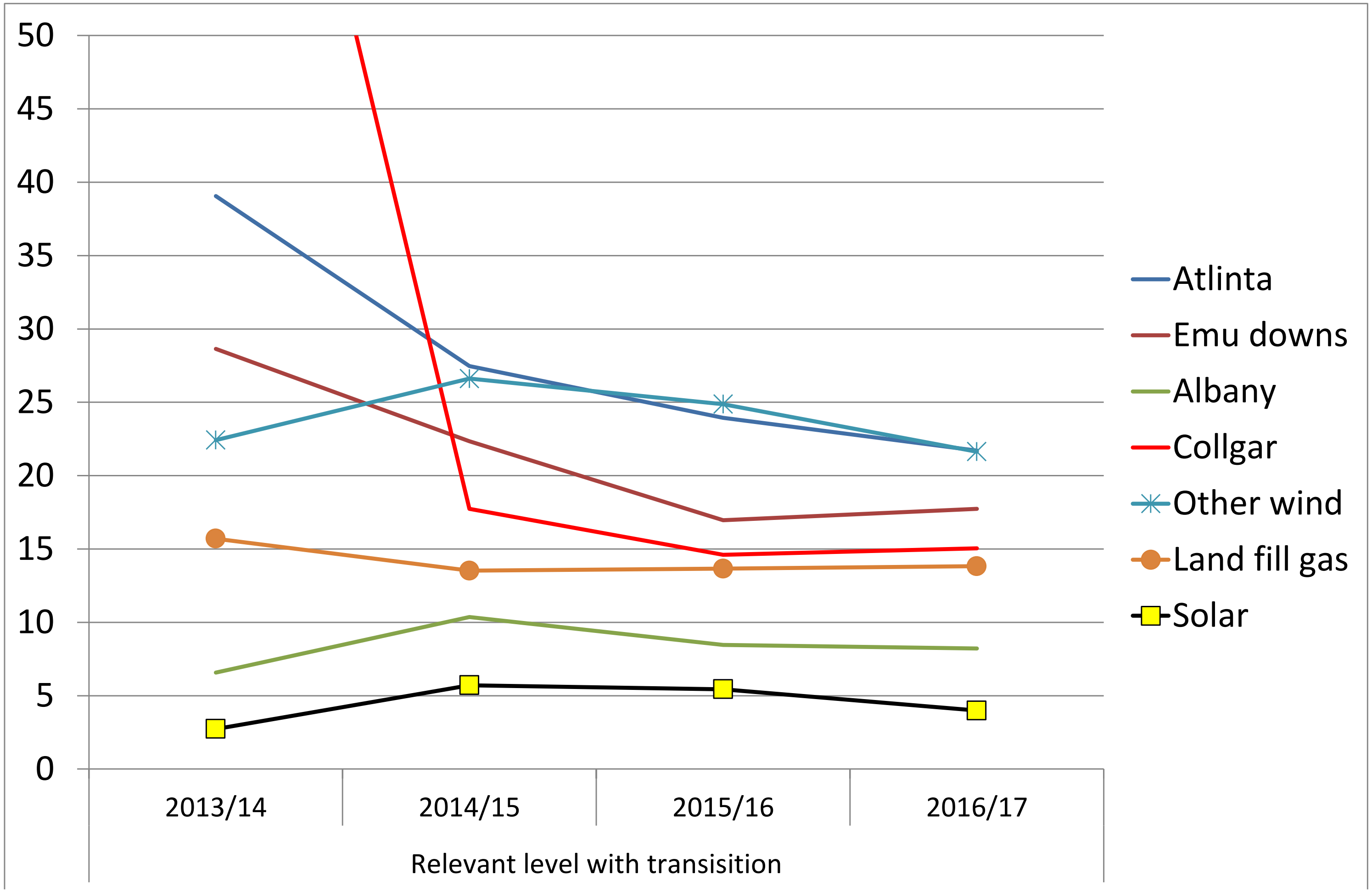
   an approximation method that aims to measure ELCC as if IGF output accurately represented output when there is no surplus

2. The U-factor adjustment

   an adjustment reflecting that the IGF output captured is not representative of times when there would be no surplus

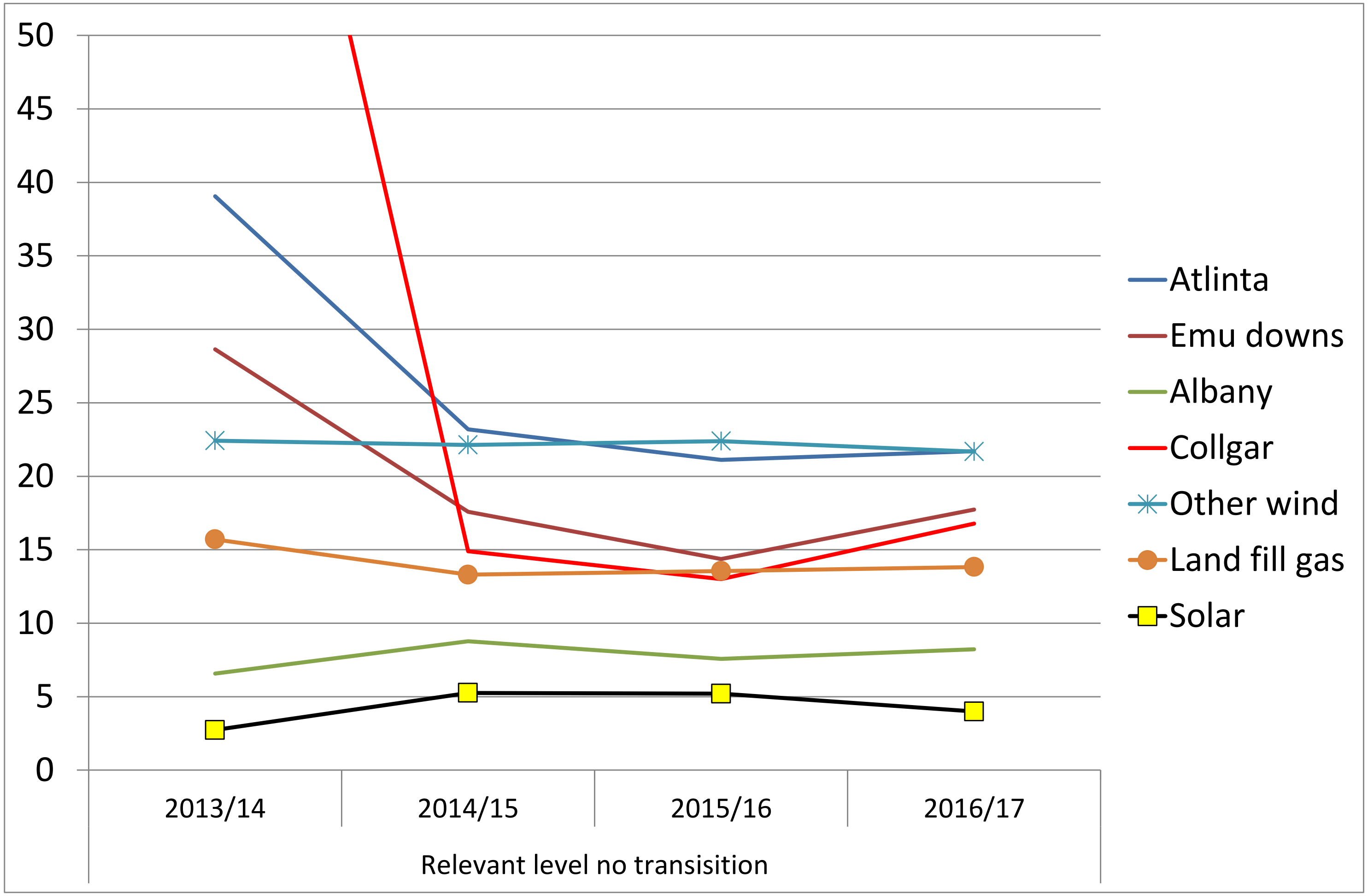
Peak LSG used at it represents times of highest LOLP

