Department of Energy & Climate Change

Annex C: Reliability Standard Methodology

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Contents

Introduction

1. One of the key objectives of Electricity Market Reform is to ensure future security of electricity supply. The Capacity Market will protect consumers against the risk of supply shortages by giving investors the certainty they need to put adequate reliable capacity in place. The decision on how much capacity is needed to ensure security of supply will be informed by an enduring reliability standard.

2. Chapter 3 of the draft EMR Delivery Plan explains why a reliability standard is needed, how it will be used and the proposed standard to be used in the Great Britain (GB) market. In this section we provide more technical detail on why the standard is expressed in terms of loss of load expectation, and more detail on how the reliability standard is derived.

Why is the reliability standard expressed in terms of Loss of Load Expectation?

3. There are a number of metrics which could be used to set a reliability standard. Each of these metrics is a way of measuring security of supply. The most common of these include:

   i. *De-rated Capacity margin*

      The de-rated capacity margin measures the amount of excess supply above peak demand. De-rating means that the supply is adjusted to take account of the availability of plant, specific to each type of generation technology. It reflects the proportion of an electricity source which is likely to be technically available to generate at times of peak demand. For example, in Ofgem's Electricity Capacity Assessment, a combined cycle gas plant is assumed to be available 85% of the time.

   ii. *Loss of Load Expectation (LOLE)*

      LOLE represents the number of hours per annum in which, over the long-term, it is statistically expected that supply will not meet demand. This is a probabilistic approach – that is, the actual amount will vary depending on the circumstances in a particular year, for example how cold the winter is; whether or not an unusually large number of power plants fail to work on a given occasion; the power output from wind generation at peak demand; and, all the other factors which affect the balance of electricity supply and demand. However, it is important to note when interpreting this metric that a certain level of loss of load is not equivalent to the same amount of blackouts; in most cases, loss of load would be managed without significant impacts on consumers.

iii. Expected Energy Unserved (EEU)

This is the amount of electricity demand - measured in MWh – that is expected not to be met by generation in a given year. This combines both the likelihood and the potential size of any shortfall. Just as in the case of LOLE, the EEU figure should not be taken to mean there will be that particular amount of blackouts, because we expect that in the vast majority of cases, this would be managed without significant impacts on consumers.

4. We have proposed in this consultation document that we should express the GB reliability standard in terms of the LOLE. This involves setting a standard which sets out the average number of hours per year in which demand is not expected to be met by supply in a typical year.

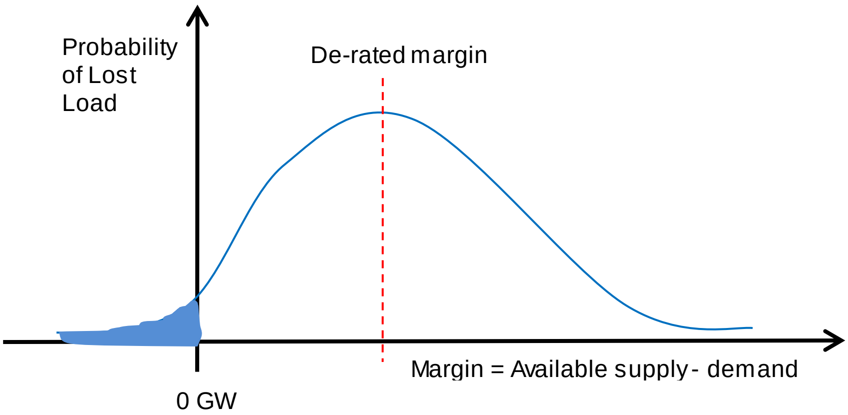
5. We propose not basing the reliability standard on a de-rated capacity margin. There are a number of arguments in favour of using LOLE over de-rated capacity margin.

   - LOLE forms the basis of the reliability standard in all of our interconnected neighbours. For example, The Republic of Ireland targets an LOLE of 8 hours per year; France targets the same standard of 3 hours per year, and the Netherlands 4 hours per year.

