The Value of Lost Load, the Market Price Cap and the Market Price Floor

A Consultation Paper

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1 Introduction

There are various actions that the Trading and Settlement Code ("the Code") requires the Regulatory Authorities to undertake. These actions include determining various administered prices, namely:

- the value of lost load (VOLL);
- the market price cap (PCAP); and
- the market price floor (PFLOOR)

This paper discusses the various factors that might affect the Regulatory Authorities' decision on these various prices and makes proposals.

The Regulatory Authorities welcome the views of interested parties on these proposals. It is intended to publish all responses received. If any respondent wishes all or part of their submission to remain confidential, then this should be clearly stated in their response.

Comments on this paper should be sent to James Curtin and Tony Doherty, preferably electronically, to arrive no later than noon on Friday 27th July 2007.

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2 Background

There are various actions that the Trading and Settlement Code ("the Code") requires the Regulatory Authorities to undertake.[1] These include determining three administered prices, namely:

- the value of lost load (VOLL);
- the market price cap (PCAP); and
- the market price floor (PFLOOR)

This consultation paper discusses the various factors that might affect the Regulatory Authorities' decision and makes proposals. Each is discussed in turn below.

3 The Value of Lost Load

3.1 Role in the SEM

The Value of Lost Load (VOLL) is defined in the Code as the value (in €/MWh) which "represents the end-customer's willingness to lose supply" and as the value that "consumers would place on a unit of non-delivered electricity."[2] VOLL is used in the Code only in the determination of Capacity Payments. The determination of Capacity Payments is set out in Section 4 of the Code (in pages 88 through 98 of Version 2.0). The relevant sections are summarised in Annex A below.

VOLL affects two scaling factors: the Capacity Payments Price Factor and the Capacity Payments Generation Price Factor. These two factors are used to scale capacity payments for demand and scheduled generation based on the level of the System Marginal Price and VOLL. Broadly speaking, the capacity payment paid to a generator unit that is scheduled to run in a trading period is scaled down by the difference between VOLL and SMP, on the grounds that the smaller the difference between VOLL and SMP the more would the generator unit be recovering its fixed costs through the energy price (i.e., SMP) with a concomitant reduced need to recover those costs through capacity payments. Similarly, for a generator that is available but not scheduled to run, the capacity payment is scaled down by the difference between the generator's offer price and VOLL.

3.2 Estimating VOLL

Because most customers do not respond directly to real-time prices, there is almost no market information on the value customers put on a unit of non-delivered electricity. This means that the value of reliability has to be derived by indirect methods.

There are broadly two methods used to derive an estimate of VOLL:

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1 Version 2.0 of the Trading and Settlement Code was published on 31st May 2007. It can be found on the AIP website (http://www.allislandproject.org). The reference number is AIP/SEM/07/224.

2 See the respective definitions on pages G-47 and G-74 in the Glossary to the Code.

- by surveying customers directly on what value they would put on their electricity supply not being interrupted; and

- by using the pre-existing generation security standard and the fixed and variable costs of a new peaking plant to put an implicit value on lost load.

These two methods are discussed briefly in turn below.

3.2.1 Surveys

VOLL is defined in the Code as the "estimate for the value that consumers would place on a unit of non-delivered electricity." This suggests that Irish electricity consumers should be surveyed directly to find out what value they put on the reliability and continuity of their electricity supply. But using surveys to find out what consumers are willing to pay to avoid their electricity supply being interrupted poses several problems:

- because security of supply has some 'public good' characteristics, consumers have an incentive to under-report their true willingness to pay, hoping to 'free-ride' on any security enhancements provided;

- different consumers will have different levels of willingness to pay; and

- the same consumer will put a different valuation on his or her willingness to pay, depending on the timing of any interruption, its duration, the number of interruptions over a given period, whether there was any advance warning of an interruption and the weather conditions at the time of the outage.

Annex B briefly summarises the results of a sample of surveys of customers in Finland, England and Wales and Australia over recent years. The evidence presented there suggests that the range of estimates of the value a customer would put on not being interrupted is very wide, from a low of around €250/MWh (from a 1996 survey in England) to a high of as much as €50,000/MWh (from a 2002 in Australia), all in today's prices and at today's exchange rates.