Relevant level with transition



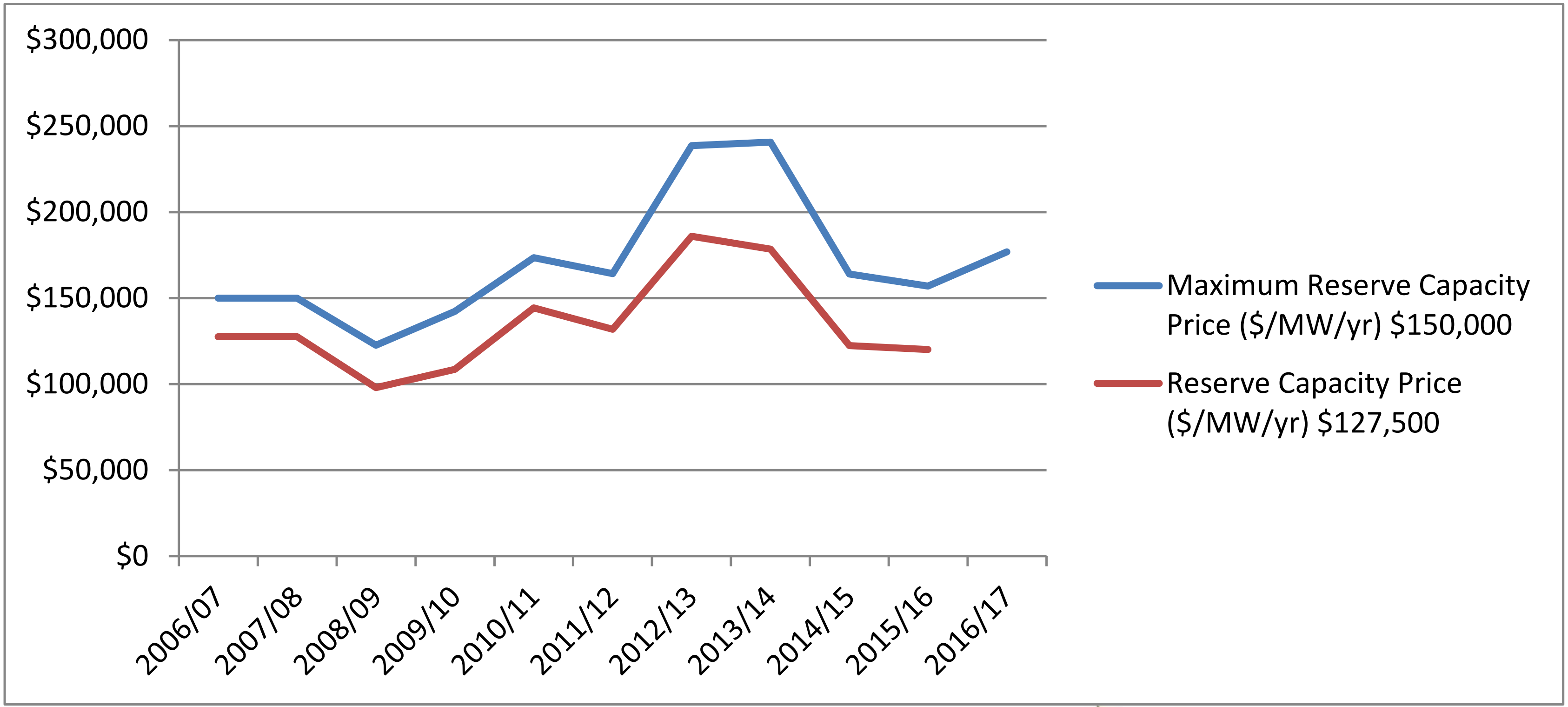
For 2013/14 Capacity Credits are shown. For 2016/17, the RL is an estimate.

Removing transition



At same time $ value of capacity has fallen

- Result is cost of 'adjustment' has become less significant



Changes since 2011

- Transition arrangements phased out
- Changes in facilities
  - Some exits
  - Some facilities have become operational including new large wind and a solar facility
  - More facilities assigned capacity for 2015/16 but not yet operational
- Implications
  - Varying amount of data by year.
  - For some IGFs have some estimated and some actual data

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Criteria for evaluating

Market Objectives

a) to promote the economically efficient, safe and reliable production and supply of electricity and electricity related services in the SWIS

b) to encourage competition among generators and retailers in the SWIS, including by facilitating efficient entry of new competitors

c) to avoid discrimination in that market against particular energy options and technologies […]

d) to minimise the long-term cost of electricity supplied to customers from the SWIS , and

e) to encourage the taking of measures to manage the amount of electricity used and when it is used.

Criteria simplified

Criteria used

1. **Accuracy** i.e. extent to which RL methodology estimates the capacity value of an IGF

