An Estimate of the Value of Lost Load for Ireland

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Abstract: This paper estimates the value of short term lost load in the all island electricity market which includes the Republic of Ireland and Northern Ireland. The value of lost load, also known as the value of security of electricity supply, is inferred using a production function approach. Detailed electricity use data for the Republic of Ireland allows us to estimate the value of lost load by time of day, time of week and type of user. We find that the value of lost load is highest in the residential sector in both the Republic of Ireland and Northern Ireland. Our results can be used to advise policy decisions in the case of supply outages and to encourage optimum supply security. In the context of this study short term is taken to be a matter of hours rather than days or weeks.

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1. Introduction

The value of lost load is the average willingness of electricity consumers to pay to avoid an additional period without power. In an efficient market, it should be equal to the wholesale peak price of electricity. The value of lost load would then affect decisions regarding investment in new generation capacity and closure of older, less efficient plants. Due to regulation in the Irish electricity market, customers cannot express their willingness to pay. Thus, the value of lost load has to be inferred.

According to Lyons et al. (2007), it appears that peak and reserve capacity is undersupplied in Ireland and Bazilian et al. (2006), Lyons et al. (2007) and Malaguzzi Valeri and Tol (2006) are of the opinion that the possibility of supply shortages is real, although the risk is smaller now due to the recession. As Ireland’s electricity supply becomes increasingly variable, primarily because of the growing share of wind power in total power generation, capacity management and reward is extremely important. New forms of electricity demand, such as electric and hybrid vehicles, as well as increased interconnection will also lead to variability in demand and supply. An accurate and up to date assessment of the value of lost load is therefore essential to inform future planning.

This paper updates Tol (2007) which is the first and only published empirical estimate of the value of lost load for the Republic of Ireland (ROI). The main advantage of this paper is that access has now been provided to data on the time profile of electricity use per type of user in ROI. Whereas Tol (2007) assumed that the probability of a brown-out\(^1\) is constant across consumer groups, we can now estimate which users would be hardest hit by such an event. We use this data to estimate the value of lost load in ROI between 2001 and 2008. We also estimate the value of lost load for Northern Ireland (NI) between 2000 and 2007. Thus, this paper constitutes a substantially refined estimate of the value of lost load in the all island market.

In 2007 the regulatory authorities of the Single Electricity Market\(^2\), the Commission for Energy Regulation (CER) and the Northern Ireland Authority for Utility Regulation

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\(^1\) A brown-out is defined as a condition where the voltage supplied to the system falls below the specified operating range, but above zero volts. A black-out is a total loss of electrical power in a region.

\(^2\) The Single Electricity Market is a joint electricity market between the Republic of Ireland and Northern Ireland.
(NIAUR), set the value of lost load at €10/kWh based on the estimated peak price of planned electricity capacity (CER and NIAUR, 2007). The stated reasoning is rather unrealistic since it assumes that planned capacity will always equal desired capacity. The value has been re-estimated on an annual basis by using the previous year’s value and adjusting it by applying the weighted average of the year-on-year increase in the Irish Harmonised Index of Consumer Prices (HICP) and the UK HICP. Using this method, CER and NIAUR (2009) find that the value of lost load for 2010 is €10.27/kWh.

The paper continues as follows. Section 2 presents the methodology and Section 3 the data. The results are discussed in Section 4 and Section 5 provides a discussion. Section 6 concludes.

2. Methodology

The value of lost load can be estimated in three ways. The first is that used by Beenstock et al. (1998) which relies on consumer surveys and is based on stated preferences. Beenstock et al. (1998) find that the value of lost load for Israeli households was $7/kWh in 1990 prices. Since no Irish data of this kind exists, this method is unavailable to us. Corwin and Miles (1978) estimated the value of lost load using cost estimates from previous supply outages. The underlying assumption is that the past and the future are similar, which is not appropriate for Ireland given the rapid economic and structural changes that have taken place. The third alternative, which is employed in this paper, is based on estimates of production functions. Production functions imply demand functions but additional assumptions are required such as rationality of economic agents and divisibility of goods and services. Typically, production functions are estimated for a year as a whole, and may not be appropriate for an assessment of the impact of an event such as electricity interruptions for a few hours. Nonetheless, the production function approach is adopted here as the only viable option given data availability.