3.2.2 Implicit valuation using the generation security standard

As the discussion in the previous section suggests, evidence from customer surveys shows that there is a large variation in the values of willingness to pay to avoid an interruption to supply. Moreover, it may not be valid to use estimates of VOLL derived from other countries and at very different times for the value of VOLL in the SEM. This suggests that an alternative method to estimating VOLL is required to derive a single applicable value of VOLL.

According to Hunt, in a centrally planned system the most efficient number of hours of interruption to allow is a function of VOLL and the fixed and variable costs of a peaking plant.[3] A straightforward cost analysis shows that load would be efficiently unserved in hours when the cost of meeting that load would exceed VOLL. In algebraic terms interruptions would be efficient so long as:

[3] Hunt, Sally: *Making Competition Work in Electricity*, Wiley-Finance, 2002.

$$VOLL \times D^* \leq FC_{peaker} + (VC_{peaker} \times D^*)$$

So that:

$$VOLL \leq (FC_{peaker} / D^*) + VC_{peaker}$$

where D^* is the optimal annual average duration (in hours) of interruptions to supply, FC_{peaker} and VC_{peaker} are the fixed and variable costs of a peaking plant respectively and *VOLL* is the value of lost load.

The capacity payments mechanism in the SEM uses estimates of the optimal number of hours of interruption (i.e., the pre-existing generation security standard) and the fixed and variable costs of a best new entrant (BNE) peaking plant to calculate the annual capacity payment sum ($ACPS_y$). A value of VOLL can therefore be derived using these estimates and the equations above. Table 1 below sets out the calculations. The estimates of the variable operating costs of the BNE peaker were taken from the PLEXOS runs used to compute the infra-marginal rents used in the calculation of $ACPS_y$ for 2007 and 2008. The other variable values were taken from the $ACPS_y$ calculations themselves.[4]

Table 1: VOLL Estimates

Time Period	FC_{peaker} **€/MW/year**	VC_{peaker} **€/MWh**	***Security Standard (D*)*** **Hours**	***VOLL*** **€/MWh**
November/December 2007	64 730	148	8	8 239
2008 Q1, Q2 & Q3	79 160	161	8	10 056
Weighted average				9 725

This calculation suggests a value of VOLL of about €10,000/MWh for the first eleven months of the SEM (i.e., for the period from 1 November 2007 to end-September 2008). This is within the range of estimates derived from customer surveys in other countries, as described in Annex B below, but above the old English and Welsh Pool value (€5,000/MWh in today's money) and the current value of VOLL in the National Electricity Market in Australia (€6,000/MWh a today's exchange rate).

3.3 Conclusion

The Regulatory Authorities recognise that:

- the definition of VOLL in the Trading and Settlement Code (the value an end-customer would willingly pay to avoid having his or her supply interrupted) should theoretically be measured using customer surveys; and
- that a value for VOLL derived from the fixed and variable costs of a peaking plant and the generation security standard is not strictly an estimate of the value of energy

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[4] See Annual Capacity Payment Sum, Final Value for 2007, published on 18th May 2007 and Annual Capacity Payment Sum, Indicative Value for 2008, published on 1st June 2007. Both are available at http://www.allislandproject.org/en/capacity-payments-consultation.aspx

at the margin to customers, but an estimate of the cost required to reduce load shedding to eight hours a year.

While the RAs are aware both of the difficulty of defining the concept of value of lost load and of estimating its value, they are of the opinion that deriving the implicit value for VOLL from the costs of the BNE peaking plant and the generation security standard is an adequate methodology to use in the circumstances. The Regulatory Authorities therefore propose to:

- set a value for VOLL of €10,000/MWh for the eleven months beginning 1st November 2007, based on the fixed and variable costs of the BNE peaker and the generation security standard of 8 hours used in the calculation of the capacity payment sums for 2007 and 2008.
- use the relevant constituent elements of the capacity payment sum calculations each year to derive the implicit value for VOLL for that year.