2. **Robustness** – i.e. Robust to changing circumstances

3. **Volatility** – i.e. Not sensitive to small changes

4. **Practicality and simplicity**

Evaluating accuracy

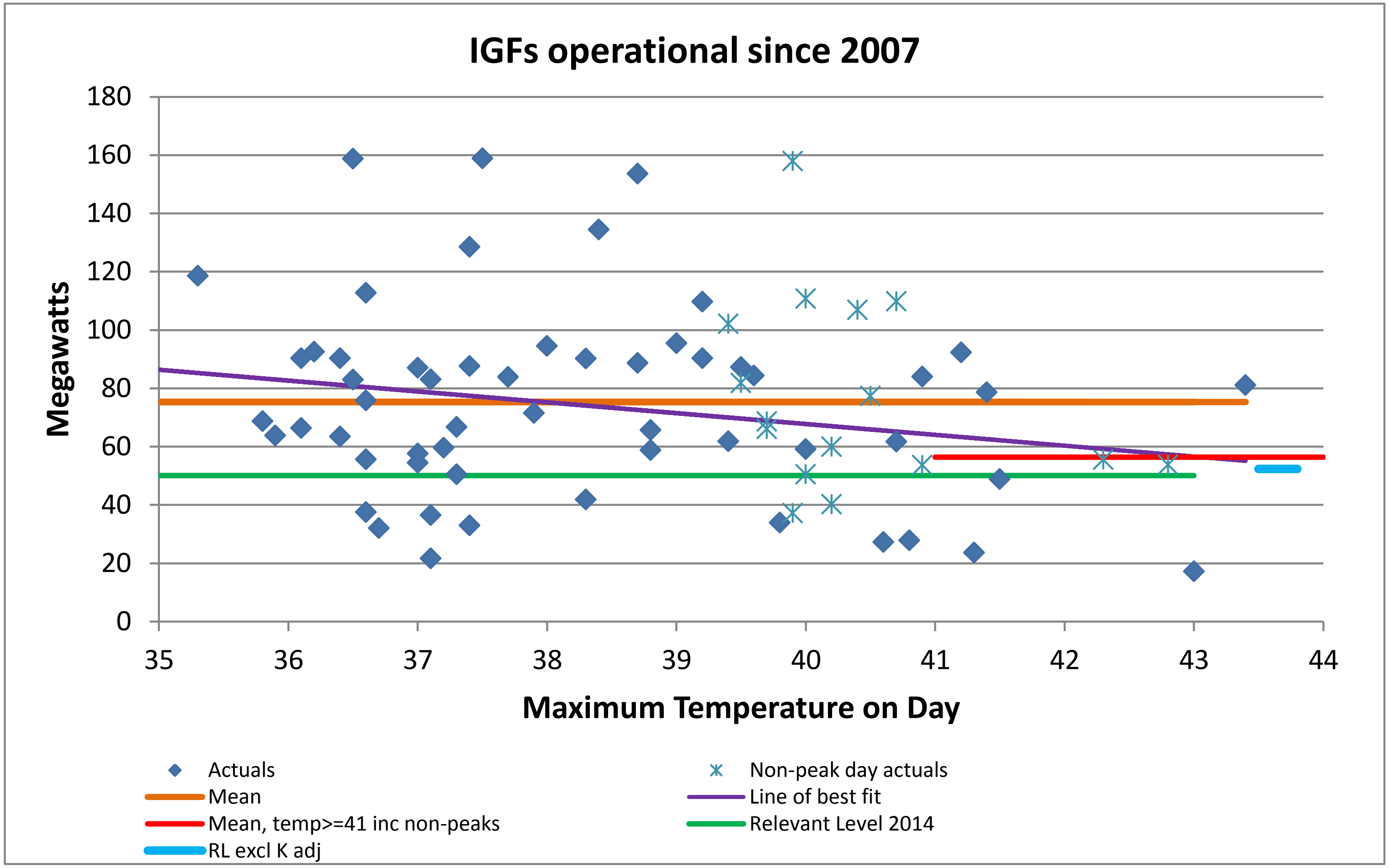
'Mean less K-adjustment' component

- Cannot assess this component visually

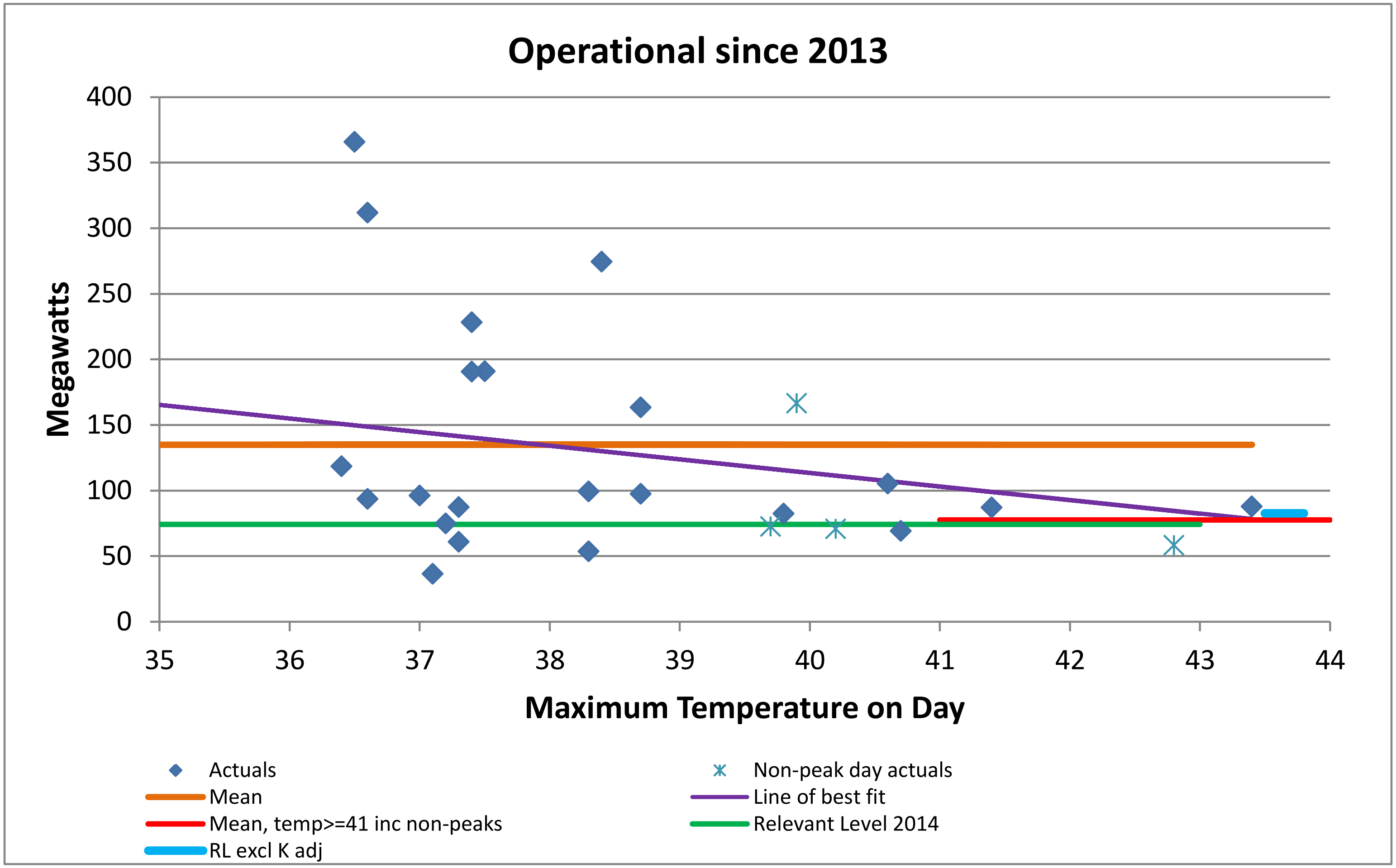
U-adjustment component

- Reasons to have reservations
- Evaluating
  - The RL (excluding K-adjustment) should approximate mean output at times of extreme stress
  - Measure of extreme stress predicted by very hot days
  - Expect max daily temperature in Perth of 1 in 10 year peak to be a around 43.8 degrees

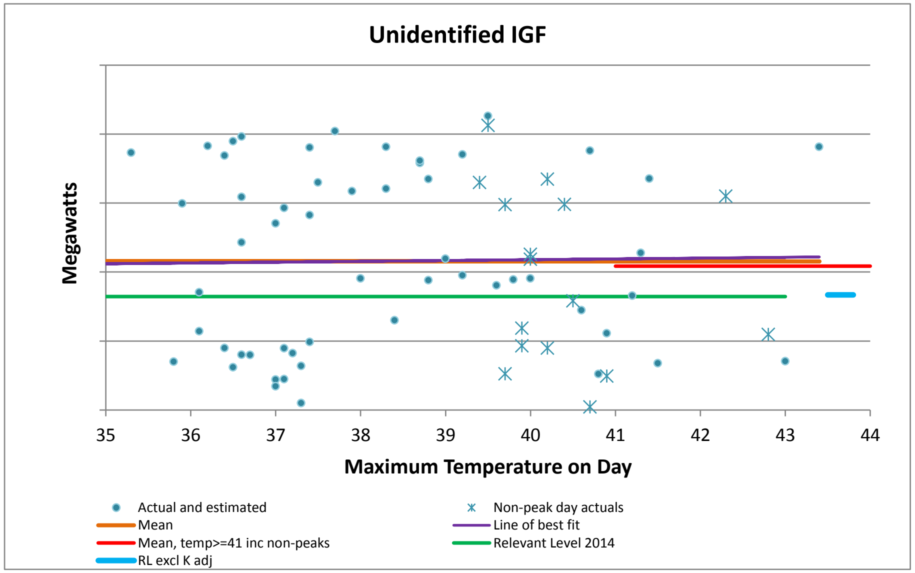
Appears to provide reasonable results

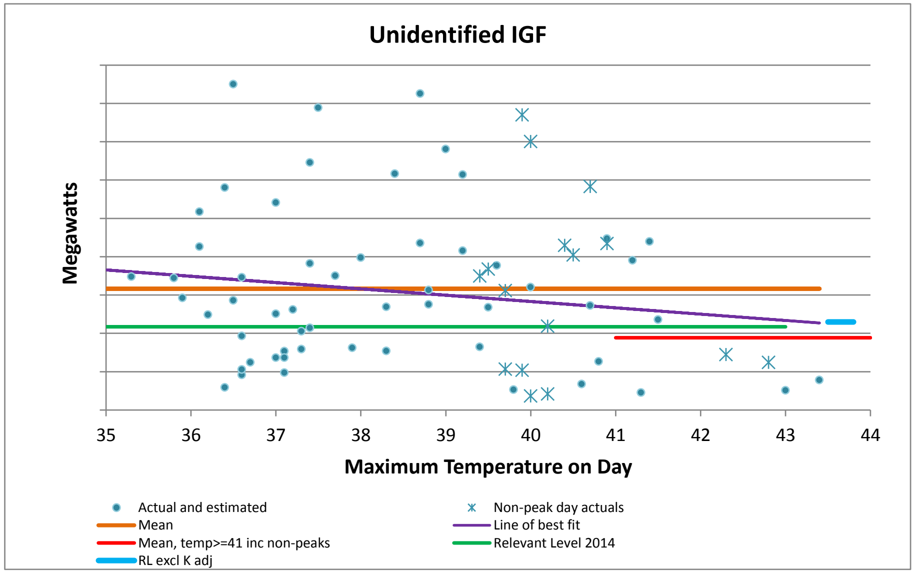


Appears to work for more recent facilities



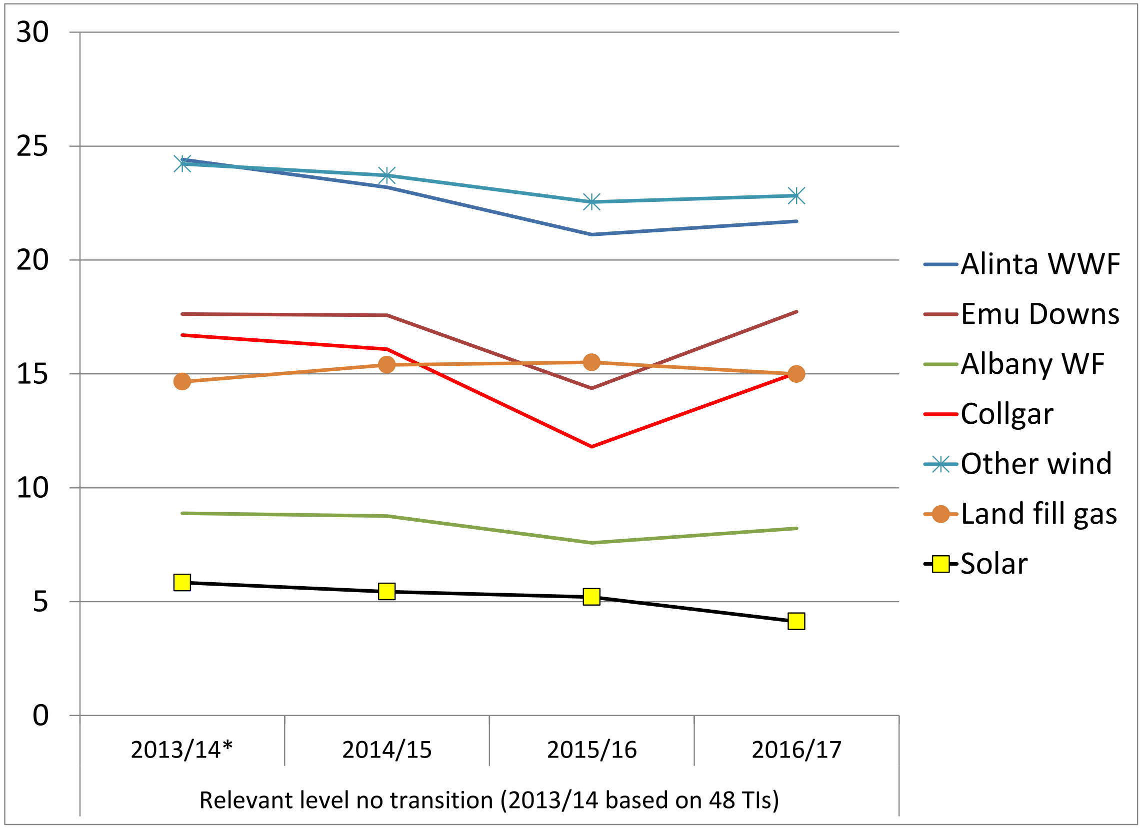
Adjustment appears more clear cut in some cases than others





Volatility

Appears reasonable, relative standard error 3 to 15%



Other criteria

- Robustness
  - K-factor based on probability theory
    - Should be robust for all but large facilities
  - U- factor adjustment
    - Appears to have been reasonable for different technology types

- Practicality
  - No major issues

Summary

- Methodology has had a significant impact
- ‘Mean less K times variance’ component consistent with probability theory
- U-factor adjustment.
  - Reasons for reservations with this
  - But so far has produced results that appear reasonable

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  - Overall method and use of LSG
  - K-factor adjustment
  - U-factor adjustment
  - Other issues with trading intervals used

Overall method – no clear alternative

- Time based approximation method
  - Only advantage appears to be simplicity
  - Significant change
- ELCC Risk Method (detailed risk calculation)
  - Lack of sufficient data
  - Not transparent
  - Doesn't overcome need for U-adjustment

Use of LSG as basis for select TIs

Clear rationale for using LSG

- All else being equal highest LSG is when surplus is lowest and LOLP is highest
- Automatically addresses the problem of covariance of output between facilities
- If market generation (**MG**) would need to account for correlation between facilities, which appears impractical.