The production function approach relates electricity use to firm output, or in the case of households, the value of time spent on non paid work. This technique enables us to estimate the value of lost load by dividing Gross Value Added (GVA) (in € millions) in a specific sector by the amount of electricity in (Gigawatt hours (gWh)) used. This will

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3 The Irish HICP is given a weight of 2/3 and the UK HICP is given a weight of 1/3. Year on year increases are based on July estimates.
give the value per kilowatt hour (kWh) that this sector generates, roughly equal to the value that would be lost in the case of a brown-out. In estimating VoLL for NI we follow the exact methodology of de Nooij et al. (2007) and Tol (2007). For ROI, more detailed data allows us to extend the technique so that more detailed results can be generated. de Nooij et al. (2007) found that the average VoLL in the Netherlands in 2001 was under €9/kWh. Tol (2007) found that the average VoLL in Ireland in 2005 was much higher; €40/kWh.

For NI, we assume that each sector’s production function is linear and that companies are able to shift production within the year. Thus, the time at which the brown-out occurs is not important, but of course some production will be lost due to the brown-out. This assumption is a reasonable one for most activities. Another assumption is that the duration of the electricity outage does not matter. This is also reasonable as any brown-outs that could occur in NI are likely to be for short periods. For households we define the value of lost load as the value of time spent on non paid work divided by electricity used. We assume that all activity stops when there is no electricity. Thus, an hour without electricity is an hour of time lost. This seems a generous assumption, but risk and annoyance are not taken into account. The value placed on time spent on non paid work varies with electricity use by time of day. Exelon (2007) shows that in the UK 44% of household electricity is used during the day, 35% in the evening, and 20% at night. For NI we estimate the value of time spent at non paid work by day, evening and night for midweek days and weekend days.

For ROI, we have more detailed data so we employ a slightly more elaborate method. The ROI data consist of the electricity profiles of the residential, industrial and commercial sectors for each hour of 2001. We derive the proportion of electricity used by each sector at each hour and use it as a proxy for the proportion used by each sector in each hour in later years. For the industrial and commercial sectors, we estimate the annual average value of 1 kWh of electricity as before. Since we do not know the value added by the industrial and commercial sectors per day and hour, we cannot derive the value of lost load per time of day or year. However, we can estimate the total hourly value of electricity by multiplying the average value of 1 kWh of electricity by the amount of electricity used.

To evaluate lost load in the residential sector, we incorporate data from the 2005 Time Use in Ireland Survey (ESRI, 2005). Using this data we can assess the activities in which
people are involved over two 24 hour periods; one midweek and the other weekend. For those who are not at home or at home but asleep, the cost of a brown-out is zero. For those who are working from home we assume that the opportunity cost of time spent on non paid work is equal to the average wage after tax. For those at home and neither working nor asleep, the opportunity cost of time spent on non paid work is equal to half of the average wage as in de Nooij et al. (2007) and Tol (2007). Thus, the opportunity cost varies throughout the day and between midweek and weekend days. As we have data on the profile of household electricity use, we can find hourly values of lost load by dividing the value of time spent on non paid work in that hour by the amount of electricity used.

There are of course limitations associated with the use of production functions to estimate the value of lost load. One drawback is that additional assumptions are required such as rationality of economic agents and divisibility of goods and services. Also, production functions are usually estimated on an annual basis and thus may not be appropriate for estimating the impact of hourly electricity interruptions. We are unable to account for restart time in businesses after an outage or annoyance in households caused by a supply interruption.

3. Data

Estimates of annual electricity use in NI are taken from the Department of Energy and Climate Change (DECC) (2008). NIAUR (2010) provides figures for household electricity use. However, estimates of electricity use in other sectors are not available. Instead, we allocate electricity use in these sectors using the appropriate United Kingdom (UK) and ROI shares. Thus, we have two estimates for the value of lost load in these sectors. GVA per sector data is taken from the Office for National Statistics (ONS) (2009) and we convert these to constant prices using a deflator specified by HM Treasury (2010). Operating hours in the industrial and service sectors are taken from de Nooij et al. (2007). Estimates of the number of hours worked and average earnings are from the Annual Survey of Hours and Earnings (ASHE) 1999-2008 (ONS, 2010a). UK tax rates are taken from the Organisation for Economic Co-operation and Development (OECD) (2009) while estimates of the number employed are taken from the Department of Enterprise, Trade and Investment (DETI) (2010). Wages are adjusted for inflation using
the Consumer Price Index for the UK (ONS, 2010b). The population of NI is estimated by the Northern Ireland Statistics and Research Agency (NISRA) (2008).