4 The Market Price Cap (PCAP)

4.1 The role of PCAP in the Code

The role of the Market Price Cap in the determination of prices in the SEM is dealt with in Section 4 of the Code. Broadly speaking under the Code:

- generators cannot submit price offers that exceed the Market Price Cap – see Section 4.11;
- for any trading period when an Insufficient Capacity Event has occurred within a run of the Market Scheduling and Pricing (MSP) Software, then SMP for that trading period is set equal to the Market Price Cap – see Section 4.79; and [5]
- in the event that SMP is calculated to exceed the Market Price Cap, SMP in the Trading Period will be set to equal the Market Price Cap – see Section 4.81.

4.2 Justification for a price cap

Price caps in wholesale electricity markets are usually justified on the grounds that:

- there is a risk that the market does not clear as a result of insufficient generating capacity (i.e., load has to be shed) and the price is effectively pushed to infinity; or
- the price in any half hour rises above the value of lost load and it would be more efficient to shed load than to allow prices to be determined at a level higher than customers' willingness to pay; and/or

[5] Section 4.73 of the Code defines an Insufficient Capacity Event as one which occurs for a Trading Period within a run of the MSP Software for a Trading Period where the MSP Software identifies that the Schedule Demand in that Trading Period cannot be met in full by Price Maker Generator Units.

- where there is market power, in the sense of "the ability of a market participant, acting independently, to raise market prices consistently and profitably above competitive levels for a sustained period of time."[6]

4.3 International evidence

No consistent pattern emerges from a sample survey of price limits or caps in other jurisdictions. A number of countries – such as the BETTA market in Great Britain - have no price caps or floors at all, relying instead on competition to keep prices in check and welcoming prices spikes in energy-only markets to remunerate capacity and provide the right entry and exit signals.

Markets that do have caps include:

Australia

The National Electricity Market (NEM) in Australia is an energy-only market. Prices are capped at VOLL, which is currently set at AU$10,000/MWh (equivalent to about €6,000/MWh at today's exchange rate).

However, the risk of excess returns to generators is seen as a potential problem in the Australian market. A Cumulative Price Threshold (CPT) was therefore introduced alongside the VOLL price cap. The CPT is a mechanism to cap the potential financial risk in the NEM. If the cumulative price over the 336 trading intervals in a rolling 7-day period exceeds a threshold, the maximum spot price is reduced from VOLL to an Administered Cap, set by the Australian Energy Market Commission (AEMC). The maximum price remains at the Administered Cap until the conditions that caused the trading period prices to rise have passed. The current CPT is set at AU$150,000 and the Administered Cap is AU$100/MWh in peak times and AU$50/MWh in off peak times.

North America

A number of – but not all - regional markets in the USA and Canada have price caps, as follows:

6 See AIP/SEM/02/06

Table 2: Market Price Caps in North America

Jurisdiction	Value
California	US$ 400/MWh
New England	US$ 1,000/MWh
New York	US$ 1,000/MWh
Ontario	CA$ 2,000/MWh
PJM	US$ 1,000/MWh
Texas (ERCOT)	US$ 1,500/MWh

There have been significant changes to some of these price caps over time. The price cap in New York was set initially at US$10,000/MWh but reduced to US$1,000/MWh in 2001. Federal Energy Regulatory Commission (FERC) approved bid price caps in the Californian wholesale electricity market varied between US$250/MWh and US$750/MWh, US$500/MWh between 1998 and 2001. The cap was raised to its current level of US$400/MWh in February 2006. It is due to rise to US$500/MWh (in November 2007), US$750/MWh a year later and to US$1,000/MWh by November 2009.

The Midwest market in the US has no price cap.

4.4 Proposal

The Regulatory Authorities have developed an approach both to limit market power and to control the abuse of any residual market power in the SEM. That approach is founded on a number of building blocks which include:

- imposing a requirement on ESB Power Generation to make available to eligible suppliers a suite of Directed Contracts at prices and on terms determined by the Regulatory Authorities. This is intended to reduce the incentive for the seller of those contracts to submit price bids above competitive levels.

