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Capacity value of intermittent generation: Public report

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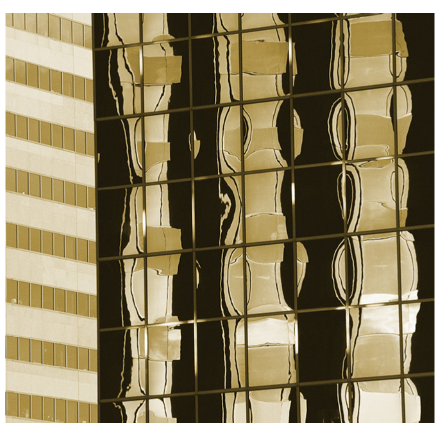

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Summary

Introduction

Currently the capacity of Intermittent Generation Facilities (**IGF**s) in the Wholesale Electricity Market (**WEM**) is based on the average output of facilities measured over all periods of a number of years. It is widely recognised this is inappropriate as it does not align the output with the peak demand — when capacity is required.

Sapere Research Group (**Sapere)** was commissioned by the Independent Market Operator (**IMO**) Board to provide independent advice on the two proposals by Griffin Energy (**Griffin**) and the IMO in relation to the allocation of capacity credits to IGFs and identify if there where modifications that could be made that would make them more robust and simpler.

In particular, Sapere was asked whether simple changes could be made so as to allocate capacity credits based solely on individual performance while ensuring performance is during peak periods and significant volatility is not introduced.

This report also examines the transition between the current capacity valuation and the future method (i.e. provide 'a glide path').

Note: While this report includes estimates of the implications of different proposals, these estimates should be considered preliminary as they are yet to be peer reviewed.

The IMO and Griffin proposals

In summary the methodologies for calculating IGF capacity credits are as follows:

- The IMO proposal (documented in RC_2010_25). IGF credits based on:
  - the average output of the top 250 trading intervals (**TI**s) over 3 years,
  - adjusted to reflect the 95% Probability of Exceedence (**PoE**) of average annual fleet performance during top 12 TIs over the prior 8 years.
- The Griffin proposal (documented in RC_2010_37): IGF credits based on:
  - the average output of the top 750 TIs over 3 years,
  - with no adjustment.

Both methodologies determine the top trading intervals based on Load for Scheduled Generation (**LSG**), which is equal to total generation less intermittent generation.

The two methodologies produce significantly different results, primarily due to the fleet adjustment in the IMO proposal. As shown in Table S2, the average output measured in the top TIs is similar under the IMO and Griffin proposals but due to the fleet adjustment, the capacity credits under the application of the IMO proposal are almost half that of the Griffin proposal.

Assessment and alternatives

There are a number of different approaches that have been considered internationally and by the IMO to estimate the capacity value of IGFs. Broadly, the approaches attempt to achieve a balance between accuracy and simplicity.

In general, the more accurate the methodology the more likely the method will align with the Wholesale Market Objectives including those relating to reliability, technical neutrality and encouraging efficient investment. However, simplicity and ease of application are also desirable objectives.

Both proposals provide an improvement over the current methodology in that they focus on output during the peak periods, thereby rewarding IGFs whose output is aligned with periods of peak demand.

In examining the Griffin and IMO proposals and alternatives in more detail it is useful to consider the following generic formula for capacity credits — appropriate for power systems where intermittent generation is reasonably low relative to peak load:

Capacity credits =	*1. Average facility output during peak periods*	***Less***	*2. An adjustment for the variability in output*

An assessment against these two components is discussed below.

The average facility output

Both IMO and Griffin proposals calculate an average facility peak output; however the IMO proposal makes an adjustment based on fleet output during the peaks. In calculating the average, both the Griffin and IMO proposals suffer from a clustering problem. These methods use average output from the TIs regardless of day. As load is highly correlated during a day the TIs selected tend to occur on a limited number of days. For example, in all years examined, the top 12 are clustered in 2 or 3 days. This results in excess volatility (i.e. defeats the purpose of averaging over 12 TIs) and results in TIs being selected outside of very peak times (i.e. 3:30pm-5pm) — the later problem is particularly significant for the top 250 and 750 TIs.

The clustering issue can be addressed by selecting intervals from separate days. By doing so an average value based on a small number of TIs per facility can be estimated without introducing excessive risk of volatility in results. There are options as to the number of TIs selected. Selecting more TIs reduces volatility but increases the risk that TIs are selected from periods that do not represent peaks.

Adjustment from the average peak period output

The Griffin proposal does not make a direct adjustment for variability in facility output. The IMO proposal, by adopting a 95% PoE approach of yearly average values, incorporates an adjustment to the average facility output based on the standard deviation of the annual average fleet output during peak periods. Due to the clustering problem described above there is excessive volatility in yearly averages and the standard deviation is large, which results in a large adjustment.

The IMO proposal's adjustment based on standard deviation is not appropriate for estimating a facility level output as it does not align well with theory and suffers from an aggregation problem that cannot be simply addressed.

It is also more accurate that the capacity credit valuation of a new facility be dependent on its correlation in output with existing facilities. By selecting TIs based on LSG some adjustment is made. However, a more accurate adjustment is possible.

Alternative method

An alternative method that reflects the above considerations is:

Capacity credits =	*1. Average facility output during Top 12 TIs drawn from separate days from 5 years*	***Less***	*2. K x variance of facility output during peaks*

Where *K* is a parameter to be determined
Variance of facility output is determined over the same peak TIs

Two main adjustments to the IMO and Griffin proposals are:

- Facility level averages used are drawn from the top 12 TIs that are drawn on separate days.
- Adjustments are based on the facility variance (i.e. the square of the standard deviation) rather than fleet standard deviation over the same TIs

It is also recommended that the top TIs used for analysis are drawn from 5 rather than 3 years as this provides additional stability and appears to have no downside.

This proposed alternative has clear advantages over the Griffin and IMO proposals and it is recommended this (or a close variant) be adopted. This approach has a stronger theoretical foundation and has been adopted internationally. Such an approach is also simpler to apply at a facility level. A summary of the methods is shown in Table S1.

Table S1: Options

	Average	Adjustment to average	Comments
Griffin	*IGF output during top 750 TIs*	*No direct adjustment made*	• Suffers from clustering problem • Lack of adjustment results in overvaluation and favours large IGFs
IMO Method	*IGF output during top 250 TIs scaled to average fleet output over 8 years*	*Based on standard deviation (SD) of fleet averages*	• Suffers from clustering problem • Adjustment based on SD less accurate and more unwieldy than based on variance
Alternative	*IGF output during top 12 TIs selected from separate days over 5 years*	*Based on variance of IGF output*	• Clustering problem addressed • Structure of adjustment has a stronger theoretical basis and used internationally

Under the alternative, the outcomes for individual IGFs depend critically on the size of the adjustment to the average used (determined by the parameter *K*). A large adjustment is not necessarily warranted. Although the output of IGFs is variable, so is demand and (because of outages) conventional generation. The extent of the adjustment should thus reflect how the variability of IGF output combines with the variability of demand and conventional generation. In general, the greater the variability of demand, the less the variability of IGF output matters. Furthermore, some adjustment for variability is automatically included by using LSG to determine the TIs from which averages are determined.

International benchmarks would suggest the *K* parameter would be reasonably small (in the region of 0.002 to 0.005 per MW^{-1}). This would lead to capacity credits as percent of nameplate capacity of around 37% overall (33% for wind farms).

However, an additional, much more significant, adjustment is warranted. A key concern is that information held does not capture the peak demand scenario and that performance of IGFs at the very peaks may be different to that observed in the TIs selected. Analysis presented in this report suggests this is probable — there are indications of a negative relationship between very high temperatures and IGF output.

Unfortunately, there is no precise way of addressing the issue that IGF output may differ during the very peak scenarios. Ideally an adjustment to each facility's average should be made, however, with very few data points at extreme demands and temperatures, an apparent relationship in the data might not signify a real underlying statistical relationship.

An alternative simple adjustment is to replace the parameter *K* in the formula with an adjusted value (*G)* that reflects the additional uncertainty (thus *G=K +U* where *U* is a parameter that that reflects the additional uncertainty). Such an approach is simple and does not penalise those generators whose output during the peaks is stable. To prevent the adjustment caused by the parameter *U* being biased against large facilities it is recommended that *U* be scaled downwards in proportion to average output.

Setting values

A closer examination of the fleet IGF output during the extreme peaks suggests that the fleet result should fall between that implied by the current IMO and Griffin proposals. The fleet result of the IMO proposal once modified to select TIs on separate days gives a result consistent with the results observed during the peak temperatures. This leads to a capacity value for the IGF fleet of around 29% (for wind-farms around 25%) and implies the *G* parameter be set at an initial average value of 0.0303 (measured in units of MW^-1). It is recommended that starting values be K = 0.003 MW^{-1} and U = (0.623/average IGF output) MW^{-1}.