But an issue in measuring output

- Theory is based on output of IGF
  Measure output at peak LSG TIs. But what is peak LSG?
  - With or without the IGF's contribution in calculating LSG?
  - Currently choose peak using LSG *with* IGF's contribution
- Ultimately interested in the contribution in reducing the peak, which is between two values
- We could measure peak reduction but simpler to just adjust the K-value as this has similar effect

Simple example

Trading interval	MG	IG1	IG2	LSG	LSG excl IG1	LSG excl IG2
15:00	2120	20	50	2050	2070	2100
15:30	2190	35	40	2115	2150	2155
16:00	2200	40	60	2100	2140	2160
Maximum (over the TIs)	2200			2115	2150	2160
	a			***b***	***c***	***d***

Calculations

1	Fleet output at peak MG	100	*= IG1 + IG2 at 16:00*
2	Peak reduction due to the fleet	85	= *a* - *b*
3	*Marginal peak reduction of IG1*	*35*	*= c – b*
4	*Marginal peak reduction of IG2*	*45*	*= d – b*
5	Sum of individual peak reductions	80	
6	Fleet output at peak LSG	75	*= IG1 + IG2 at 15:30*
	Marginal benefit of IGs considered in order		
7	*Peak reduction of IG1 (assuming no IG2)*	*40*	= *a* - *d*
8	*Peak reduction of IG2*	*45*	*= d - b*
9	Sum of individual peak reductions (considered in order)	85	= *a*- *b*

Sum of marginal contribution vs total contribution of fleet

- Generally the contribution of the fleet is greater that the sum of the marginal contribution of each facility
- If award IGFs based on their marginal contribution then
  - Existing IGFs impacted by New IGFs
  - Gap between capacity awarded and that delivered
- Two options to address the gap
  - Determine LSG for using only facilities that already existed
  - Reallocate gap
- In effect, what currently happens is a bit of both
  - Process of impact of IGFs on other facilities is slow
  - U-factor adjustment estimated based on fleet contribution

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  - K-factor adjustment
  - U-factor adjustment
  - Other issues with trading intervals used

The K parameter value

- Prior value based on an international benchmark
- Two steps
  - Estimate a K value relevant to SWIS
  - Adjust for how output is measured
- Net effect was to offset each other and so recommended value is zero

Estimating K-value for SWIS

- K can be estimated as $K = \frac{f_M'(0)}{2f_M(0)}$
- where
  - $f_M(S)$ is the density function of the distribution of surplus load (S)
  - $f_M(0)$ is the value when surplus load is zero
  - $f_M'(0)$ is the first derivative

- Distribution estimated from estimate of peak demand
  - Surplus load is available capacity less system demand
  - Estimated available capacity using Reserve Capacity Target (RCT)

Estimating K for the SWIS

- Approach
  - Distribution of surplus calculated as distribution of peak demand less reserve capacity target
  - Recent SWIS Electricity Demand Outlook forecast 10%, 50% and 90% probability of exceedance (POE) for peak demand
  - Fit a skewed distribution to POE values and apply formula
- Values
  - We expected K for SWIS to be relatively large because the SWIS demand is small and peaky
  - However peak demand offset by skewed distribution of peak
  - Estimated unadjusted K value of 0.0022 to 0.0024

Adjustment

- Issue
  - IGF output can shift timing of peak
  - IGF's output measured at peak LSG may underestimate its marginal contribution in reducing the peak
  - Similar affect to K parameter – bigger effect for facilities with higher variance
- Approach: Estimate the K parameter equivalent of the effect
- Result:
  - Total affect similar in size to value of unadjusted K parameter
  - Conclude best to use a K-parameter of zero

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The issue – Performance of IGFs at peak TIs

	Peak (MW) reduction by			
	Wind	**LFG**	**Solar**	**Count of days**
Max temp<40	97.21	14.18	4.60	77
Max temp>=40	75.16	13.75	1.79	19
All	92.85	14.10	4.13	96
% reduction on 40+ Degree Days	-23%	-3%	-61%	

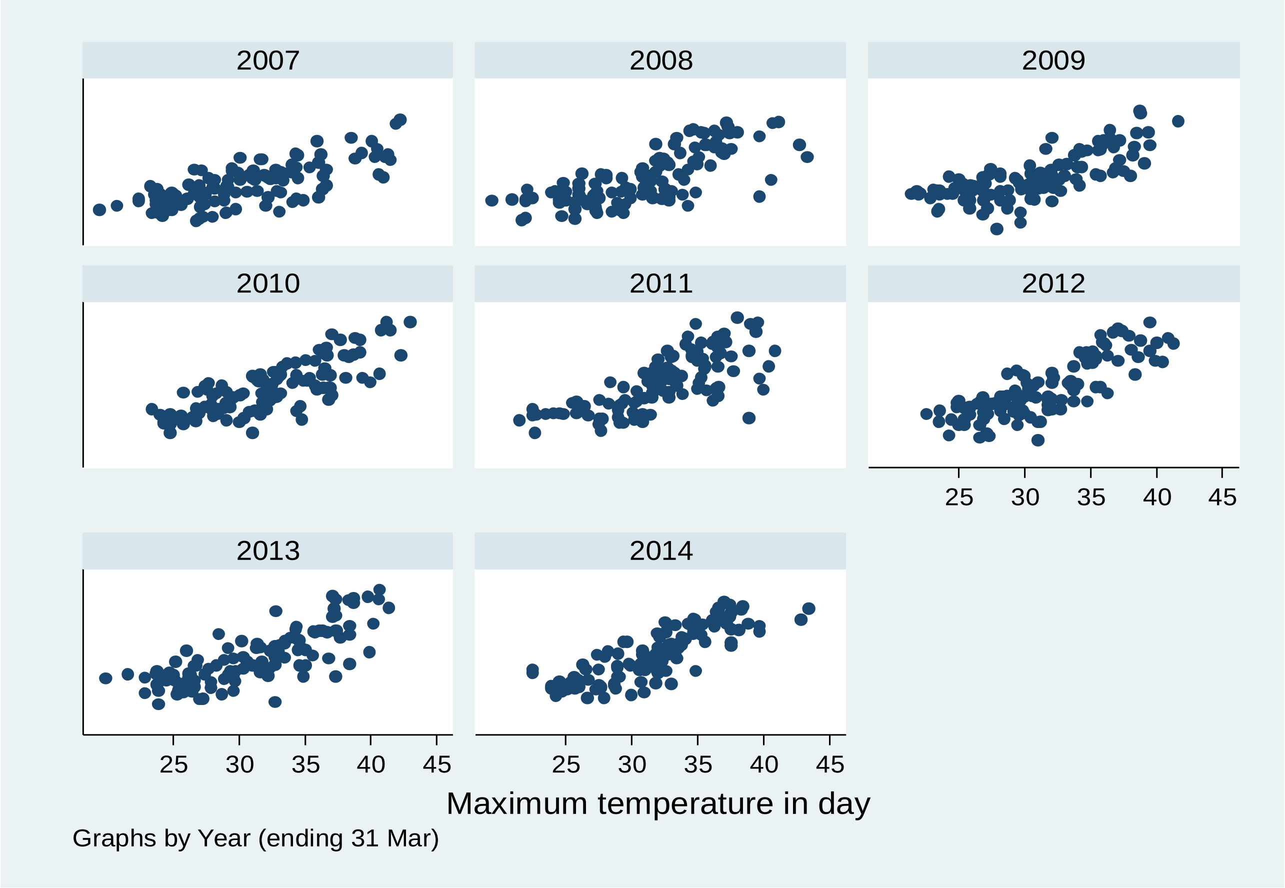
•Data taken from years 2008 through to 2014. When a facility is not operational the data is treated as missing

•Output shown is the average peak reduction in the day by type of facility.

What’s going on

- Wind
  - Very hot days and extreme demand couple will lulls in wind
- Solar
  - 2014 experience is peak LSG shifted later on some TIs when solar performed worse

Maximum temperature in day single best predictor of peak



Options

1. Use only TIs from extreme peaks

2. Make an adjustment to reflect the negative relationship between demand and output at the extreme peaks
   a. the current approach, whereby an adjustment is based on the variance (and mean) of output at the peaks, and
   b. a ‘regression’ approach, whereby the adjustment is based on correlation between output and temperature (or other factors that drive peak demand).