- a licence condition in all generation licences obliging the licensee to bid their plant at short run marginal costs (SRMC).

The Regulatory Authorities are satisfied that these various measures will mitigate market power in the SEM, with the corollary that a cap on wholesale prices is not warranted as a defence against the abuse of market power. Moreover, the requirement on generators to bid SRMC should avoid prices in the SEM from spiking for reasons other than a spike in short run marginal costs (e.g., reflecting a spike in fuel prices) or from a spike in uplift. The need for a price cap in the SEM to minimise volatility is thereby greatly reduced.

The Regulatory Authorities therefore propose to set a value for PCAP equal to that of VOLL (i.e., €10,000/MWh).

The Regulatory Authorities would expect this price to be binding very rarely, if at all. But they acknowledge that there is a risk that prices will spike as a result of uplift. As the Regulatory Authorities noted in AIP/SEM/07/5, they intend to monitor the effectiveness of the uplift methodology, both in the context of the desired objectives of the mechanism itself and having regard to the stability of SEM prices.[7] Should this monitoring suggest that there is a problem with uplift, it might be appropriate to set a lower Market Price Cap than €10,000/MWh, until such time as the problem with uplift has been rectified.

5 The Market Price Floor (PFLOOR)

5.1 The role of PFLOOR in the Code

The provisions in the Code with respect to the market price floor (PFLOOR) mirror those in respect of the price cap. Thus:

- generators cannot submit price offers that are lower than the Market Price Floor (PFLOOR);
- when a so-called Excessive Generation Event has occurred in accordance with Paragraph 4.74 of the Code, SMP in the relevant trading periods are set equal to the Market Price Floor (PFLOOR);[8] and
- in the event that SMP is calculated to fall below the Market Price Floor (PFLOOR), SMP in the trading period will be set to equal the Market Price Floor (PFLOOR).

5.2 International evidence

Price floors (even of a zero price) are seldom imposed in other markets. There is no price floor in the BETTA market in Britain. And there are none in the USA, as far as the Regulatory Authorities are aware.

There is a price floor of - CA$2,000/MWh (equivalent to about - €1,400/MWh at today's exchange rate) in the Ontario market. There is also a price floor (of – AU$1,000/MWh, equivalent to - €630/MWh at today's exchange rate) in the NEM in Australia.

5.3 Proposal

The Regulatory Authorities see advantages and disadvantages in allowing a negative PFLOOR.

On the one hand, a negative price floor would allow generators to bid negative prices, as their licences expressly permit them to do. And it would allow negative prices in the SEM in conditions where there is excessive price maker generation. Customers would benefit from negative prices at times of very low demand. And if customers are not exposed to

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[7] SMP Uplift Parameters Decision Paper,15th March 2007 (AIP/SEM/07/51)

[8] Section 4.74 of the Code defines an Excessive Generation Event as one which "occurs for a Trading Period where Schedule Demand in that Trading Period is less than the sum of the Market Schedule Quantities for Price Maker Generator Units as calculated by the MSP Software in that Trading Period."

appropriate pricing (including negative pricing) then the efficiency benefits arising from changing demand patterns are lost.

On the other hand, a negative price floor would expose price taker generators to the risk of potentially significant losses. The Regulatory Authorities would expect that most if not all price taker generators will be protected from low or negative prices through their contract positions, but they would be interested to know if this is not the case and the extent to which it is not.

The Regulatory Authorities wish to maintain a balance between minimising the exposure of participants to negative prices without excessively dulling an efficient price signal. The Regulatory Authorities propose to set a value for PFLOOR of - €500/MWh. This is smaller in absolute value than that proposed for PCAP and comparable (though less negative) to price floors seen in those markets that have them.

As in the case of the price cap, the Regulatory Authorities would expect this floor to be binding very rarely, if at all.