It is recommended that the application of the formula and *G* value be reviewed in 3 years time. As part of this review, consideration should also be given to:

- addressing the issue of correlation between IGF output. It is desirable that the capacity value of new facilities is relatively less if their output is positively correlated with existing facilities. Another related modification is that the LSG used for existing facilities exclude newer facilities. This would ensure that an existing facility is not disadvantaged by a new facility coming on-line.
- altering how TIs are selected for analysis. For example, accuracy may be improved by using a different number of TIs and/or weighting the TIs used.
- using more sophisticated techniques such as regression analysis to forecast IGF output at extremes. As more data is obtained, this would potentially enable a more accurate measure to be developed.

It should be noted that none of the proposals considered in this report would be appropriate for accurately determining the capacity value of IGFs when IGF penetration is significant. As a guide, a review of the approaches should be considered once the average output of the IGF fleet at peak periods approaches 300 MW.

Transition

Preliminary results and the financial impact of the recommend option are shown in Table S3. The total financial impact is significant, amounting to a reduction of around $5 million over the current method.

Two broad options for transition relief that have been identified are:

1. Use a simple average between the current and future methodology.
2. Modifying the size of the adjustment to the average over time (i.e. the parameter *G*).

The two options would provide slightly different results. The second option provides transitional relief based on the major change in approach (i.e. the use of an adjustment to the average) — it gives no transition relief due to a shift from measuring output over all TIs to measuring output just at peak times. This second element of the change is, arguably, more predictable. Furthermore implementation of the second option is simpler as it applies just one set of rules. For these reasons the second option is recommended.

Both options could be used to achieve a steady transition. For example, a simple transition path is as follows:

Capacity credits in year *t* up to year T (the transition period)	=	(1-t/T) x starting method	***Plus***	(t/T) x future method

Where under Option 1 the starting method is the current method, under Option 2 the starting method is the proposed alternative method with *G* set to zero.

A question exists as to how quickly a transition might be applied. Ultimately the time period should reflect the rationale for transition and size of transition desirable. It would seem reasonable that the transition period reflect the time period over which a review to the methodology is undertaken. A 3 year period seems reasonable and is recommended; in which case the increase in the financial impact each year would be around $1 million.

Summary recommendations

- The following formula for capacity credits is adopted:
  (subject to calculations being verified)

Capacity credits =	*1. Average facility output during Top 12 TIs drawn from separate days from 5 years*	***Less***	*2. G x variance of facility output during peaks*

Where *G = K + U* reflects both known variability (reflected in *K)* and *uncertainty* of IGF distribution (reflected in U).

K is initially set at *K = 0.003* MW^{-1}.

U is initially set at U=0.635/(average facility output during peaks*)* MW^{-1}.

All averages and variances are measured from facility output in MW determined over the same peak TIs.

The parameter for U is set so that the total fleet capacity credits matches that given by IMO Proposal modified to select TIs from separate days.

- Transition arrangements, if desired, be conducted over 3 years by a straight-line adjustment of the parameter *G* in the above formula.
- The formula and parameters are reviewed in 3 years time. At which time consideration be given to:
  - addressing the issue of correlation between the output of separate IGFs.
  - altering how TIs are selected for analysis.
  - using more sophisticated techniques such as regression analysis to forecast IGF output at extremes
  - whether IGF penetration is so significant that alternative methods are required.

Table S2: Comparison of IMO and Griffin methods

Facility Information		Current Method		IMO proposal (RC_2010_25)			Griffin proposal (RC_2010_37)	
Name	Nameplate capacity	Capacity Credits	as % of nameplate capacity	Avg. of Top 250 TIs by 3 years	Capacity Credits	as % of nameplate capacity	Avg. of Top 750 TIs by 3 years = Capacity Credits	as % of nameplate capacity
Wind farms – Sum	192.7	75.5	39%	65.6	29.5	15%	67.1	35%
- Minimum value			31%			9%		25%
- Maximum value			43%			18%		38%
Land fill gas – Sum	23.5	15.6	67%	15.1	6.8	29%	15.1	64%
- Minimum value			34%			13%		30%
- Maximum value			85%			40%		88%
Sum of all	216.2	91.1	42%	80.7	36.3	17%	82.2	38%

Caution: IMO proposal amounts are based on 5 years data to 2011 rather than 8 years as proposed. Due to the clustering issue (described in this paper) the results from the IMO proposal are very sensitive to the years used and results from 8 years data may be materially different.

Table S3: Financial implications

	Current		Proposed alternative (Value if *G*=0)		Proposed Alternative Final value (*G average* =0.0303)		Value of credits ($000s) based on Reserve Capacity Price 1/10/12 – 1/10/13 =$186,001				Change $(000)s
Generator	Capacity Credits	as % of nameplate	Capacity credit	as % of nameplate	Capacity Credits	as % of nameplate	Current Methodology	Transition Year 1	Transition Year 2	Transition Year3	Current to Final
Wind farms - Sum	**75.5**	**39%**	**65.5**	**34%**	**48.9**	**25%**	**14,041**	**11,149**	**10,119**	**9,090**	**(4,951)**
- Minimum value		31%		19%		12%					
- Maximum value		43%		50%		39%					
Land fill gas – Sum	**15.6**	**67%**	**14.8**	**63%**	**14.1**	**60%**	**2,910**	**2,716**	**2,674**	**2,631**	**(278)**
- Minimum value		34%		35%		31%					
- Maximum value		85%		84%		82%					
Sum of all	**91.1**	**42%**	**80.3**	**37%**	**63.0**	**29%**	**16,951**	**13,865**	**12,793**	**11,722**	**(5,229)**

Caution: Estimates are preliminary.

1 Introduction and background

Currently the capacity of Intermittent Generation Facilities (**IGF**s) in the Wholesale Electricity Market (**WEM**) in Western Australia is based on the average output of facilities over a course of a year. It is widely recognised this is inappropriate as it does not align the output with the peak demand — when capacity is required.

To examine the issue, the Independent Market Operator (**IMO**) established the Renewable Energy Generation Working Group (**REGWG**) to determine a new approach. A number of alternative proposals were considered but neither a consensus nor a compromise was achieved.

Following the REGWG, two proposed rule changes were developed and submitted by the IMO (RC_2010_25) and Griffin Energy (**Griffin**) (RC_2010_37) in relation to the allocation of capacity credits to IGFs. This paper briefly assesses these two proposals and examines potential modifications which could be made to develop a new approach.

Sapere Research Group (**Sapere)** was commissioned by the IMO Board to provide independent advice on the two proposals by Griffin and the IMO in relation to the allocation of capacity credits to IGFs. Sapere was asked to assess the two proposals and identify if there were modifications that could be made that would make them more robust and simpler.

In particular, Sapere was asked whether simple changes could be made so as to allocate capacity credits based solely on individual performance while ensuring performance is during peak periods and significant volatility is not introduced. The report also examines the transition between the current capacity valuation and the proposed future method (i.e. provide a 'glide path').

PLEASE NOTE: The calculations in this report should be considered preliminary. They are based on only 5 years data — not 8 years data as envisaged by the IMO proposed method.

2 Summary of the IMO and Griffin Energy Proposals

The IMO proposed methodology calculates capacity credits as:

- *a facility value* based on output in top 250 trading intervals (**TIs**) over 3 years,
- multiplied by, *a fleet adjustment factor* which incorporates a 95% Probability of Exceedence (**PoE**) based on average annual output during the top 12 TIs over 8 years.

  Where:

  – the top TIs are those with highest Load for Scheduled Generation (**LSG**) being the difference between total sent out generation and that of IGFs

  – the 95% PoE is calculated as: Mean of the 8 yearly averages – 1.895 x Standard Deviation (**SD**) of 8 yearly averages.

Thus the method can be written as:

$$\textit{Capacity credits} = \underbrace{\text{Average facility output in top 250 TIs in each of 3 years}}_{\textit{A facility value}} \times \underbrace{\frac{\text{95\% PoE of 8 yearly average fleet output from top 12 TIs}}{\text{Sum of each facility output average from top 250 TIs by 3 years}}}_{\textit{A fleet adjustment factor}}$$

Alternatively the methodology can be written as

$$\textit{Capacity credits} = \underbrace{\text{The 95\% PoE of 8 yearly averages fleet output from Top 12 TIs}}_{\textit{The fleet result from the top 12 TIs}} \times \underbrace{\frac{\text{Average facility output in top 250 TIs over 3 years}}{\text{Sum of average facility output in top 250 TIs over 3 years}}}_{\textit{allocated across facilities based on output during the top 250 TIs}}$$

In comparison, Griffin's proposed methodology entails setting capacity credits as:

$$\textit{Capacity credits} = \underbrace{\text{Average facility output in top 750 TIs in each of 3 years}}_{\textit{A facility value}}$$

Both methodologies determine the top trading intervals based on LSG. LSG is used as reflects when schedule generators are stressed and additional capacity has highest value.

The effects of the application of both methodologies are provided in Table 5 on Page 30.

A summary of the source of difference between the two proposals at a fleet level is shown in Table 1 below. While there is some differences in the averages between the top 750, 250 and 12 TIs the primary reason for the large difference is a result of the application of the 95% PoE.