First option – use a smaller selection

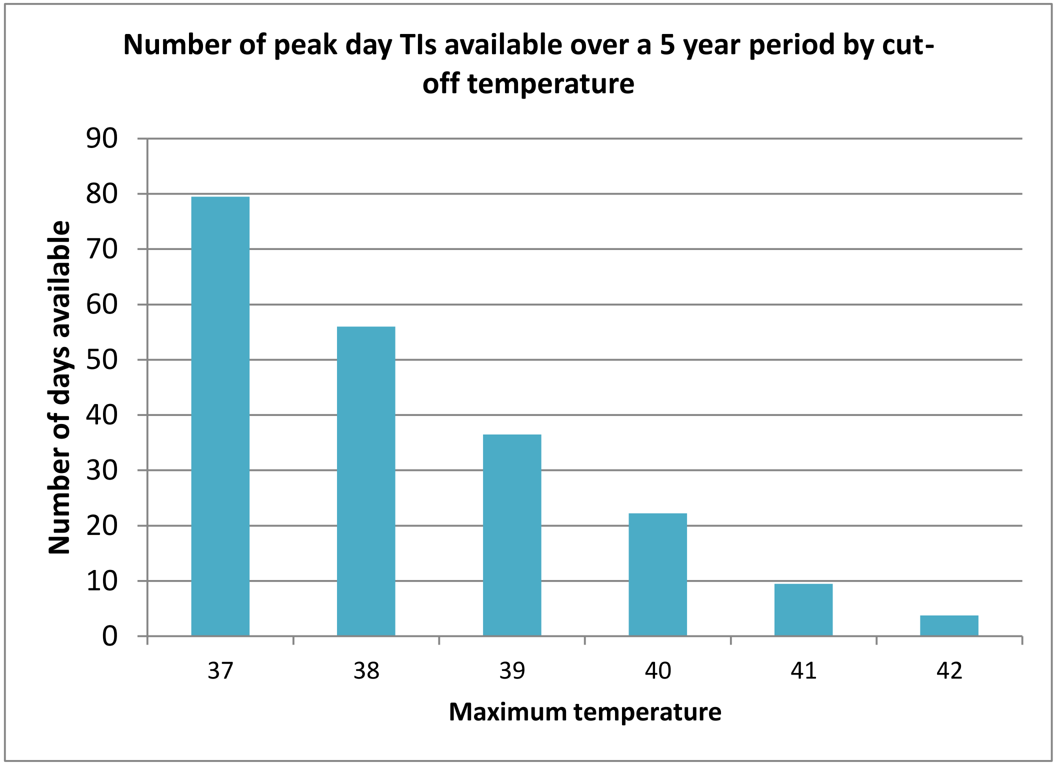
- Focus on extreme peak days
- Include other very hot days that were weekends/holidays etc
  - Boosts the number of days that can be used
  - No reason to think IGF output changes on such days
- First step check the selection based on max temperature is reasonable

Check: max temp days are the higher ranked days

Peak Trading Intervals on 40+ Degree Days

Year	Trading Interval	Rank of day in year	Max temperature on day	Comment
2006/07	Wed 7/3/2007 15:30	1	42.2	
2006/07	Tue 6/3/2007 15:30	2	41.9	
2006/07	Fri 2/2/2007 15:30	4	40.1	
2006/07	Sat 3/2/2007 14:00	6	40.5	Weekend
2006/07	Sun 28/1/2007 16:00	9	41.3	Weekend
2006/07	Sat 27/1/2007 16:30	12	41.1	Weekend
2007/08	Thu 28/2/2008 15:30	1	41.2	
2007/08	Thu 17/1/2008 15:00	3	40.7	
2008/09	Fri 16/1/2009 14:30	3	41.7	
2009/10	Thu 25/2/2010 16:00	1	41.2	
2009/10	Mon 18/1/2010 14:00	2	43	
2009/10	Fri 12/3/2010 16:00	3	40.8	
2009/10	Tue 19/1/2010 15:00	4	41.5	
2011/12	Sat 28/1/2012 16:30	7	40.9	Weekend
2011/12	Thu 26/1/2012 15:00	11	41.3	Holiday
2012/13	Tue 12/2/2013 16:30	1	40.7	
2012/13	Thu 21/2/2013 17:30	5	40.6	
2012/13	Mon 31/12/2012 16:30	9	41.4	Christmas eve
2013/14	Sat 11/1/2014 17:30	5	43.4	Weekend

But not going to work – simply not enough very high temperature days



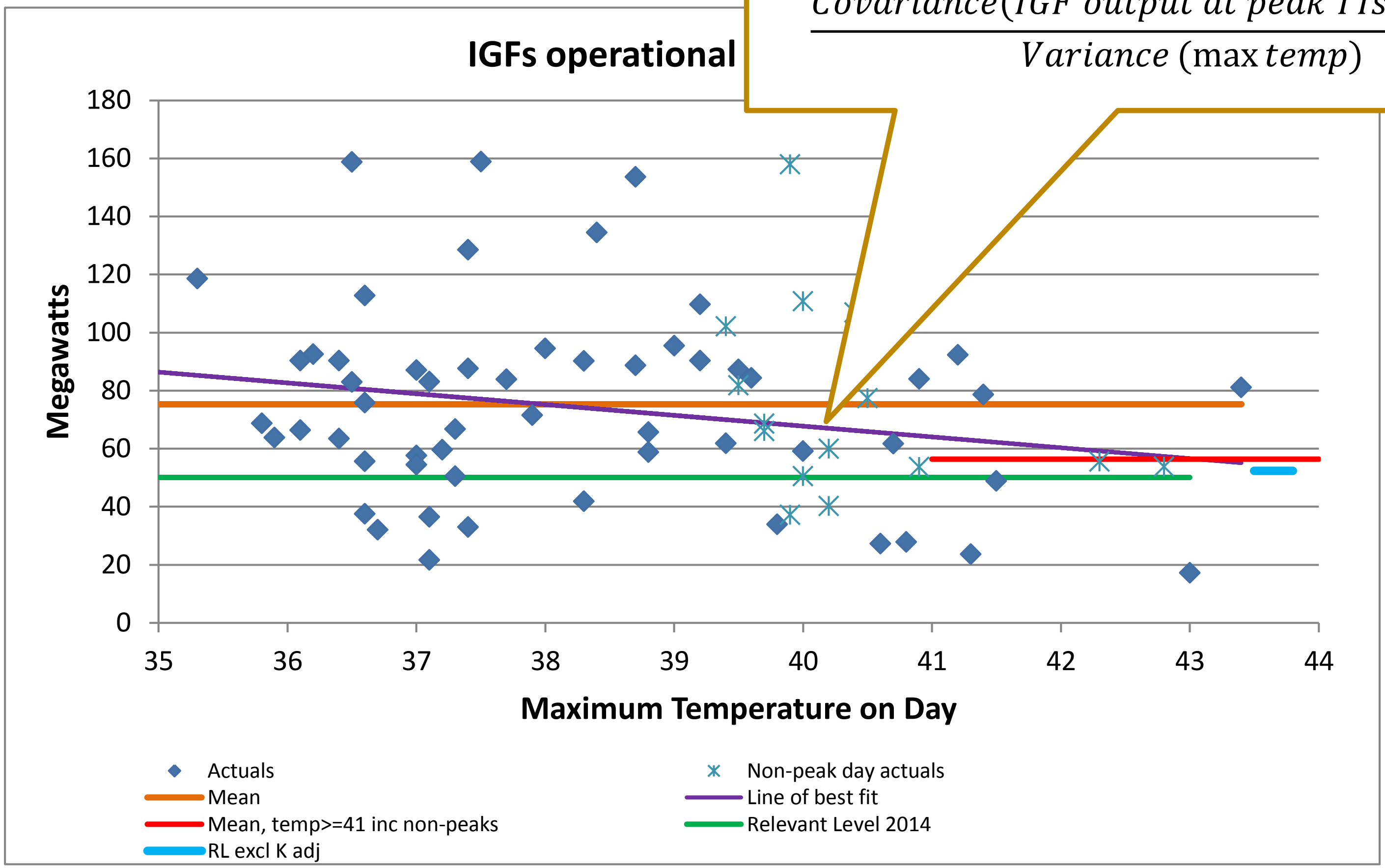
A ‘regression’ approach

- In effect, forecast what average output will be like at extremes for each IGF using existing data
- Potentially simple
  - Use the same data as current method plus temperature data
  - Simple formula if using one-variable regression (a line of best fit)

Calculating the regression line

Slope =

$$\frac{Covariance(IGF\ output\ at\ peak\ TIs, \max temp)}{Variance\ (\max temp)}$$



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Promising, but not recommended

- Approach is attractive as it doesn't penalise IGFs whose output is not lower on extreme days
- But concerns
  - Relationship is not necessarily linear
  - Result is sensitive to outliers
- Analysis
  - In most cases similar to current U-factor approach
  - Some cases where it might improve results, others clearly not
  - Large increase in volatility of results