6 Conclusion

The Regulatory Authorities are required by the Code to set values for VOLL, PCAP and PFLOOR. They propose to set the following values for the period from 1 November 2007 to 30 September 2008:

VOLL €10,000/MWh

PCAP €10,000/MWh

PFLOOR - €500/MWh

These values will be reviewed annually and published in accordance with the provisions in the Code, namely:

- in the case of VOLL, at least four months before the start of the first capacity period in each year (or at least two months before the start of the year according to Table E.2 in Appendix E to the Code);
- in the case of PCAP and PFLOOR, at least four months before the start of the year.

The Regulatory Authorities will also keep these values under review in the first year of operation of the SEM and reserve the right to change them in the event that conditions warrant it.

ANNEX A: ROLE OF VOLL IN THE TRADING AND SETTLEMENT CODE

The Capacity Payment (*CPuh*) for each Generator Unit *u* in Trading Period *h* is calculated according to Section 4.123 of the Trading and Settlement Code, as follows:

$$If \quad CPPFh \neq 0 \quad then$$

$$CPuh = CPGPh \times CPEALFuh \times \left(\frac{CPGPFuh}{CPPFh} \right)$$

$$else$$

$$CPuh = CPGPFuh \times CPEALFuh \times \left(VCGPh + FCGPh + ECGPh \right)$$

where

1. *CPPFh* is the Capacity Payments Price Factor in Trading Period *h*

2. *CPGPh* is the Capacity Payments Generation Price in Trading Period *h,* as determined by the equation:

$$CPGPh = \left(VCGPh + FCGPh + ECGPh \right) \times CPPFh$$

3. *CPEALFuh* is the Loss-Adjusted Capacity Payments Eligible Availability for Generator Unit u in Trading Period *h*

4. *CPGPFuh* is the Capacity Payments Generation Price Factor for Generator Unit u in Trading Period *h*.

5. *VCGPh* is the Variable Capacity Payments Generation Price in Trading Period *h*

6. *FCGPh* is the Fixed Capacity Payments Generation Price in Trading Period *h*

7. *ECGPh* is the Ex-Post Capacity Payments Generation Price in Trading Period *h*

Thus capacity payments to generators are dependent on the values of the two scaling factors, *CPGPFh* (the Capacity Payments Generation Price Factor) and the *CPPFh* (the Capacity Payments Price Factor). Both these scaling factors depend on VOLL.

The Capacity Payments Generation Price Factor *(CPGPFuh)* is determined for each Generator Unit *u* in Trading Period *h* by the following equation:

$$if \quad \left(MSQuh + \sum_i UCOQuhi \right) \neq 0, \quad then$$

$$CPGPFuh = \frac{\left((MSQuh \times CPPFh) + \sum_i \left(UCOQuhi \times Max \left\{ \frac{VOLL - UCOPuhi}{VOLL}, 0 \right\} \right) \right)}{MSQuh + \sum_i UCOQuhi}$$

$$else \quad CPGPFuh = 0$$

where

1. *MSQuh* is the Market Schedule Quantity for Generator Unit *u* in Trading Period *h*

2. *CPPFh* is the Capacity Payments Price Factor for Trading Period *h* in the Capacity Period *c*

4. *UCOQuhi* is the Unscheduled Capacity Offer Quantity for Generator Unit *u*, for Price Quantity Pair *i* which is applicable in Trading Period *h*

5. *UCOPuhi* is the Unscheduled Capacity Offer Price for Generator Unit *u*, for Price Quantity Pair *i* which is applicable in Trading Period *h*

6. *VOLL* is the Value of Lost Load

The Capacity Payments Price Factor (*CPPFh*) is determined in Section 4.109 of the Code as follows:

$$CPPFh = Max \left\{ \left(\frac{(VOLL - SMPh)}{VOLL} \right), 0 \right\}$$

where

1. *SMPh* is the System Marginal Price in Trading Period h

2. *VOLL* is the Value of Lost Load

Thus VOLL influences the Capacity Payment for each Generator Unit in any half hour through both the Capacity Payments Price Factor, which affects in turn the Capacity Payments Generation Price, and the Capacity Payments Generation Price Factor.