   - LOLE represents the metric used in many countries which use a reliability standard for the purposes of administering a Capacity Market. For example Ireland uses a reliability standard expressed in terms of LOLE to determine the level of its capacity payments. In addition, the PJM market and ISO-NE markets in the USA also use this metric. This comparability also provides the basis for choosing LOLE over EEU and other risk based metrics which could also be suitable.

   - The de-rated capacity margin is a measure of the average or mean; it does not give an indication of the variation around this average value (this is illustrated in figure 1). The de-rated margin was an appropriate indicator at times where intermittent generation was not significant and the proportion of each type of generation in the fleet was roughly constant year on year. However, the increasing penetration of wind power is likely to make this issue more significant in the future. This is because we expect the variability of the de-rated capacity margin around the mean to increase. We therefore do not expect the de-rated capacity margin to remain a good metric of security of supply.

Figure 1: Illustrative example of the relationship between the de-rated capacity margin and the probability of lost load occurring.



Deriving the reliability standard

6. This section details the analysis behind the reliability standard proposed for the GB electricity market.

7. In setting the Standard we have taken an analytical approach, which takes into account consumers' Value of Lost Load (VoLL) and the cost of new plant. The Value of Lost Load represents the value that customers place on security of supply, or alternatively the cost to customers of being disconnected. The optimal level of security of supply trades the cost of providing additional capacity against the associated benefit of a reduced chance of blackouts.

8. This method has the advantage of choosing a level of capacity that is explicitly linked to the value that consumers place on electricity (VoLL). The use of VoLL also allows for an approach consistent with the use of this metric for other proposed Capacity Market arrangements, such as the suggested penalty regime for non-delivery in the Capacity Market[1] and Ofgem's proposals for reforming Cash Out.[2]

Outline of Concept

9. The analytical basis underpinning the reliability standard for the GB electricity market is represented in Figure 2.

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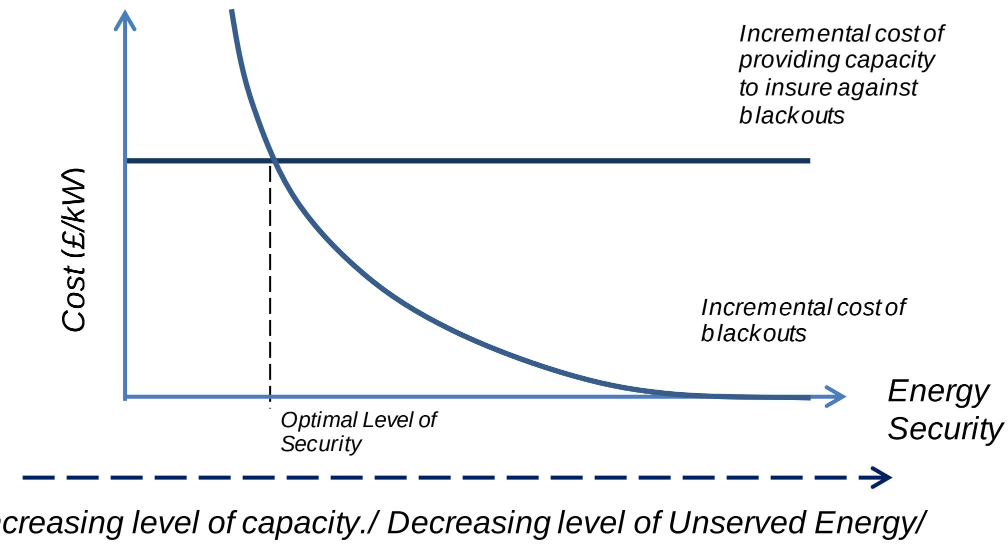
[1] Capacity Market detailed design proposal, page 33.

[2] http://www.ofgem.gov.uk/MARKETS/WHLMKTS/COMPANDEFF/ELECTRICITY-BALANCING-SCR/Pages/index.aspx

Figure 2: Illustrative optimal level of security of supply



10. The optimal level of security of supply is found by finding the point at which the incremental cost of insuring customers against blackouts is equal to the incremental cost to customers of blackouts.

Incremental Cost of Blackouts to consumers

11. The downward sloping curve in Figure 2 represents the incremental cost of blackouts to consumers as capacity is increased. It describes the link between the level of capacity and the associated cost of blackouts.