Table 1: Comparison of elements of IMO and Griffin proposals

	MW	% of Current
Current capacity credits (2012/13)	91.1	100%
Griffin proposal: **Average fleet output over Top 750 TIs (over 3 years)**	82.2	90%
Average fleet output over Top 250 TIs (over 3 years)	80.7	89%
Average fleet output over Top 12 TIs (over 5 years)	74.8	82%
IMO proposal: 95% PoE Value of yearly fleet output	36.3	40%

3 Assessment and alternatives

3.1 Introduction

There are a number of different approaches that have been considered internationally and by the IMO to estimating the peak load capacity value of IGFs. Broadly the approaches attempt to achieve a balance between accuracy and simplicity.

In general, the more accurate the methodology the more likely the method will align with the market objectives including those relating to reliability, technical neutrality and encouraging efficient investment. However, simplicity and ease of application are also desirable objectives.

The bulk of this section analyses the accuracy of the IMO and Griffin proposals and potential modifications.

With regards to simplicity and ease of application:

- Both proposals are also reasonably simple to implement once the required data has been collected. The Griffin proposal is simpler primarily because it requires information only from the prior 3 years whereas the IMO method requires information from 8 years and requires an additional step in the calculation.
- At first glance, the Griffin proposal appears to be based solely on facility level performance. However both the Griffin and IMO proposals are based on the top TIs

as determined by LSG. The IMO proposal uses this same information in making the fleet level adjustment.

3.2 Background to estimating peak load capacity

The capacity credit valuation is designed to reflect two reliability criteria (see Appendix A.1). It is understood that the key criteria of interest — and the criterion considered in this report — is the capacity to meet peak load.

The peak load capacity requirement is based on the risk that the supply will not meet demand during peak times. Both demand and IGF output are random variables and thus the capacity value of an IGF is determined by how the IGF contributes to average peak load supply and the variability of the load required to be supplied by scheduled generation.

In theory, the capacity value of intermittent generation can be calculated as the Effective Load Carrying Capability (**ELCC**) – a measure of the additional load that the system can supply with the particular generator of interest, with *no net change in reliability*.[1] A common approach to estimating capacity values is to undertake studies using the ELCC theory. A variety of statistical methods (e.g. Monte Carlo analysis) are used. Two key issues are:

- the cost and complexity of undertaking such a study, and
- the lack of data on IGF output to estimate its probability distribution over peaks.

A common alternative is to use approximation methods. These include statistical approximation methods or a simple time-based average such as output during observed peak periods.

A useful generic formula for estimating peak load capacity credits using a number of approximation methods is:

Capacity credits =	1. Average IGF output in top peak periods	***Less***	2. An adjustment for the variability of IGF output

This generic formula becomes a useful framework for evaluating the proposals and considering modification to the proposals. The structure of this formula is appropriate when IGF penetration is reasonably low. When IGF penetration is low the variability of IGF output will be low compared to that of the system and its reliability value will be

[1] A similar measure is Equivalent Firm Capacity (EFC) which measures the capacity of a scheduled generator that would deliver the same reduction in risk.

close to the mean (i.e. average) output at peak times. The adjustment from the mean is necessary to account for the variability of available IGF output being much greater than that of conventional plant.

The IMO and the Griffin proposals are variants of the formula. In particular:

	1. Average facility output in top peak periods	*Less*	2. An adjustment for the IGF variability
IMO Proposal	Average fleet output during top 12 TIs allocated by IGF contribution to output during the top 250 TIs		A multiple of standard deviation of average fleet output allocated by IGF contribution to output during top 250 TIs
Griffin proposal	Average IGF output in 750 TIs		No adjustment made

An evaluation of the IMO and Griffin proposals against these two elements is considered below.

3.3 Average peak load output

Under the IMO proposal the average facility value is based on the fleet output in the top 12 TIs allocated to facility by relative performance in the top 250 TIs. A rationale for using the fleet approach is that it allows a calculation based on output in the top TIs while averaging over multiple facilities to reduce the risk for an individual facility.[2]

The Griffin proposal deals with the volatility by averaging over a large number of TIs. This increases the risk that the TIs analysed are not representative of the peaks.

Both the Griffin and the IMO proposals provide an improvement over the current methodology in that they focus on output during the peak periods, thereby rewarding IGFs whose output is aligned with peaks.

However, both the IMO and Griffin proposals suffer from an issue of clustering. Clustering is a significant issue whereby the top TIs tend to be drawn from a small number of days. For example, the top 12 selected TIs tend to be drawn from only 2 or 3

[2] The volatility of different options can be assessed by examining the variation of yearly results. Table 4 in Appendix A (Page 14) compares a volatility measure (the ‘coefficient of variation’ = the standard deviation divided by the mean) of results under different approaches. For wind farms the volatility increases substantially from moving from the top 250 to the top 12 TIs. Of note, the volatility of land fill gas output is hardly impacted by the choice of measure.

days. This leads to volatility in determining averages and has the additional unwanted outcome that some TIs selected are from time periods which are very unlikely to be when the absolute peak occurs. This clustering issue is described in detail in Appendix C.

A simple modification that would address the clustering issue is to require the top TIs to be selected from separate days. This change would also enable the average facility output to be estimated based on a small number of TIs which are focussed on peak periods.

The impact of using separate days for TIs on volatility is shown in Table 4 in Appendix B (Page 29). Of note, the volatility over yearly averages from the top 12 TIs drawn from separate days (over 5 years) is generally smaller than that over the top 250 TIs (over 3 years as per the IMO proposal). Thus, there appears to be little benefit of the current fleet adjustment approach over selecting a facility average from the top 12 TIs on separate days.

Given these considerations a reasonable alternative to the IMO and Griffin proposals is to determine an IGF average output based on a small number of top TIs selected from different days.

Within this alternative, there are a number of options.

- First, there is a choice as to how many TIs should be used. Using too few TIs creates a risk for IGFs as to the average output. If too many TIs are used then there is a risk that TIs are selected from periods that are not representative of the peak times. Further analysis could be undertaken to assess how many TIs might be selected.
- Second, TIs may be weighted so that the very peak days receive greater weight. While slightly more complex it could provide more accurate results if the very high peak days were in some way correlated with IGF output.

Table 2 below shows preliminary[3] results of the different approaches for the sum of the fleet of IGFs.

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[3] Note: The IMO proposal requires 8 years of data. For this report only 5 years was available.

Table 2: Average values from top TIs (Fleet Total)		
Option Description	**Assessment**	**Total Fleet result**
A1. Griffin's proposal Top 750 TIs (over 3 years)	• Large clustering problem	82.2
A2. IMO proposal: Top 12 TIs (over 5 years)	• Involves a fleet adjustment • Significant clustering problem	74.8
A3. Facility output drawn Require top 12 TIs to be drawn from different days (over 5 years)	• Simple • Removes clustering problem	80.2
A4. Require top 12 TIs to be drawn from different days but weight** them so highest use days count more (over 5 years)	• Potential more accurate approach than A3 but adds to complexity • Weighting desirable if very high use days are somehow correlated with IG output	79.4
Capacity Credits - current methodology (2012/13)		91.1

Note: Weight chosen in this example is the square of LSG.

All options are broadly consistent with the Wholesale Market Objectives (**market objectives**). However, Option A3 and Option A4, by resolving the clustering issue, would perform better than A1 (Griffin proposal) and A2 (IMO proposal) when assessed against:

- the reliability criteria in market objective (a), and
- the discrimination criteria in market objective (c), by aligning the TIs used with the highest peaks in LSG — as doing so removes a discrimination against technologies whose output is very closely aligned to the very highest peaks.

Of note, if the IMO proposal was changed to select TIs from separate days, the overall results would be much higher as a result of reducing the volatility in annual fleet average output. Table 5 also includes the results of applying the IMO proposal using TIs from separate days. The overall impact is to increase the capacity credits for the fleet from 36.3 (17% of nameplate capacity) to 63.0 (29% of nameplate capacity).

3.4 Adjustment to the average peak load output

The size and the structure of the adjustment is a critical issue as the adjustment is the primary difference between the current method and proposed alternatives.

Theoretic and empirical findings

Some guidance on the optimal structure and level of adjustment to the peak load average output can be found from theoretical and empirical studies that have examined the effective load carrying capacity of IGFs when IGF penetration is low. Some key findings are as follows.

First, theory suggests that a downward adjustment to the average peak load output is appropriate and that the size of the adjustment will be roughly proportional to the variance in IGF peak output (see Box 1 below). Generally the ratio of the variance to output increases with IGF output.[4] As such:

- when the facility (and variance) is very small, a negligible adjustment will be required, and
- large facilities will generally have a lower capacity rating than smaller facilities.

Box 1

The mathematics of capacity value

The capacity value of an IGF can be assessed by considering its ELCC.[5] Since demand and IGF output are random, the ELCC will depend on the distribution of IGF output relative to demand and other IGFs.

