Department of Energy & Climate Change

# Annex C:Reliability Standard Methodology

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# Annex C

## Reliability Standard Methodology

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 5 of this document explains why a reliability standard is needed, how it will be used and the proposed standard to be used in the GB market. In this section we provide more technical details on why the standard is expressed in terms of loss of load expectation, and more detail on how the reliability standard is derived.

### 1.1 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 of supply above peak demand. De-rating means that the supply is adjusted to take account of the availability of plant, which is 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.

   ii. *Loss of Load Expectation (LOLE)*

      LOLE represents the number of hours/periods 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 the vast majority of cases, loss of load would be managed without significant impacts on consumers[1].

iii. *Expected Energy Unserved (EEU)*

This is the amount of electricity demand - measured as volume of electricity 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 unmet demand.

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 number of hours per year in which demand is not expected to be met by supply.

5. We propose not to choose a de-rated capacity margin approach. There are a number of arguments in favour of using LOLE over a de-rated capacity margin.

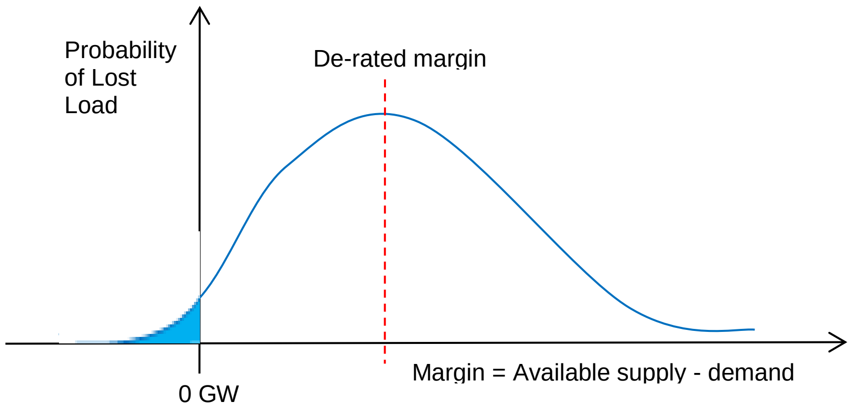
- LOLE forms the basis of the Reliability Standard in all of our interconnected neighbours. For example, Ireland targets a LOLE of 8 hours per year; France targets 3 hours per year, and; The Netherlands 4 hours per year;

- LOLE represents the metric used in many countries which use a Reliability Standard for the purposes of administering a capacity mechanism. 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 mean; it is not a good metric for security supply because it does not give an indication of the variation around this average value (this is illustrated in figure 1). The de-rated margin was a good 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 makes it likely to make this issue more significant in the future. This is because we expect the variability of the capacity margin around the mean to increase.

[1] The system operator (National Grid) can call upon a range of tools to mitigate the effects of unmet demand including reducing the voltage of electricity on the system; calling upon generators to increase to their maximum possible output, and; drawing upon emergency services via interconnectors. Only in exceptional circumstances, once all these measures had been called upon, would consumer disconnections need to be considered.