Summary

- Alternatives to U-factor were considered
- Nothing practical appears viable
- Hampered by lack of information of performance of IGFs at extremes
- In absence of alternatives, can only recommend keeping with current approach

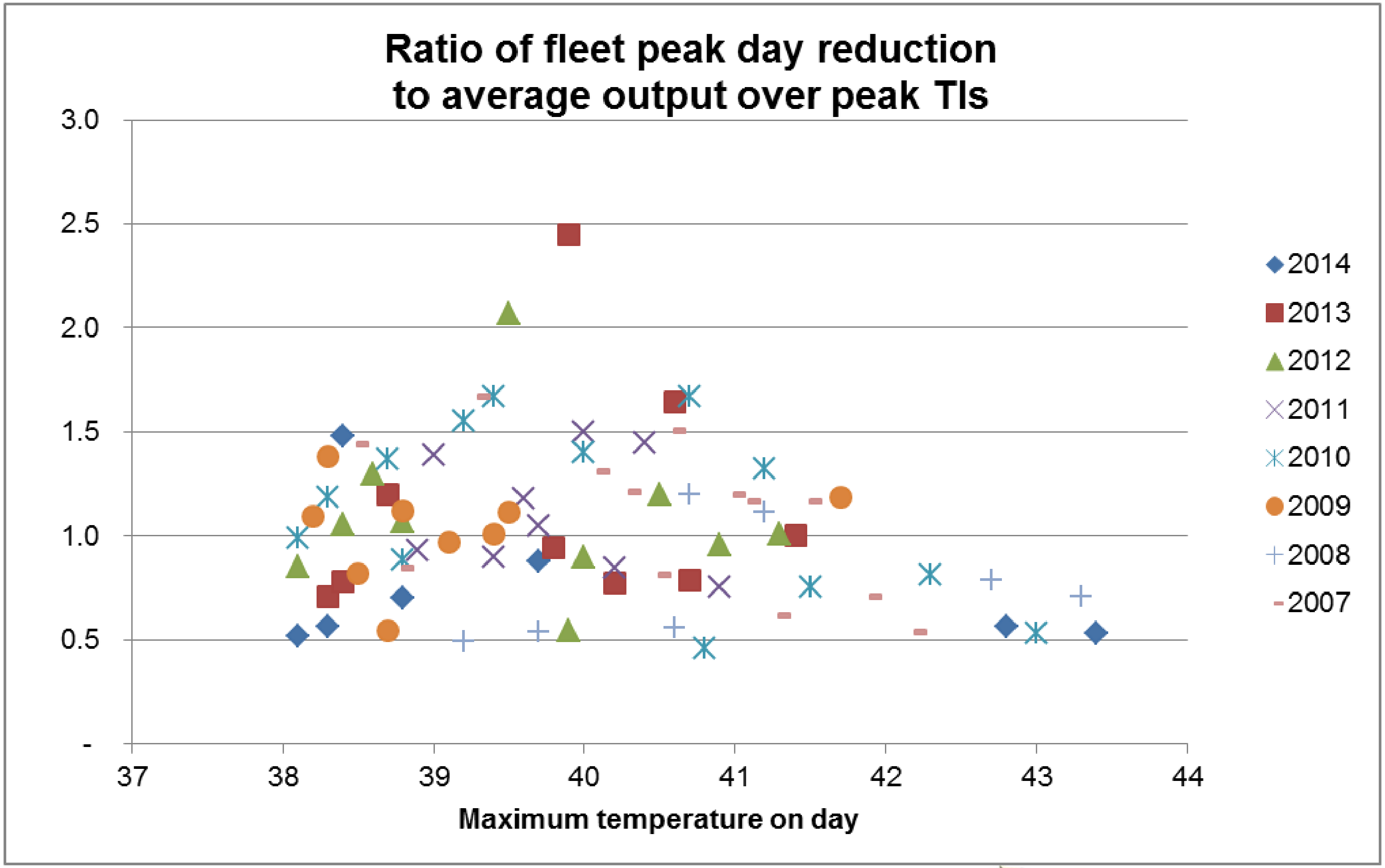
Revised U-factor

Recommend no change i.e. U-factor of 0.635

Why no change

- As earlier noted, current adjustment appears, in general, reasonable
- The RL for the fleet determined using this U-factor coincides with the peak reduction at the most extreme temperatures.

Size of U-adjustment required



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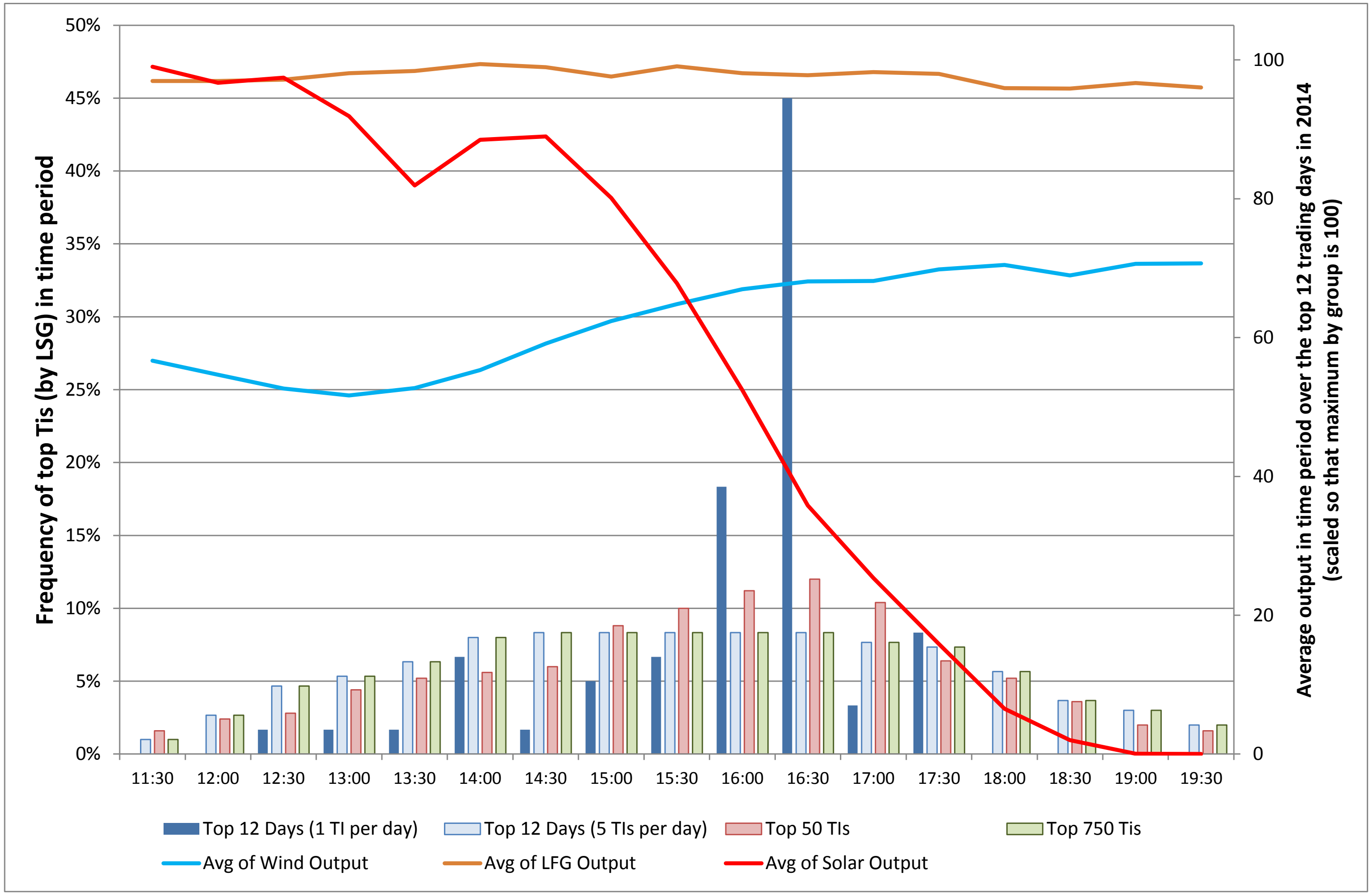
Which trading intervals to use

- Currently
  - One per Trading Day
  - 12 days per year
  - Five years
  - All TIs have equal weight
- How to evaluate
  - Too many TIs – less representative of peaks?
  - Too few TIs – too volatile

Why just one TI per day?

- Negligible benefit to using more i.e.
  - Very high correlation of output in adjacent TIs
  - Therefore, doesn’t provide much more information
- High cost
  - By construction the additional TIs would not be representative of the peak

IGF output and timing of peak TIs



Notes: Frequency data from 5 years to April 2014. Output data was limited to actual output in the year ending April 2014. Top 50 and top 750 refer to the top 50 and 750 TIs in each year. In all cases the top TIs are by LSG.