It can be shown[6] that for small increases in capacity where IGF output is not correlated with surplus load (equal to the surplus of available conventional plant over load) then:

$$\text{ELCC} \approx \bar{I} - K\,\sigma_I^2 \qquad (1)$$

Where: $\bar{I}$ and σ_I^2 are the mean and variance of peak load IGF output and K is a constant.

The value of K can be estimated. For example, if the surplus load is distributed normally, then:

$K = \frac{\bar{S}}{2\sigma_S^2}$ where $\bar{S}$ and σ_S^2 are the mean and variance of surplus load.

When the IGF output is correlated with surplus load (which incorporates existing facilities) then the formula (1) can be modified to reflect the statistical dependence between IGF output and surplus load. When IGF penetration is large and/or the IGF considered is very large the formula will not be accurate and alternative methods (see Dent, Keane and Bialek, 2010) should be considered.

Source: Adapted from Zachary and Dent (2011)

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[4] All else being equal, a facility that doubles in size will have four times the variance.

[5] As noted earlier, ELCC is the Effective load Carrying Capacity, i.e. the amount of further demand which may be added while maintaining the same level of risk.

[6] Zachary and Dent (2011) discus the theory. Stoft (2008) provides numerical examples.

Second, the size of the adjustment will depend on how the peak output from the IGF correlates with demand and output from existing facilities. The value of a new IGF is greater the less it is positively correlated with existing facilities and the more it is positively correlated with demand. There are some important implications of this:

- There is benefit in a diversification of facilities
- The incremental capacity value of IGFs will depend on the order in which they are introduced.

Third, a common finding from detailed studies on the capacity valuation of IGFs is the capacity credit valuation of IGF decreases as the penetration of the IGFs increases. For example, Figure 1 below shows a summary of a number of technical studies assessing the capacity value of wind power. A clear result is that the capacity credit valuation is lower if the wind power penetration is higher. Of note, in these studies the capacity credit valuation varies between 20 and 40 percent for low (<20%) wind power penetration and 5 and 25 percent for high (>20%) wind power penetration.

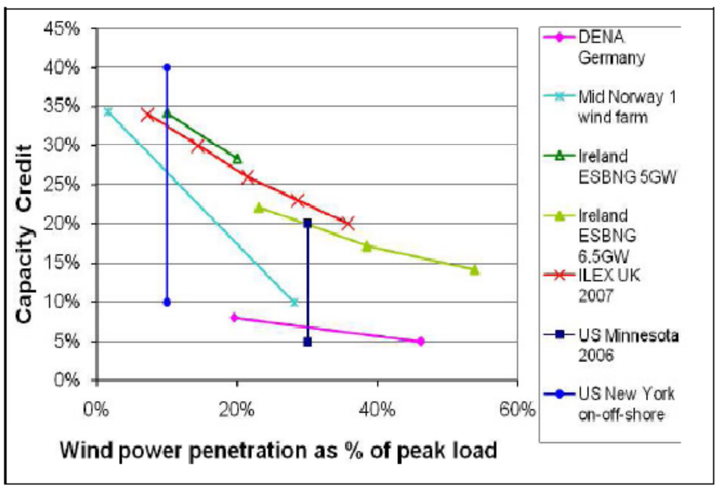

Figure 1: Capacity value of wind power: Summary of studies (Source: Keane et al. 2011)

Uncertainty of distributions

An additional consideration is making an adjustment for unknown outcomes. Statistical methods discussed above are limited because they rely on analysing the distributions of historical data. A challenge, in particular when dealing with analysis of the peak demand scenario, is that there may be limited information on what occurs during the very peak periods. A risk is the combined event scenario, where adverse weather conditions affect both demand and supply. A recent example from Texas — which relates primarily to conventional capacity — is described in Box 2. There is no recognised method for incorporating this type of uncertainty.

Box 2

Combined event scenario: Texas February 5, 2011

Extracts from 'Winter Weather Readiness for Texas Generators'

> *Severe winter weather affected power generators in the Electric Reliability Council of Texas (ERCOT) power region from the morning of February 1, 2011 to the afternoon of February 5, 2011.*
>
> *The strong arctic front that arrived in North Texas on February 1, 2011 was the most intense cold wave for the majority of the state of Texas since December 1989. [...] The winter weather event of February 1-5, 2011 was determined to be a one in ten year event for some regions of Texas in terms of low temperature extremes and duration.*
>
> *Generating unit issues that affected reliability were mostly attributed to frozen instrumentation due to convective heat losses greater than instrumentation design, faulty instrumentation heat tracing or compromised insulation. [...]*
>
> *In addition, the cold and wind affected the units that were not operating. [...]*
>
> *ERCOT also reported a new record winter peak of 56,334 megawatts.*
>
> *The high load demand, coupled with generation issues within ERCOT, resulted in actions from ERCOT that triggered an Operating Condition Notice (OCN) issued for cold weather at 08:55 on February 1. The event level escalated to an EEA2A (Energy Emergency Alert) declaration at 05:18 on February 2 to deploy responsive reserves, followed quickly by an EEA3 declaration at 05:58 on February 2 to begin shedding firm load to maintain system frequency at 59.8 Hz or greater. The event continued until ERCOT cancelled the EEA at 09:58 on February 3.*

Source: Calpine, CPS Energy, LCRA, Luminant, NRG Energy, (2011)

Evaluation of the structure of the Griffin and IMO proposals

In light of the theory and international evidence discussed above, with regard to the adjustment to the average peak IGF output the current Griffin and IMO proposals are not optimal.

The Griffin proposal formula makes no explicit adjustment to the average value of peak load facility output for fleet volatility of IGF output. While measuring average IGF output at LSG makes some adjustment for variability of IGF output, this effect is small.[7] More significantly there is no allowance made for the uncertainty associated with IGF

[7] See discussion in Box 3 Section 3.5 below.

performance during the very high peaks. As such, an application of the Griffin proposal will likely overvalue the capacity credits of IGFs. A related implication is that it will be relatively less favourable towards small facilities and facilities with a low variance.

The IMO proposal formula makes an adjustment based on the standard deviation of annual peak fleet output through the use of the 95% PoE calculation. While, as desired, this adjustment will likely be greater for larger facilities, the method does not closely align with theory. For example, compared with the optimum, the IMO proposal will make a relatively large adjustment to facilities with small variance in output (e.g. land fill gas).

An additional issue with the structure of the IMO proposal is that it is difficult to apply at a facility level. The IMO proposal cannot be applied at an individual facility level, without significant adjustment, as the sum of individual IGF 95% PoEs will be less than the fleet 95% PoE. This 'aggregation issue' is because the standard deviation of the fleet will be lower than the sum of the standard deviation of the individual facilities.[8]

The IMO proposal is similar in structure to the approach used by the Australian Energy Market Operator (**AEMO**) to determine a capacity contribution for wind-farms in the National Electricity Market (**NEM**). These tend to be significantly lower than those currently applied in the WEM. They are calculated on a facility basis using a PoE of 85%.[9]

While consistency with the AEMO approach may seem desirable, care should be not to place too much weight on the AEMO approach and results. The AEMO circumstances are significantly different. In particular:

- The AEMO does not run a capacity market. As such the capacity valuations are solely used for overall supply-demand planning. They do not have financial consequences and are not a material consideration in investment decisions. As such a simplified approach is taken.
- The nature of the NEM wind-farms is that their output is not closely aligned with peak times.

[8] That is (Fleet 95% PoE)/(Sum of Facility 95% PoE) >1 because (Fleet SD) /(Sum of Facility SD) <1.

[9] Source: Author's correspondence with AEMO staff.

3.5 Alternative proposal

An alternative model[10] that is similar in structure to the existing proposals, but which better reflects theoretical underpinnings (described in Box 1 above) is to have the adjustment proportional to the variance[11] of the IGF output. That is:

Capacity credits =	1. Average facility peak output	***Less***	2. A constant (K) x the variance of facility output.

A variant of this approach is commonly known as the 'z-method'[12] and has been applied by PacifiCorp in North Western United States since 2006.

This alternative method is a small modification to the existing IMO proposal. It principally involves using a facility average and replacing an adjustment based on the standard deviation of the fleet output with one based on the variance of the individual facility output.

This alternative method lends itself to facility level application as variances (of facilities with independent output) can be added without modification. For example, under this formula the sum of the capacity credit value of two facilities (e.g. a wind-farm and a solar generator) assessed independently will be the same as if they were assessed jointly.[13] This is not the case if the standard deviation were used.

In implementing this method some design choices are required. It is proposed that:

- The facility average is taken from the top 12 TIs taken from separate days. Doing so minimises the modification from the IMO proposal. In future reviews a different number of TIs might be considered.
- Five years of data be used. In modifying the IMO proposal it also is necessary to select the number of years of data to use (the IMO proposal uses a combination of

[10] Other alternatives were considered (see page 20 for some discussion) but nothing was found that improved upon this approach.

[11] The variance is equal to the square of the standard deviation.

[12] Developed in Dragoon and Dvortsov (2006).

[13] Whichever approach is used there is an additional complication when IGF output is not independent (i.e. correlated) — this issue is discussed below on page 16.