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




## 1.2 Deriving the reliability standard

6. This section details the analysis behind the Reliability Standard for the GB electricity market.

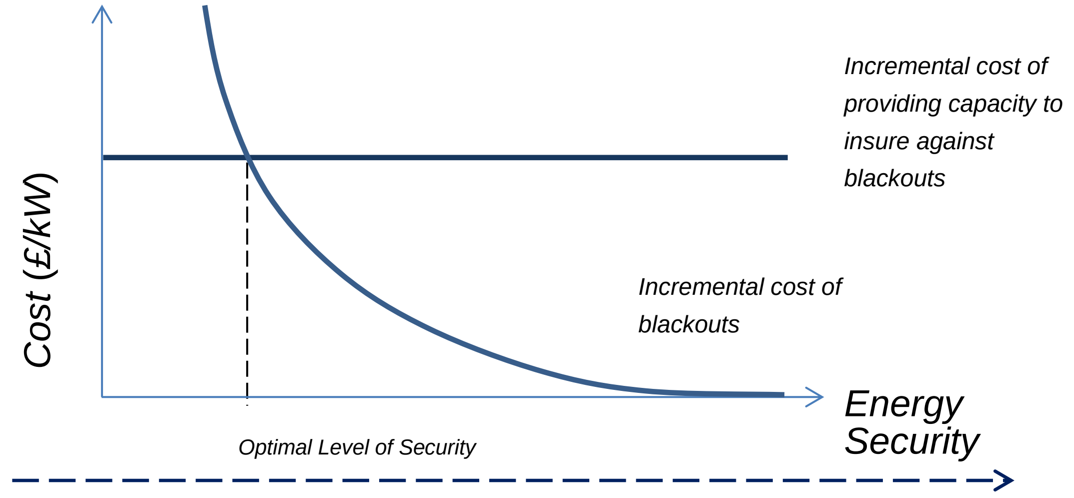
7. In setting the Standard we have taken an analytical approach, which takes into account consumers' Value of Lost Load (VoLL) and the cost of new peaking plant. The Value of Lost Load represents the value that customers place on security of supply, or alternatively the cost to customers of being disconnected.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

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). This should drive a more efficient outcome.

*Outline of Concept*

9. The analytical basis underpinning the Reliability Standard for the UK electricity market is represented in figure 1.

*Figure 2: Optimal level of security of supply*




*Increasing level of capacity. / Decreasing Loss of Load Expectation*

The optimal level of security of supply is determined by 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*

10. The downward sloping curve in figure 1 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.

11. Intuitively it is clear that the level of capacity on the system declines as 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 study used a stated preference choice experiment to estimate the VoLL in terms of willingness-to-accept (WTA) payment for an outage and willingness-to-pay (WTP) to avoid an outage of different lengths, seasons, days of the week and times of the day for domestic and SME electricity users.

The empirical WTA estimates produced by the study are larger than comparable WTP estimates. This is a common result in studies of this kind and can be explained by the fact that individuals feel a sense of ownership for something they already have (in this case a reliable electricity service). If we were to use WTP values this would bias downward the VoLL and as a result London Economics suggest that WTA estimates are more appropriate than WTP for use in the context.

It is often difficult to determine precisely who has been disconnected and for how long during power emergencies. Thus the VoLL, while in theory a marginal concept, is in practice a weighted-average approximation of the marginal impact of a disconnection on a group of customers at the most likely time that a disconnection would occur. Therefore, London Economics, Ofgem and DECC analysts concluded that we should calculate a headline VoLL figure using the willingness to accept (WTA) results, as a load-share weighted average across domestic and SME users for the winter peak weekday figure.

The value of lost load of large commercial and industrial consumers has not been taken into account 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.

More information on the VoLL study can be found in the London Economics Report[2] .

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf

**Box 2: Consumer's VoLL and Ofgem's estimate of the cost for disconnections and voltage reduction in cash-out**

Several respondents to the consultation pointed out there was an inconsistency between the VoLL presented in DECC's consultation document, and the disconnections and voltage reduction control cost of £6,000 which Ofgem[3] have proposed using as part of cash out reform.

To set the price for disconnections and voltage control, Ofgem took into account the VoLL estimate of £17,000 from London Economics, but this was not their only consideration. There were other considerations which led Ofgem to set this to £6,000/MWh such as international comparisons as well as the risk for market participants of having a very high price for disconnections.

However, another crucial consideration was that DECC is introducing a Capacity Market which means that the cash out price does not need to fully reflect customers marginal VoLL in order to provide security of supply.

The introduction of a GB Capacity Market, with associated capacity payments presents an alternative route for capacity providers to collect sufficient revenues above their short-run marginal costs to cover their fixed costs. With a well-functioning Capacity Market, the main benefit of including VoLL in cash-out arrangements would be to provide a performance incentive for market participants and rewards for flexible plant. Therefore, if the real-time price signal is mainly used as a performance/ flexibility incentive (rather than as an investment incentive), there is a strong argument to suggest that prices do not need to rise to the full VoLL level. This reduces performance risk considerably whilst achieving results similar to the higher VoLL figure.