If SMP is equal to or greater than VOLL in any half hour, *CPPFh* will be set at zero and capacity payments to generators will be zero in that half hour, on the grounds that generators will be recovering all their capacity and energy costs through SMP. Paying them a capacity payment in addition would amount to double payment (although noting that the overall capacity payment made in each month remains fixed in advance).. If SMP is less than VOLL in the half hour, such that *CPPFh* takes a value between 0 and 1, then the sum of the variable, fixed and ex-post capacity payments for each generating unit in that half hour is scaled down by the proportionate difference between VOLL and SMP.

Similarly, the Capacity Charge levied on each Supplier Unit in each Trading Period is scaled by the value of the Capacity Payments Price Factor *CPPFh*.

ANNEX B: SURVEYS OF WILLINGNESS TO PAY

This Annex gives a brief summary of a small and by no means exhaustive number of consumer surveys of willingness to pay to avoid a supply interruption.

Australia

VOLL plays an important role in the National Electricity Market (NEM) in Australia. But the Australians use another concept – the value of customer reliability (VCR) - to describe the value that customers place on supply reliability. The Australian Energy Market Commission's Reliability Panel argues that VOLL is not the same as the value of customer reliability, arguing that that VCR is an indicator of customer valuations of supply reliability whereas VOLL is the market price cap intended to balance customer demand preferences with the capacity investment signals provided to suppliers.

A number of studies have been undertaken in Australia to assess VCR. These support the findings from the European studies cited earlier that VCR is potentially very high and varies widely according to a range of factors and the basis on which they are measured (i.e., willingness to pay or cost to avoid).

In a survey of VCR for VENCorp in 2003, Charles River Associates (CRA) found an average value of customer reliability of AU$29,600/MWh across customer types in Victoria.[9] The basis of the study was the use of market research to obtain, via quantitative surveys, data on the cost impacts of unplanned electricity supply interruptions directly from a wide cross section of customers. These data were then to be used to estimate the value that customers place on supply reliability.

Table B.1 below presents CRA's calculations of sector-level VCRs for the whole sample and Table B.2 the sector-level VCRs for Victoria alone. CRA then derived a state-level VCR for Victoria of AU$29,600/MWh (equivalent to about €20,000/MWh at today's prices and exchange rates). CRA derived this weighted value from the figures in Table B.2 using the total electricity consumed by the sector relative to the total State consumption of electricity as weights.

[9] See CRA: Assessment of the Value of Customer Reliability (VCR) Submitted to VENCorp December 2002

Table B.1: Sector VCRs as Functions of Un-served Energy and Load AU$/kWh and AU$/kW

Interruption Duration	Residential		Commercial		Agricultural		Industrial	
	AU$/ kWh	AU$/ kW	AU$/ kWh	AU$/ kW	AU$/ kWh	AU$/ kW	AU$/ kWh	AU$/ kW
20 minutes	-	-	64.9	21.6	88.4	29.5	48.8	16.3
1 hour	21.1	21.1	42.2	42.2	35.9	35.9	19.0	19.0
2 hours	-	-	63.8	127.6	64.6	129.1	16.7	33.4
4 hours	12.7	51	81.7	326.8	85.3	341.2	15.9	63.4
8 hours	7.8	62	67.2	537.4	56.1	448.9	14.6	116.8
24 hours	3.8	90.5	23.4	562.1	42.5	1,020	7.9	189.1

Source: CRA, 2002

Table B.2: Sector-level VCRs for Victoria AU$/kWh of Unserved Energy

Interruption Duration	Sector			
	Residential	Commercial	Agricultural	Industrial
20 minutes	--	2.42	3.29	1.82
1 hour	9.39	18.75	15.99	8.44
2 hours	-	18.83	19.06	4.92
4 hours	2.13	13.64	14.24	2.65
8 hours	0.31	2.66	2.22	0.58
24 hours	0.06	0.38	0.69	0.13

Source: CRA, 2002

Finland

A survey of Finnish customers in 1977 provided the value of VOLL used by the Electricity Pool in England and Wales for the valuation of capacity payments. By averaging over the different customer classes surveyed, the study derived a function relating VOLL to duration of outage (see Table B.3 below). VOLL ranged from US$1,800/MWh for an outage lasting longer than 24-hours to US$3,800/MWh for a one-hour outage.[10]

[10] See Cramton, P and Lien, J; "Value of Lost Load," mimeo, February 2000.