8 years for fleet and 3 years for facility calculations). Given 5 years of data is currently available it seems reasonable that 5 years be used.[14]

- LSG be used for selecting top TIs (as with the IMO and Griffin proposals). The use of LSG has gained acceptance and has some attractive properties in helping to address issues of correlation between facilities. The use of LSG does have implications for calculation of the K parameter in the formula above.

It is also appropriate for the formula to be reviewed periodically to improve its accuracy. The value of the parameter *K* should be reviewed periodically (e.g. every three years). Consideration should also be given to other potential improvements including correlation between facilities and weighting of TIs used to measure averages. Such factors need to be jointly considered.

As intermittent generation penetration increases, alternative and more complex structures may become appropriate. Other calculation approaches available, which are short of a full stochastic modelling exercise, are discussed in Dent, Keane and Bialek (2010).

Determining the value of the K parameter

The value of the parameter *K* in the above formula is a critical value as it determines the overall level of adjustment.

In estimating the value of K there are a number of considerations.[15]

First, there is the distribution of demand and output from conventional generation facilities that can be drawn from historical data. If full information were available then the value of *K* could be precisely determined from this data using a stochastic modelling approach or estimated using a simplified method.[16] Based on comparison with Ireland, another small system, the resulting K^{-1} (i.e. the inverse of K) would be expected to be in the low hundreds of MW. If this were the only consideration, it would be reasonable to expect a *K* value in the range of 0.002 to 0.005 per MW^{-1}.

Second, an important consideration is the use of LSG for determining peak TIs. To an extent the use of LSG makes some automatic adjustment due to the variability (see Box

[14] Facility level data is not currently available from the period 1 April 2006 to early September 2006. As peak periods in other years have not occurred in these months it is very unlikely that this missing data will affect results.

[15] Note: that K is dimensional — that is it depends on the units being used. In this report K is measured in units of 1/MW.

[16] See Dent, Keane and Bialek (2010) for a discussion of methods.

3 below). The use of LSG warrants consideration should a modelling exercise be undertaken.

Box 3

The effect of Load for Scheduled Generation (LSG)

The value of IGFs and the impact of using LSG can be shown in the following simple two-period example. The example shows how IGFs contribute to reducing the peak load to be met by Scheduled Generators.

Period	**a. Peak MG**	***b. IGF output***	**LSG (=a – b)**	
1	**2,100**	***100***	2,000	Old peak period
2	2,080	***50***	**2,030**	New peak period
Reduction in peak = 2,100 – 2,030 = **70.**				

In the absence of IGFs the peak load to be met by Scheduled Generators would be 2,100 units (in period 1). With IGFs, the peak load to be met by Scheduled Generators is determined by the peak LSG which is 2,030 units (in period 2). Thus the value in peak reduction from the IGF fleet is 70 units. However, the fleet output at the peak LSG is only 50 units and fleet output at peak market generation (MG) is 100 units.

More generally it is clear that:

Fleet IGF output at peak LSG	≤	Reduction in peak to be met by scheduled generation (i.e. Peak MG minus Peak LSG)	≤	Fleet IGF output at peak MG

If IGF output was constant then all three values would be identical. By taking the IGF output at the peak LSG some adjustment for volatility in output is being made.

Third, consideration should be given to how covariance of output[17] between facilities is managed. Preferably a covariance term should be included in the capacity credit formula. As covariance between facilities is more generally positive, until such a term is included a higher value of *K* might be appropriate.

[17] More accurately stated statistical dependence of output

Finally, there is the concern that historical information does not capture the peak demand scenario and that performance of IGFs at the very peaks may be different from the TIs analysed. At the present time, it is this consideration that becomes the dominating factor. This is considered in more detail below.

Adjustments for uncertain distributions

Evidence of an issue

To further consider the risk of historical information being not representative of peak demand scenarios, it is useful to more closely examine the IGF output during periods that have characteristics of the highest peak.

While there are a number of factors that affect demand, some preliminary analysis was undertaken on the basis of extreme temperatures. Higher peak demand is associated with higher temperatures. This is demonstrated in Figure 2 below which shows the total market output from the top TIs (selected from separate days) against temperature. Within each year there is a clear positive relationship between total load required and temperature. Of note, the very high temperatures do not occur in all years. As can be seen from the figure (at the 3pm time chosen) the air temperature did not exceed 40 degrees in 2011 or 2009. This highlights the risk of placing equal weight to the TIs selected.

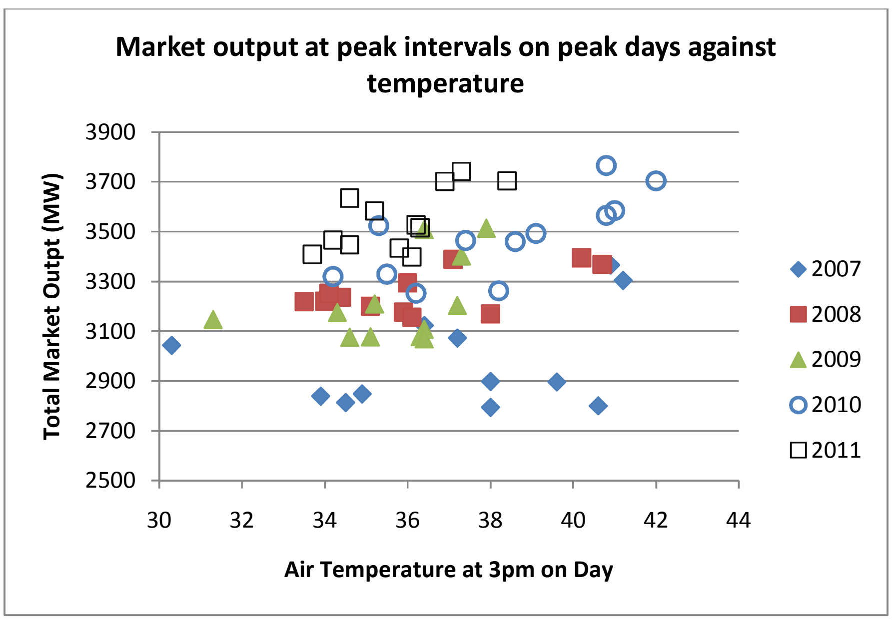

Figure 2: Peak demand on very hot days

Note: The chart shows a single peak for each day. The temperature is taken from the same time (3pm) so as to be on a consistent basis and does not necessarily represent the temperature at the time of the peak TI.

Figure 3 examines the relationship between IGF output selected from peak demand TIs and temperature. Points on the scatter-plot represent the top 12 peak demand days in each year. The scatter-plot maps the IGF fleet output at the peak period on these days against the temperature (as measured at 3pm) on these days. This graph highlights the concern that circumstances that drive higher demand may coincide with lower IGF output. The total IGF output at the peak periods appears to materially lower for the very high temperatures.

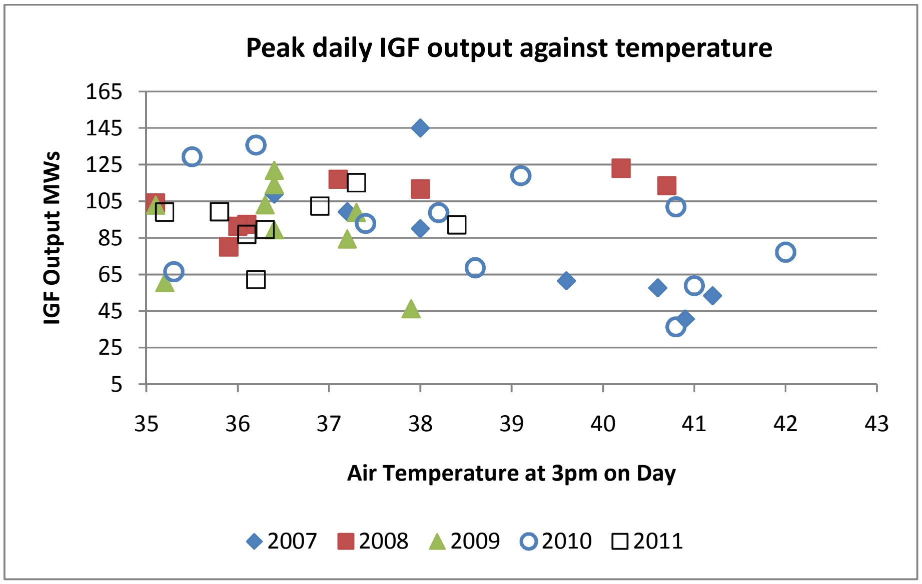

Figure 3: IGF output and very high temperature peak-demand TIs

Note: Based on the top 12 TIs on separate days. As in Figure 4 a single data point is taken from each day. The temperature is taken from the same time (3pm) so as to be on a consistent basis. Similar results were found if different times were used.