12. Intuitively it is clear that as the level of capacity on the system declines, the amount of unserved energy rises. We price any unserved energy at the cost to customers of being disconnected. This curve gets shallower as security of supply is increased.

> Box 1: Study on the value of lost load.
>
> London Economics has carried out a survey of domestic and business customers' value of lost load (VoLL) at different times of the day and year. This has been used to establish a single average VoLL for use in the Reliability Standard.
>
> The final VoLL figure is a weighted average of VoLLs for domestic customers and SMEs at times of winter peak demand. However it has excluded the value of lost load of large commercial and industrial consumers because they are assumed either to be able to participate in the capacity market through demand side response, or else to be able to change their electricity use in response to price signals.

Incremental cost of insuring consumers against blackouts

13. The incremental cost of insuring consumers against blackouts (shown in figure 1) is the cost of procuring additional capacity.

> Box 2: The Cost of New Entry
>
> The Gross Cost of New Entry (CONE) represents the cheapest cost of a new entrant peaking plant. Gross CONE is the rental rate of the marginal peaking plant; that is the yearly amount of revenue needed to pay for capacity such that the discounted value (NPV) of its operations is zero over its technical operating lifetime, assuming the plant does not earn energy market revenue. Currently the cheapest new plant on this basis is a large scale Open Cycle Gas Turbine (OCGT).
>
> Parsons Brinckerhoff (PB) have set out the assumptions that feed into the calculation of CONE, and this is also represented in the DECC Levelised Cost report published alongside this document. They cover all cost assumptions, including the annual and short run marginal costs of running the plant as well as construction.
>
> In addition, PB has also provided the inputs on timings – pre-development, construction and operational lifetime.
>
> For the reliability standard we take the central estimates from all these sources. These include an OCGT lifetime assumption of 25 years.

Calculation

14. In Box 3 of Chapter 3 of the draft EMR Delivery Plan, We explained that the reliability standard is computed from two parameters: the cost of new entry and the value of lost load. This result can be derived mathematically and is shown in the appendix to this section.

$$\frac{cost\ of\ new\ entry}{value\ of\ lost\ load}$$

15. Using this result (i.e. that the reliability standard is the ratio of the cost of new plant entry to the value of lost load), we present a range of values for the reliability standard in the table below.

Equilibrium Reliability Standard in LOLE (hrs/yr)		***Cost of New Entry (£/kW)***		
		LOW **£31.89**	**CENTRAL** **£47.18**	**HIGH** **£66.21**
VoLL (£/MWh)	**35,490**	0.90	1.33	1.87
	16,940	1.88	**2.78**	3.91
	10,290	3.10	4.59	6.43

16. Depending on which level of VoLL and CONE is chosen, the optimal level of security of electricity supply could lie between 1 and 6 hours of LOLE each year.

17. We have chosen a reliability standard of 3 hours of Loss of Load Expectation per year. To five significant figures, we estimate the cost of new entrant capacity to be £47,177/MWh and the value of lost load to be £16,940 and therefore the Reliability Standard would be around 2 hours, 47 minutes and 6 seconds. However, given the level of uncertainty in estimating the associated parameters, it would not be appropriate to express a reliability standard to such a degree of accuracy which is why we have chosen to express it to 1 significant figure as is common elsewhere.

VoLL The low estimate reflects an average VoLL at winter peak for just domestic customers; the high estimate reflects an average value for SMEs, and; the central estimate is an average of the two, weighted by the proportion of electricity generation SMEs and domestic consumers respectively use.[3]

CONE The Low value of CONE takes low cost assumptions; a low hurdle rate (6%), and as long technical lifetime (35 years); The Central value of CONE takes central cost assumptions; a central hurdle rate (7.5%) and a central technical lifetime (25years) The high value of CONE takes high cost assumptions; a high hurdle rate (9%) and a low technical lifetime (20 years). Further information on the low, central and high estimates of CONE is provided below.