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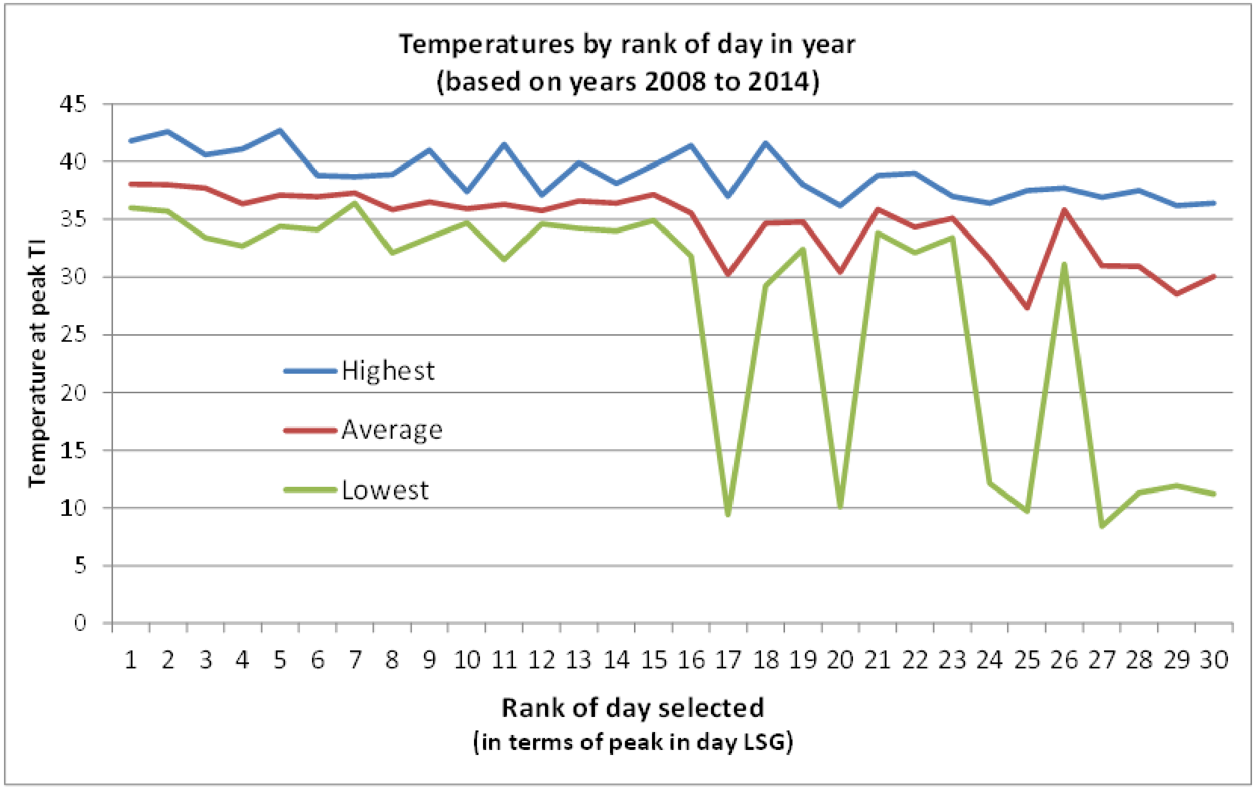
Number per year?

- Examine how key variables change as we increase the number of days used
  - Temperature
  - Time of year
  - Time of day

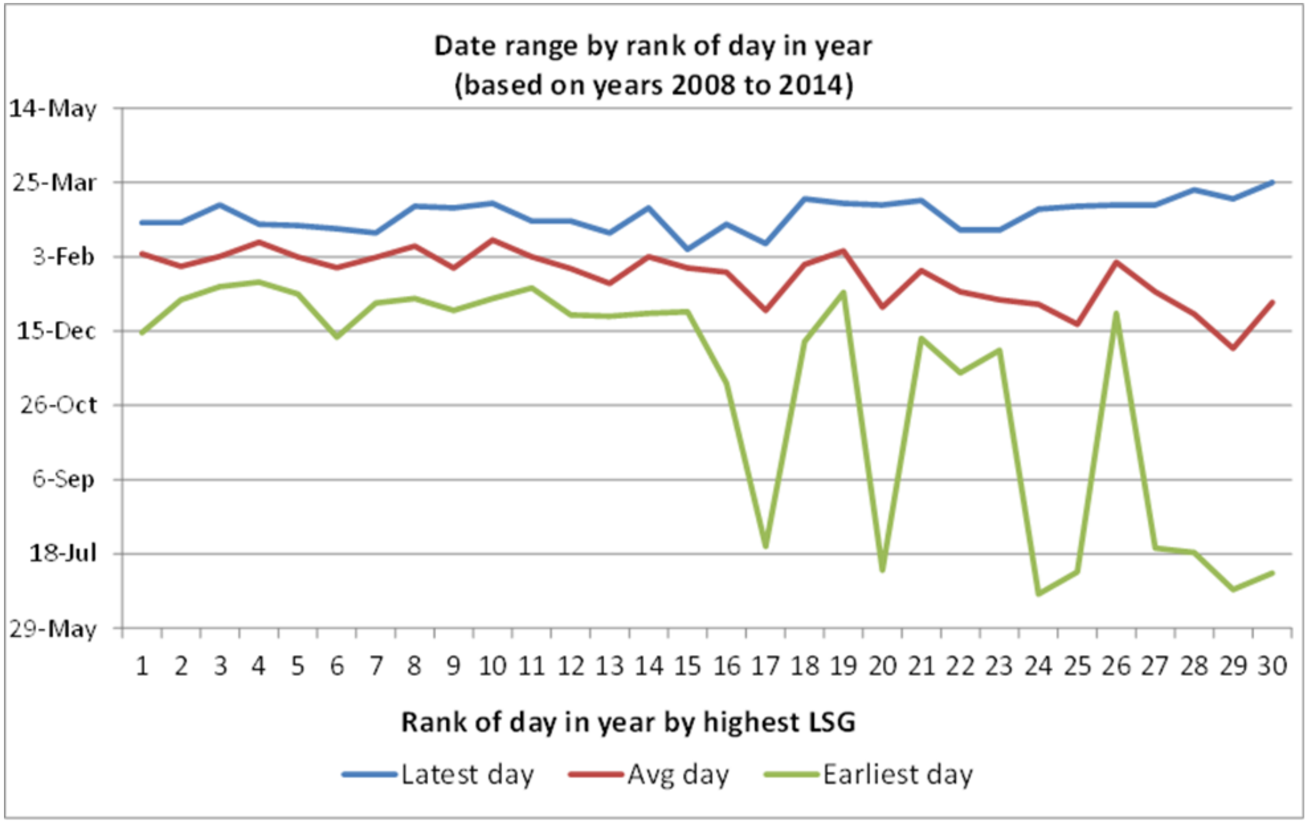
How many TIs – Are temperatures representative?



- As expected temperature at peak falls as greater peaks selected
- Clear issues from 15+ days

New

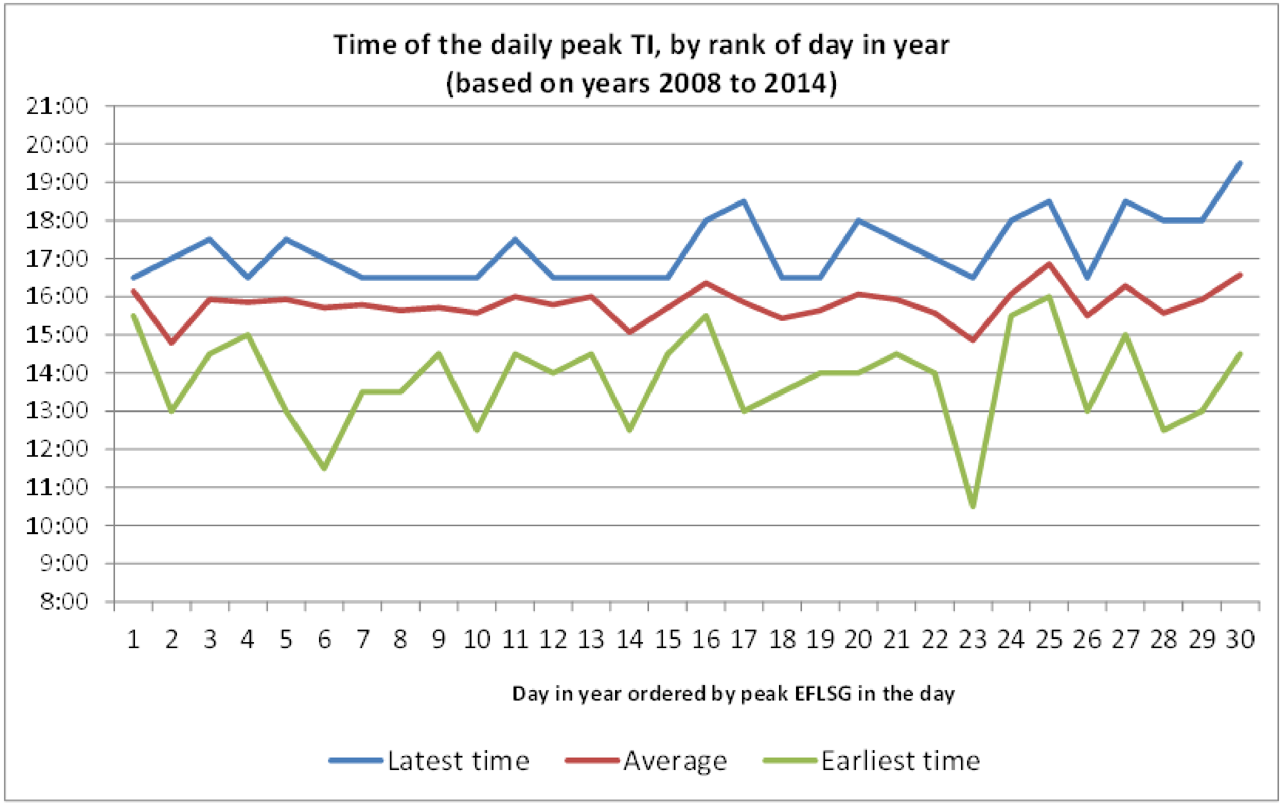
How many TIs? – When do peaks occur



- Later peak days tend to happen earlier
- Clearly unrepresentative from around 15+ trading days
- No indication of differences in first 12 peak days