Figure 3 contains the top TIs selected from just 12 peak demand days for each of 5 years. To examine a broader set of data that compares intermittent generation output with temperature, the requirement that the day be a top 12 peak demand day was removed. This enables more information (e.g. results from weekends to be displayed). The results from the broader data set are shown in Figure 4. Using the larger data set enables a clearer relationship between air temperature and IGF output to be seen. A regression analysis,[18] undertaken on this data set, showed a statistically significant negative relationship between IGF output and temperature. [19]

[18] The regression used was a linear regression between total IGF fleet output and air temperature based on facilities that were operating over the entire period. Results were

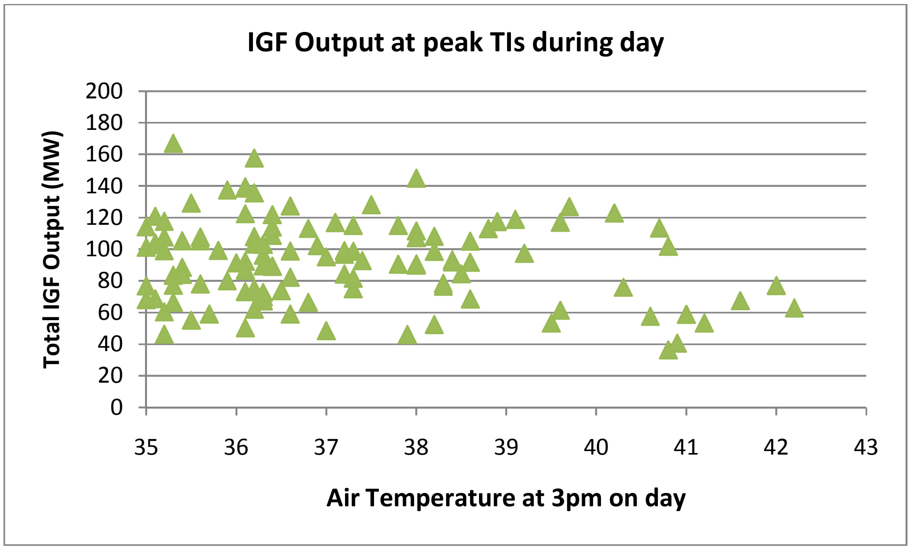

Figure 4: IGF output at peak demand during day (temperature at 3pm >35 degrees)

These results themselves are based on a small number of TIs and should not be considered as strong evidence of IGF output during extreme demand/temperature scenarios. However, they do provide enough evidence to suggest that a further adjustment is warranted based on the level of uncertainty.

Modification of method for additional uncertainty

The above analysis suggests that there is a material risk that IGF output during very peak periods is less than the average IGF output captured using the proposed methods (whether it be the IMO, Griffin or alternative proposal). There is no recognised method for dealing with such uncertainty. Ideally, if the average output is lower during these extreme peak times then the average output in the formula should be modified. However, there is no simple way to do this in a uniform way that would not disadvantage IGFs who have stable output.

An alternative approach is to make a further adjustment based on variability of output during peak periods. Potentially an adjustment could be based on the variance of

significant (with robust standard-errors) at 95% confidence interval. Result were the similar whether the top TIs were selected using market generation of LSG.

[19] Note: Over the years examined there was some small changes to the IGFs included in the fleet. The analysis was also conducted on just the IGFs that were present for all years — there was not material change to the results.

facility output or some other measure of variability (e.g. standard deviation). An adjustment based on the variance is desirable for a number of reasons:

- It is simple as it involves a small modification to the proposed method, and
- It reflects that the relative risk is greater for facilities with greater volatility of output.

For these reasons it is proposed that the parameter *K* in the formula is replaced with an adjusted value (*G)* that reflects the additional uncertainty (thus *G=K +U* where *U* is a parameter that that reflects the additional uncertainty*)*.

However, the variance as a proportion of average output increases with facility size and the size of the adjustment required is so significant that an adjustment based solely on the variance would result in larger facilities receiving lower capacity credits than smaller facilities. To address this issue it is proposed that the additional adjustment be scaled downwards according to the average output; that is setting:

$U = U_1$/(average facility output), where U_1 is a constant.

Parameter values

To determine a reasonable value of *G*,*K* and U_1 further examination of IGF output on the few very peak intervals (as taken by high temperature) was undertaken. Due to the very limited available data, the average IGF output (and its impact on the peak) varies substantially depending on what selection was used. For example, the average reduction in peak due to IGF output was 71 MW for days with temperature ≥39 degrees, 67 MW for days with temperature ≥40 and 51 MW for days with temperature ≥41. In comparison, the average IGF output during the top 12 TIs on separate days was around 80 MW. At these highest temperatures there appeared to be no correlation between demand and IGF output. The analysis suggests, however, that the results from application of the IMO proposal were too conservatively low and results from application of the Griffin proposal were too high.

Ultimately in determining a value some judgement is required. Based on the results observed, an IGF fleet output equivalent to the fleet results of the IMO proposal modified to select TIs from separate days provides a result that is consistent with the mean and range of output that is being recorded in the extreme scenarios. That is *G* is set such that:

Fleet output under proposed method	=	95% PoE of yearly average fleet output of top 12 TIs taken from separate days over past 8 years, calculated as average output minus 1.895 * Standard deviation of annual averages

This gives an average *G* value of around 0.0303 per MW^{-1}.

As it is proposed that *U* vary with facility size it is necessary to separately determine *K* and U_1. Given the considerations discussed in the previous section, it is recommended that the starting value of *K* is *K* = 0.003 per MW^{-1}. While there are techniques to calculate K more precisely there is little value at this time given its significance relative to *G*. Based on the data available the starting value of U_1 is set at $U_1=0.635$.

On this basis it is recommended that the alternative method be adopted that (subject to values being verified):

Capacity credits =	*1. Average facility output during Top 12 TIs drawn from separate days over 5 years*	***Less***	*2. G x variance of facility output during peaks*

Where $G = K + U$ reflects both know variability and *uncertainty of IGF distribution.*
K is initially set at $K = 0.003$ *per* MW^{-1}.
U is initially set at U=0.635/(average facility output *during peaks) per* MW^{-1}
Average and variance is of facility output (measured in MWs) determined over the same peak TIs

The parameters, including the structure of the calculation of *G*, should be reviewed and expected to be adjusted over time. In particular:

- As more information is obtained on the performance of IGFs at extremes, the importance of U should diminish.
- In the future, consideration of the covariance of facilities may be included in which case adjustments to the value of *K* would be warranted.

Future developments and considerations

Dealing with correlation of IGF output

An issue that becomes increasingly important with larger facilities and higher IGF penetration relates to correlation between IGF facilities.

In the proposed methods (including the IMO proposal, Griffin proposal and the alternative), the capacity credit values of all facilities are reviewed annually and determined at the same time with no consideration to the correlation between individual facilities. There are two issues with this approach.

First, the approach does not reflect that the true value of a new facility depends on what other facilities are in place (or coming onboard). For example, the capacity contribution of a new wind farm is higher if its output is less correlated with the other wind farms. To some degree the use of LSG to select TIs helps correct for this issue.

Second, an IGF's capacity value is impacted by the calculation of LSG. Thus under the proposed methods new facilities alter the value of capacity credits to existing facilities.

These issues can be addressed. PacifiCorp (who currently use the z-method) address the first issue by modifying the formula to take into account co-variance between facilities. Another potential approach would be to require a single application from facilities of a common type in region.

To address the second issue an approach that might be considered is that IGF capacity credits be based on LSG which excludes newer facilities. This simple adjustment ensures that an existing facility is not impacted by investment of new facilities. For existing facilities it may be simpler to treat all facilities as arriving at the same time (in effect averaging this adjustment across all existing facilities).

It is recommended that this issue is considered when the method is next reviewed.

Selection of trading intervals

There are a number of potential improvements in how TIs are selected. It is recommended these be considered at the next review.

Weighting the days on which peaks are used. A potentially more accurate result may be obtained by applying weights to the TIs used; that is, place greater weight to the TIs with the higher peaks.

For the purposes of this report a brief examination of using weights was undertaken. A simple means of doing this is to weight the results by some function of LSG. Results were tested using a weight equal to the square of LSG. Applying such a weight to TIs on separate days gives the highest peak (on average) around a 30 per cent greater weight than the 12th highest TI.

Alternative methods and potentially more accurate methods could be developed. For example, Zachary and Dent (2011) demonstrate that there is a natural theoretically justified weighting based on the surplus (i.e. conventional capacity in excess of demand).

A decision on whether to weight historic data should be based on more detailed statistical analysis of what dependence structure may exist. In deciding whether weighting is appropriate, considerations are:

- Weighting improves the accuracy if IGF demand is in some way correlated with unpredicted variance in demand on the very peak days. As discussed above there is some evidence that this is the case.
- Applying weights will in general increase volatility. However this might be offset by using more years over which to measure TIs.

Changing the number of TIs used on separate days. Results were examined from increasing the TIs used on separate days from 12 to 20 TIs. This has the effect (see Table 4 on Page 29) of reducing volatility for some IGFs (primarily wind farms) but increasing volatility for others (some landfill gas). The choice of number of TIs reflects a trade-off between stability of results and the risk that TIs will be selected that are less likely to be peaks. The choice of number of TIs is also related to:

- the number of years used (as greater stability might be achieved by examining more years of data), and
- the use of weights (a use of weights may have the effect of reducing the number of TIs used).