Table B.3: 1977 Finnish Study – Average Customer Valuation (1999 US$) of kWh Not Supplied

	Outage duration					
Customer category	1 hour	3 hours	6 hours	12 hours	24 hours	24+ hours
Industrial	8.2	5.5	4.4	3.3	2.9	2.4
Commercial	13.1	15.1	13.5	11.3	10.4	9.1
Agriculture	3.3	3.1	3.5	4.0	4.4	4.7
Domestic	1.8	1.6	1.1	0.9	0.9	0.9
Overall load weighted mean	3.8	3.3	2.7	2.4	2.0	1.8

Source: Cramton and Lien, op cit

According to Cramton and Lien, these estimates were converted into 1989 pounds sterling and the Electricity Pool in England and Wales began in March 1990 with an initial VOLL of £2,000/MWh (equivalent at the time to US$4,300/MWh). The VOLL used by the Pool was then inflated annually using the annual increase in the Retail Price Index. By February 1999, when the final value of VOLL was set before NETA replaced the Pool, VOLL had increased to £2,768/MWh. This is roughly equivalent to €5,000/MWh at today's exchange rate and prices.

England and Wales

One of the only studies to derive a single value for VOLL is the one done by Kariuki and Allan (1996).[11] The work was carried out in 1993 as part of a Preparatory Action Survey of British Regional Electricity Company areas (Manweb, Midlands Electricity Board and NORWEB). Some of the results are reported in Table B.4 below.

The Table shows the cost of interruptions of varying length weighted by peak demand.[12] Kariuki and Allan use data on load factors, duration distributions and customer mix to average the data in Table B.4 into a single value of VOLL.[13] Weighted by energy consumption VOLL is estimated at US$18,500/MWh (in 1999 prices), equivalent to €17,000/MWh at today's exchange rates and prices and significantly higher than the values implied by the earlier Finnish study.

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11 Kariuki, K. K. and Allan, R. N. (1996), "Evaluation of Reliability Worth and Value of Lost Load," IEE Proceedings - Generation, Transmission. Distribution, 143, 171-180

12 The cost of an interruption normalised by peak demand is equivalent to the cost of un-served energy only if the interruption occurs at the time of peak demand and the peak demand would have been sustained for the duration of the outage.

13 Kariuki, K. K. and R. N. Allan (1996), "Applications of Customer Outage Costs in System Planning, Design and Operation," IEE Proceedings –Generation, Transmission, Distribution, 143, 305-312.

Table B.4: 1993 Kariuki & Allan – UK Sector Customer Damage Functions (1999 US$/kWh of Peak Demand)

	Outage duration						
Customer category	< 1 sec	1 min	20 min	1 hours	4 hours	8 hours	24 hours
Industrial	10.5	11	24.3	42.9	122.8	204.2	255.6
Commercial	1.7	1.7	6.6	18.1	66.4	133.7	170
Residential			.26	.92	6.3		
Large Users	11.5	11.5	11.7	12.2	15.1	16.5	22.7

Source: Kariuki, K. K. and Allan, R. N. (1996)

A 1996 British study by Willis and Garrod uses the Contingency Ranking method to value lost load.[14] This study differs from the earlier studies in that it predicts a linear relationship between the cost of an outage and its duration. The predicted costs of an outage of four to eight hours are similar to the predictions of the 1993 Kariuki and Allan study, but the costs of a short outage are estimated to be much less. The VOLL implied by this study lies somewhere between the 1977 Finnish study and the 1993 British study (i.e., between €5,000/MWh and €17,000/MWh in today's prices).

14 Willis, K. G. and G. D. Garrod (1997), "Electricity Supply Reliability – Estimating the Value of Lost Load," Energy Policy, 25, 97-103.