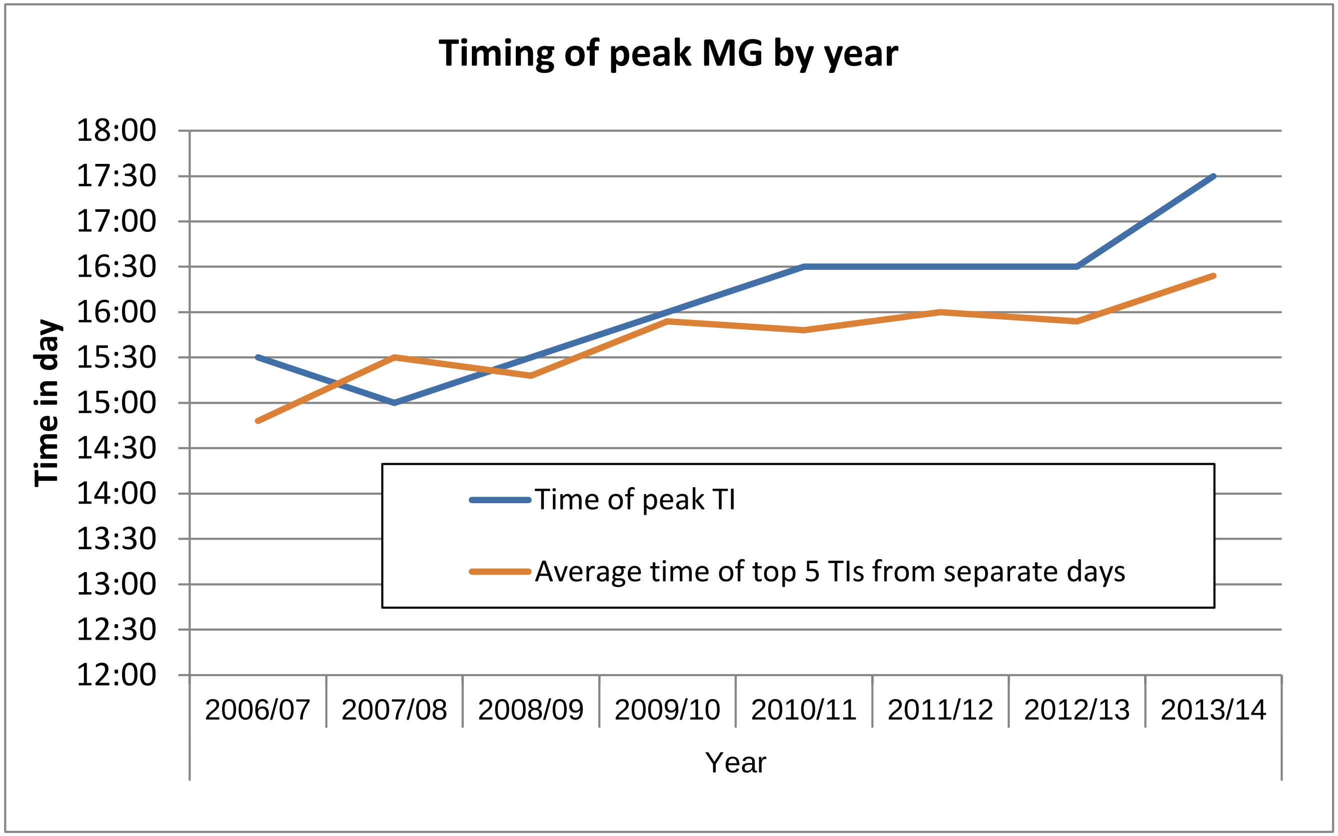
New

How many TIs – Time of day when peak occurred

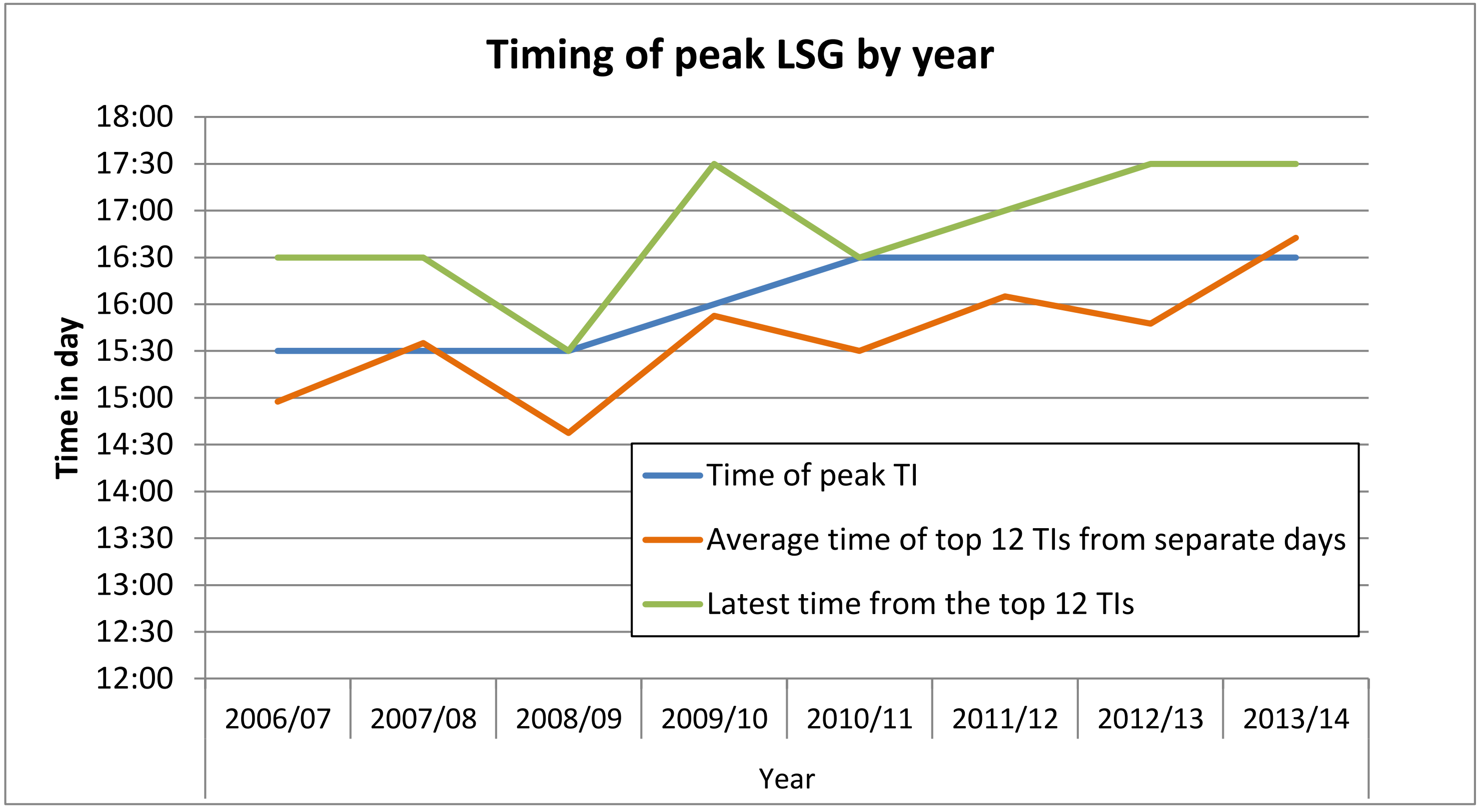


- Peak time tends to be between 3:30pm and 4:30pm
- No clear trends
- But increasing variability as more TIs are used

Number of years used.
Profile of system demand is changing



Peak LSG also changing but less significant



Weighting of TIs

- Currently equal weight given to all TIs
- Possible to give greater weight to those more likely to be representative e.g. higher LOLP
- Tried a few options but decided against
  - Very limited benefit – Nothing removed the need for the U-factor adjustment
  - Increase in complexity and sensitivity to a small number of results

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Conclusion and summary

- RL methodology appears to provide reasonable results
- Reasons for reservations over U-factor adjustment..
- …but no better alternative can be found given available data

- On the parameters, recommend
  - K parameter is changed to 0
  - U parameter is unchanged at 0.635

- No changes required to rules

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