Changing the number of years used. The IMO proposal is based on 8 years of data. Where historical IGF output does not exist it would be modelled. It would be possible to use a different number of years. Generally the more years that are used the greater the accuracy of the results.[20]

Changes in system characteristics

The structure of the proposed alternative method may become less appropriate as system characteristics change. The proposed alternative method structure is appropriate for small levels of penetration of intermittent generation. The proposed formula (i.e. average – K.variance) is only appropriate while average fleet output at the peaks is less than 1/K, which for a *K* value of 0.003 MW^{-1} is around 330 MW. Once intermittent capacity approaches this level, alternative methods (to those examined in this report) should be considered.[21]

Other modifications considered but rejected

A number of other options were briefly considered but rejected, primarily on the basis of being too remote from the proposed methodology and/or adding to complexity.

Selecting trading intervals to be analysed based on a particular time of day. This approach has some attraction in its simplicity and is popularity internationally. However as the use of intermittent generation increases, the peak demand on scheduled generators (i.e. LSG) may shift. The approach appears to have no material benefit over using the top 12 (or more) TIs on separate days and is more of a significant change from the current methodology.

Alternative to the LSG approach. Through the application of LSG to select trading intervals, the capacity credits of each IGF are determined by the output of others. However, the approach has been generally accepted and there are benefits to the approach. A more refined approach — which might further improve accuracy — could be potentially developed, however this would add significantly to complexity.

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[20] Note: The analysis presented in this paper is based on 5 years but applies a formula based on the 8 years. A more strict application using the 5 years would involve using a different t-value (the 1.895 value). If 5 years data were to be used the appropriate t-value would be 2.13 and the capacity credits would be lowered accordingly.

[21] See Dent, Keane and Bialek, (2010) for a discussion of alternative approaches.

Applying the IMO proposal to a facility level. Potentially the IMO proposal could be applied on an individual facility level. That is:

Capacity credits	= 95% PoE of 8 yearly average ***facility*** output from top 12 TIs by year
	= Mean of the 8 yearly averages – 1.895 x SD of 8 yearly averages

Such an approach appears to provide no benefit over an approach based on the variance of facility output (i.e. the proposed alternative method) as is discussed above. In particular:

- It suffers from an aggregation bias (i.e. sum of individual facilities will not match the formula applied jointly), and
- It does not align with theory on research on the capacity value of intermittent generation.

4 Financial impact and transition options

4.1 Financial impact

The financial impact of different options has been estimated based on reserve capacity price of $186,001 per MW[22] for 2012-13. The total financial impact at a fleet level for the alternative proposal (Griffin, IMO proposals and proposed alternative) is shown in Table 3 below.

[22] See http://www.imowa.com.au/mrcp.

Table 3: Financial impact of options			
Proposal	Capacity credits	Change from current	Change in value $000's
1. Current method (2012/13)	91.13	0	0
2. Griffin proposal	82.2	(9)	(1,659)
3. IMO proposal	36.3	(55)	(10,199)
4. Proposed alternative (with *G* =0.0303). Equivalent to IMO proposal using TIs selected from separate days	63.02	(28)	(5,229)

Note: Analysis is preliminary and not complete. See notes on Table 5.

The total financial impact of the proposed alternative is almost half that of the IMO proposal. Of note, the reserve capacity price has increased significantly in recent years. In 2006-07 the price was $127,500 per MW. If the recommended option was adopted, the total financial value of the capacity credits for IGFs based on 2012-13 prices would be almost identical to the financial value of the capacity credits in 2006-07.

An estimate of the financial impact of the alternative method by type of facility for the IMO proposal and the alternative method scenario is provided in Table 6 on page 31. The change in value varies significantly by IGF and the choice of method has significant implications for the facilities. The alternative recommended method tends to lessen the impact on the small facilities with more stable output.

4.2 Transition options

If transition is considered appropriate, there are alternative transition options available. Two broad options that have been identified are:

1. Use a simple average between the current and future methodology.
2. Modifying the size of the adjustment to the average over time (e.g. modifying the parameter *G* in the alternative above or the PoE level in the IMO proposal).

The two options would provide slightly different results. An argument for the second option is that it provides transitional relief based on the major change in approach (i.e. the use of an adjustment to the average) — it gives no transition due to a shift in measuring output over all TIs to a shift in measuring output just at peak times. This second element of the change was, arguably, more predictable. Furthermore implementation of the second option is simpler as applies only one set of rules. For these reasons this second option is recommended.

Both options could be used to achieve a steady transition. For example, a simple transition path is as follows:

Capacity credits in year *t* up to year T (the transition period)	=	(1-t/T) x starting method	***Plus***	(t/T) x future method

Where under Option 1 the starting method is the current method, under Option 2 the starting method is the proposed alternative method with *G* set to zero.

A question exists as to how quickly a transition might be applied. Ultimately the time period should reflect the rationale for transition and size of transition desirable. It would seem reasonable that the transition period reflect the time period over which a review to the methodology is undertaken. Again a 3 year period seems reasonable. In such case, the increase in the financial impact each year would be around $1 million.

5 Conclusions

Both Griffin and IMO proposals are likely to be an improvement over the status quo. However both can be improved upon. Both proposals suffer from a clustering problem whereby TIs used are selected from a limited number of days. This can be addressed by requiring the TIs are selected from separate days.

A robust and simple method which is a small modification from the proposals and is aligned with theory and international practice is to determine capacity credits for IGFs as follows:

Capacity credits =	*1. Average facility output during peaks*	***Less***	*2. Multiple of variance of facility output during peaks*

There are two reasons for an adjustment to average facility output:

1. To adjust for known variability in facility output.
2. To adjust for unknown performance during peak times.

Analysis of the limited data available suggests that performance of IGFs during the very peak periods may be lower than the average. As a result, this second reason becomes a dominating factor. There is no recognised method for accounting for this uncertainty. It is recommended that an adjustment proportional to historical variance but scaled for historical average output is used.

While there are statistical methods to calculate parameters for the first reason for adjustment, given the lack of data, some judgement is required to account for the second. Based on a review of the range of IGF output during peak periods, the total IGF fleet output that is produced from the IMO proposal modified to select TIs from separate days appears is reasonable. This gives estimated results of total fleet output of 29 percent of nameplate capacity (and 25 percent of wind farms).

On this basis the following formula and initial values are recommended.

Capacity credits =	*1. Average facility output during Top 12 TIs drawn from separate days from a number 5 years*	***Less***	*2. G x variance of facility output during peaks*

Where *G = K + U* reflects both known variability (reflected in *K)* and *uncertainty* of IGF distribution (reflected in U).

K is initially set at *K* = 0.003 per MW^{-1}.

U is initially set at U=0.635/(average facility output during peaks*)*

All averages and variances are determined of facility output (measured in MW) over the same peak TIs.

It is recommended that the application of the formula and *G* value be reviewed in 3 years time. As part of this review, consideration should also be given to:

- using more sophisticated techniques such as regression analysis to forecast IGF output at extremes. As more data is obtained, this would potentially enable a more accurate measure to be developed.
- addressing the correlation between output of IGFs. One potentially simple modification is that the LSG used for existing facilities be based on facilities that already in place. This would ensure that an existing facility is not disadvantaged by a new facility coming on-line.
- altering how TIs are selected for analysis. For example, accuracy may be improved by using a different number of TIs and/or weighting the TIs used.
- whether IGF penetration is significant such that more sophisticated approaches to capacity valuation are appropriate. The methods considered in this report are appropriate for small levels of penetration of intermittent generation. More sophisticated methods should be considered once the average output of the IGF at peak TIs approaches 300 MW.

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Appendices

A. Background information

A.1. The planning criterion

The current design of the WEM derives the required amount of capacity (**Reserve Capacity Target**) from the Planning Criterion. The Planning Criterion (clause 4.5.9) sets a minimum standard for the acceptable level of generating capacity and has 2 parts:

- A "defined event scenario" that sets out the requirement for reserve generating capacity which must be available during system peak as the greater of:

  5.1 8.2 percent of the forecast peak demand (including transmission losses and allowing for Intermittent Loads); and

  5.2 the maximum capacity, measured at 41 degrees Celsius, of the largest generating unit,

  while maintaining Minimum Frequency Keeping Capacity for normal frequency control. The forecast peak demand should be calculated to a probability level that the forecast would not be expected to be exceeded in more than <u>one year out of 10</u>; and

- A requirement that there be sufficient reserve to ensure that expected energy shortfalls are restricted to 0.002 percent of annual energy consumption.

The Reserve Capacity Target is set annually based on the <u>most stringent element</u> of the Planning Criterion.[23]

[23] Note that the Planning Criterion applies to the provision of generation and Demand Side Management capability and does not include transmission reliability planning.