*Incremental cost of insuring consumers against blackouts*

12. The incremental cost of insuring consumers against blackouts (shown in figure 1) is the cost of procuring additional capacity. This cost is given by the rental cost of adding peaking plant to the system.

**Box 3: The Cost of New Entry and the Long Term Marginal Cost of Peaking Capacity.**

The Gross Cost of New Entry (CONE) represents the cheapest cost of a new entrant peaking plant in a Capacity Market auction. Gross CONE ought to be 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. In the long run, we expect the

[3] https://www.ofgem.gov.uk/ofgem-publications/82294/ebscrdraftdecision.pdf

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[4]. 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. Assumptions on hurdle rates are based on a recent report from Oxera[5]. There is a question over whether the PB estimate is used to inform the CONE that is used for the very first Capacity Market auction and there is a separate consultation which considers this issue.

For the Reliability Standard we take the central estimates from all these sources. These include an OCGT lifetime assumption of 25 years for the plant and a hurdle rate of 7.5%.

*Calculation*

13. In the main section of the Delivery Plan (box 3) we explained that the reliability standard is computed from two parameters: the long term marginal cost of peaking capacity (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.

$$\frac{CONE}{VoLL}$$

14. 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.

[4] https://www.gov.uk/government/publications/decc-electricity-generation-costs-2013

[5] http://www.oxera.com/Oxera/media/Oxera/downloads/reports/Oxera-report-on-low-carbon-discount-rates.pdf?ext=.pdf

Table 1:

| *Equilibrium Reliability Standard in LOLE (hrs/yr)* | | ***Long term CONE (£/kW)*** | | |
|---|---|---|---|---|
| | | **LOW** | **CENTRAL** | **HIGH** |
| **VoLL (£/MWh)** | **35,490** | 0.90 | 1.33 | 1.87 |
| | **16,950** | 1.88 | **2.78** | 3.91 |
| | **10,290** | 3.10 | 4.59 | 6.43 |

15. 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.

**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 a weighted average of the two by the proportion of electricity generation SMEs and domestic consumers respectively use.[6]

**CONE** The Low value of CONE takes low cost assumptions; a low hurdle rate (6%), and a long technical lifetime (35years);
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)

6 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224028/value_lost_load_electricty_gb.pdf

| | | | 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 | 218.1 | 274 | 330 | *2013* |
| | Infrastructure cost | £ | 7,000.0 | 9,050.0 | 11,100.0 | |
| **5.** | **Operation and Maintenance** | | | | | *PB Power* |
| | Fixed Cost | £/MW/yr | 8,111.6 | 9,879.2 | 11,646.9 | *2013* |
| | Insurance | £/MW/yr | 413.6 | 959.1 | 1,667.5 | |
| | Connection and UoS charges | £/MW/yr | 3,440.4 | 3,440.4 | 3,440.4 | |
| **6.** | **Hurdle Rates** | | | | | *Oxera* |
| | Oxera 2013 | | 6.0% | 7.5% | 9.0% | *2011* |
| **7.** | **CONE** | | | | | *DECC* |
| | Gross CONE | £/kW | 31.89 | 47.18 | 66.21 | *2013* |

| | | | | | | |
|---|---|---|---|---|---|---|
| **8.** | **VOLL** | | | | | *London Economics* |
| | VOLL | £/MWh | 10,290 | 16,950 | 35,490 | *2013* |
| **9.** | **Reliability Standard** | | | | | *DECC* |
| | Reliability Standard | Hours of LOLE | 0.9 | 2.8 | 6.4 | *2013* |

# Appendix

## The Reliability Standard as an Economic Problem

16. 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).

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

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

18. 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 increase *(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)

19. 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

20. We refer to equation (4) as the cost of new entry into the market, or ‘CONE’

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

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

22. 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:

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

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

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

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

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

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

25. 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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