[3] London Economics 'The Value of Lost Load (VoLL) for Electricity in Great Britain' (2013)

			Low	Central	High	*Source*
1.	**Timings (Years)**					*PB Power*
	Pre-development Period		1.5	1.8	4.5	*2013*
	Construction		1.5	1.75	2	
	Plant Operating Period		35	25	20	
2.	**Capacity (MW)**					*PB Power*
	Power output		608	565	561	*2013*
	de-rated at 92%		559	520	516	
3.	**Pre-development Costs**					*PB Power*
	Pre-licensing costs, Technical and design	£/kW	16.3	18.9	24.6	*2013*
	Regulatory + licensing + public enquiry	£/kW	2.0	2.4	3.1	
4.	**Construction Costs**					*PB Power*
	Capital cost	£/kW	218	274	330	*2013*
	Infrastructure cost	£	7,000	9,050.0	11,100	
5.	**Operation and Maintenance**					*PB Power*
	Fixed Cost	£/MW/yr	8,112	9,879	11,647	*2013*
	Insurance	£/MW/yr	414	959	1,667	
	Connection and UoS charges	£/MW/yr	3,440	3,440	3,440	
6.	**Hurdle Rates**					*Oxera*
	Oxera 2013[4]		6.0%	7.5%	9.0%	*2011*
7.	**CONE**					*DECC*
	Gross CONE	£/kW	31.89	47.18	66.21	*2013*

[4] Oxera, Discount Rates for low-carbon and renewable generation technologies, 2011

Appendix to Annex C

The Reliability Standard as an Economic Problem

18. The optimal Reliability Standard is the solution to an economic optimisation problem. This problem is to maximise net benefit to consumers of having reliable electricity with respect to the level of system capacity. The solution is neatly comprised of two parameters: the value of lost load (VOLL) and the cost of new entry (CONE).

19. Using notation, the net benefit to consumers (*NB*) of receiving electricity can be expressed as follows:

$$NB(k) = REB - BC(k) - EC(k) \qquad (1)$$

20. In equation (1), *k* represents total system capacity; *REB* the reliable electricity benefit to consumers; *BC* the cost of blackouts to consumers, and; *EC* the cost of electricity. *REB* is assumed constant and so independent of the level of system capacity. The optimally condition, through differentiating (1) with respect to *k* and setting equal to zero, gives:

$$\frac{dEC}{dk} = -\frac{dBC}{dk} \qquad (2)$$

Where,

$\frac{dEC}{dk}$ = the incremental total cost of electricity as capacity is increased (3)
= incremental cost of capacity + maintenance (fuel cost negligible)

$\frac{dBC}{dk}$ = the incremental cost of blackouts (4)
(Declines exponentially as blackouts become less frequent)

21. Equations (3) and (4) form the two curves in the graphical representation of the problem; where the vertical axis shows a change in the cost per kW of Capacity, and the horizontal axis shows the level of capacity

22. We refer to equation (4) as the cost of new entry into the market, or 'CONE'

23. Now, the total cost of blackouts to consumers (BC) is given by:

$$BC(k) = EEU(k) * VoLL \qquad (5)$$

24. Where *EEU* is the expected level of unserved energy in the system and *VoLL* is the Value of Lost Load to consumers. Using this, then the incremental cost of blackouts becomes:

$$\frac{dBC}{dk} = \frac{dEEU}{dk} * VoLL \qquad (6)$$

25. We see that the incremental consumer cost is given by the change in the expected cost of energy unserved for each incremental change in capacity for a defined level of VoLL. This incremental change in EEU is number of hours of lost load, i.e

$$-\frac{dEEU}{dk} = LOLE \qquad (7)$$

26. Substituting equations (6) and (7) into our optimality condition (2) we get:

$$CONE \overset{(4)}{=} \frac{dEC}{dk} \overset{(2)}{=} -\frac{dBC}{dk} \overset{(6)}{=} -\frac{dEEU}{dk} * VoLL \overset{(7)}{=} LOLE * VoLL \qquad (8)$$

$$CONE = LOLE * VoLL \qquad (9)$$

27. Equation (9) describes the relationship at the optimum between the expected number of hours of lost load, the cost of new entry and the value consumers place on avoiding lost load.

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