B. Main tables

Table 4: Comparison of variation of yearly average output values when using different trading interval periods

		Coefficient of variation of yearly averages				
		Over 3 years from:		Over 5 years from:		
Facility	Type	Top 250 TIs	Top 750 TIs	Top 12TIs in year	Top 12 TIs on separate days	Top 20 TIs on separate days
WF1	Wind farm	0.35	0.11	0.99	0.39	0.24
WF2	Wind farm	0.28	0.18	0.36	0.19	0.15
WF3	Wind farm	0.27	0.06	0.33	0.13	0.09
WF4	Wind farm	0.22	0.06	0.42	0.25	0.17
LFG1	Land fill gas	1.12	0.51	0.49	0.44	0.44
LFG2	Land fill gas	0.46	0.16	0.48	0.32	0.30
LFG3	Land fill gas	0.41	0.17	0.14	0.17	0.15
LFG4	Land fill gas	0.27	0.13	0.14	0.11	0.11
LFG5	Land fill gas	0.17	0.05	0.06	0.05	0.07
LFG6	Land fill gas	0.16	0.06	0.21	0.18	0.20
LFG7	Land fill gas	0.06	0.01	0.13	0.10	0.09
Fleet		**0.16**	**0.04**	**0.38**	**0.13**	**0.08**

Notes: The coefficient of variation measures the ratio of standard deviation to the average. A higher value represents a higher degree of volatility. Its relationship to the 95% PoE value is shown in as:

95% PoE = Average value x (1 – 1.895 x Coefficient of variation)

Table 5: Comparison of current proposals

Facility Information		Current Method (2012/13)		IMO proposal (RC_2010_25)			Griffin proposal (RC_2010_37)		IMO proposal with TIs selected from separate days	
Name	Nameplate capacity	Capacity Credits	as % of nameplate capacity	Avg. of Top 250 TIs by 3 years	Capacity Credits	as % of nameplate capacity	Avg. of Top 750 TIs by 3 years = Capacity Credits	as % of nameplate capacity	Capacity Credits	as % of nameplate capacity
Wind farms – Sum	192.7	75.5	39%	65.6	29.5	15%	67.1	35%	51.3	27%
- Minimum value			31%			9%		25%		16%
- Maximum value			43%			18%		38%		32%
Land fill gas – Sum	23.5	15.6	67%	15.1	6.8	29%	15.1	64%	11.8	50%
- Minimum value			34%			13%		30%		23%
- Maximum value			85%			40%		88%		70%
Sum of all	216.2	91.1	42%	80.7	36.3	17%	82.2	38%	63.0	29%

Note: IMO proposal is based on 5 years data to 2011.

Table 6: Financial impact of proposals

Generator	Current		IMO Proposal		Proposed alternative Ending value *G* =(0.303)		Value of credits ($000s) based on Reserve Capacity Price 1/10/12 – 1/10/13 =$186,001				Change $(000)s
	Capacity Credits	as % of nameplate	Capacity credit	Change in value $(000)s	Capacity Credits	as % of nameplate	Current Methodology	Transition Year 1	Transition Year 2	Transition Year3	Current to Final
Wind farms - Sum	**75.5**	**39%**	**29.52**	**(8,550)**	**48.9**	**25%**	**14,041**	**11,149**	**10,119**	**9,090**	**(4,951)**
- Minimum value		31%				12%					
- Maximum value		43%				39%					
Land fill gas – Sum	**15.6**	**67%**	**6.8**	**(1,649)**	**14.1**	**60%**	**2,910**	**2,716**	**2,674**	**2,631**	**(278)**
- Minimum value		34%				31%					
- Maximum value		85%				82%					
Sum of individuals	**91.1**	**42%**	**36.30**	**(10,199)**	**63.0**	**29%**	**16,951**	**13,865**	**12,793**	**11,722**	**(5,229)**

Note: Values based on 2012-2013 reserve capacity price of $186,001.04 per MW per year

C. The clustering issue

The primary reliability criterion of interest is concerned with meeting the required load at the peak. Because in any one year there is only one peak, an average of top TIs is selected so as to attempt to reduce the volatility of results.

The IMO proposal selects the top 12 TIs based on LSG regardless of when they occur.

As is shown in the table and summarised in Table 7 below, the date and time of the top TIs is 'clustered' — in most years the top 12 TIs came from only two trading days. As is also shown in the table there is a high degree of clustering in the top 50 TIs as well.

Table 7: Date and time of top trading intervals by LSG

	Top 12 intervals		Top 50 intervals	
	Days used	Time range	Days used	Time range
2005-06	2	1430 - 1700	7	1100 - 1800
2006-07	2	1430 - 1700	5	1130 - 1900
2007-08	3	1430 - 1630	9	1200 - 1800
2008-09	2	1200 - 1630	6	930 - 1800
2009-10	2	1330 - 1700	5	1130 - 2000
2010-11	3	1200 - 1630	5	1100 - 1730

Clustering has two unwanted effects.

1. It means that the benefits of using a broader range of TIs are not being achieved. It is similar to conduct a phone survey and repeatedly calling the same household.
2. It results in TIs being used that are unlikely ever to be the peaks.

The second point is demonstrated in the Figure 5 below, which shows the times in the day when the top TIs occur over the years 2006 to 2011. The blue bars show the frequency of when the peak LSG occurs during each day based on the top 12 days with the highest peaks. As highlighted in the figure, the most likely period for the peak is in 15:30 TI. Over 60% of the peaks occurred between 15:30 and 17:00. The red, orange and green bars show when the top 12, top 50 and top 750 TIs occurred. Due to the clustering on specific days, many of these intervals are outside the period when the peak is most likely to occur. For example, in the top 12 days from each of the years in the 2006 to 2011 period, none of peaks occurred at 5pm.

The use of the top 12 (or top 750 etc) TIs (without the requirement of separate days) induces a bias in the results because, as shown in the figure, intermittent generation is also strongly correlated with the time of day. The purple line shows the average intermittent generation (based on top 750 TIs). The chart highlights that the bias increases through use of top 50 TIs (and would be even worse if the top 750 TIs were used).

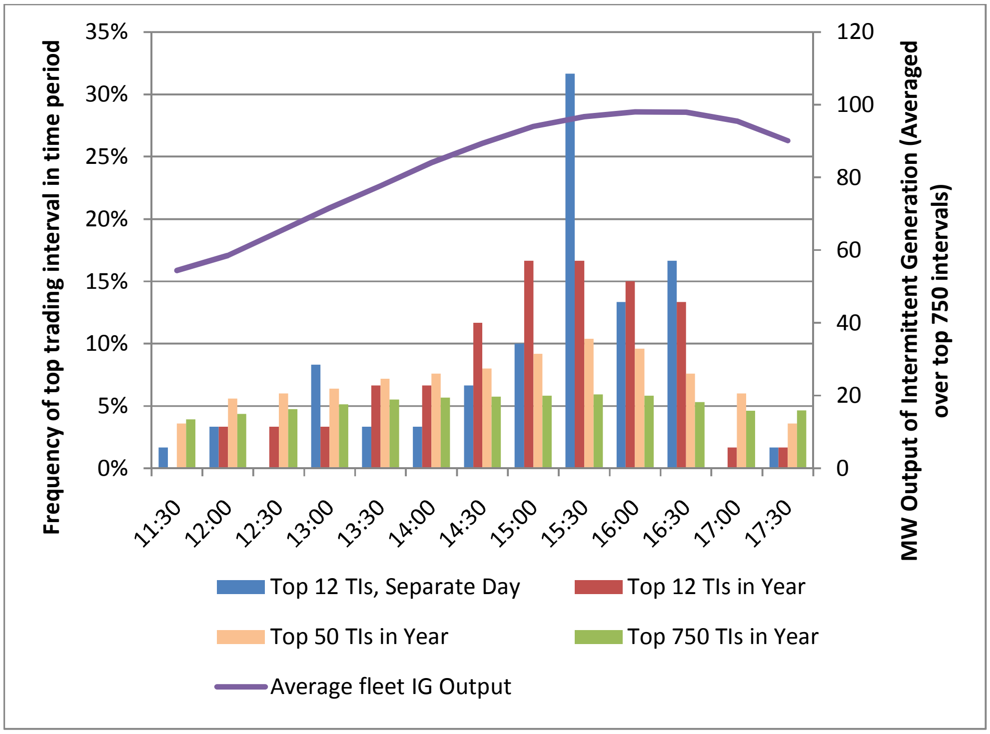

Figure 5: Timing of top trading intervals

This clustering problem can be solved by selecting the top TIs on separate days.

There is potentially some benefit in giving greater weight to the days with the very highest peaks. The IMO proposal and the Griffin proposal, in effect, simulate a weighting to some degree — however there are simpler and more accurate methods of applying a weighting. A weighting would be appropriate if intermittent generation was correlated in some way with the very high peak days.

A weighting might be applied in a number of ways. For the purposes of preparing this report, an approach was trialled by putting weights equivalent to the square of LSG. The use of the weighting did not appear to make a material difference to results, but more investigation would be required.