With regard to ROI, ESB International (ESBI) (2009) has provided data on the electricity profiles of the residential, industrial and commercial sectors for each hour of 2001. Data on annual electricity use per sector are taken from the Sustainable Energy Authority of Ireland (SEAI) (2009).

Estimates of GVA per sector in constant prices are taken from the Central Statistics Office of Ireland (CSO) (2010). Population and labour force data are taken from the Groningen Growth and Development Centre (GGDC) (2010). Data on after tax non agricultural wages in constant prices\(^4\) are taken from the Economic and Social Research Institute (ESRI) databank (Bergin and FitzGerald, 2009). In 2004 the average hourly non agricultural wage after tax was €29. In 2009 it was €33.16. As mentioned previously, we also incorporate the 2005 Time Use in Ireland Survey (ESRI, 2005) in order to estimate the value of lost load in the residential sector.

### 4. Results

Figure 1 shows the value of lost load in NI if power outages had occurred in 2007. The value of electricity to the industrial and commercial sectors varies depending on whether electricity use was allocated using ROI or NI shares. The use of ROI and UK shares result is a surprisingly similar value of lost load in the industrial sector. The value of lost load in the commercial sector varies depending on whether UK or ROI shares are used. This can be attributed to the higher share of electricity use in the UK services sector relative to that of ROI. The value of lost load in the residential sector far outweighs that of the other sectors.

\(^4\) 2004=100
Figure 1. The Value of Lost Load in NI 2007

Figure 2 shows the value of lost load in NI by time of day over the period 2000 to 2007. The value differs substantially between midweek and weekend days and by time of day. The value of lost electricity to industry is highest on midweek days between the hours of 8.00AM and 6.00PM. For households, the value of electricity is highest at the weekends, especially during the day. Because the value of lost load is so much greater to households than it is to industry, we see that this pattern is repeated in the average results. As expected, the loss is lowest during the night both midweek and at the weekend.

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5 We estimated these values using both ROI and NI electricity shares in the non residential sector and found that the results were very similar. This graph represents an average of the two results.
With regard to ROI, the average value of lost load is highest in the residential sector. This happens because of the relatively high value which is placed on time spent at non paid work on both midweek and weekend days and evenings. The total value of hourly electricity is also much higher in the residential sector than it is in the industrial and commercial sectors. The total cost of a lost hour of electricity varies considerably by time of day, especially in the commercial and residential sectors.

Figure 3 shows the average value in 2008 of a lost hour to the industrial sector at different times of year. Note that figure 3 shows the value per hour rather than the value per kWh. The bars and lines represent midweek and weekend days respectively. The pattern is somewhat similar across seasons. The value of a lost hour is lowest between the hours of 4.00PM and 6.00PM in winter. This may be partly due to a lower demand for cooling at this time of year. The value of a lost hour is highest at 7.00AM on midweek days all year round. At weekends, however, the value of a lost hour falls between 6.00AM and 8.00AM and between 3.00PM and 6.00PM. This pattern is repeated throughout the year. In general, the value of a lost hour is lower at weekends than it is midweek due to reduced activity on Saturdays and Sundays.
Figure 3. ROI Industry hourly value of electricity by season and time of week (2008)

Figure 4 shows the average value in 2008 of a lost hour of electricity in the commercial sector at different times of year for midweek (represented by bars) and weekend (represented by lines) days. Again, figure 4 shows the value of electricity per hour rather than per kWh. Both midweek and weekend days follow a similar pattern. As expected, in each case, the loss is highest during standard business hours. The value can be as high as €17 million per hour. As the commercial sector represents all of the service industry and the public service, it is not surprising that the loss is lowest in summer when the demand for electricity is also low because of natural light.
Figure 4. ROI Commercial hourly value of electricity by season and time of week (2008)

Figure 5 shows the value of a lost unit of electricity in households in 2008. Unlike figures 3 and 4, figure 5 shows the value of lost load. The bars, which represent midweek days, show that the value of lost load is low during the night and increases substantially between the hours of 5.00AM and 7.00AM. It then remains relatively steady until evening time, mainly driven by the fact that the value of time spent on non paid work is low and stable between 8.00-9.00AM and 5.00-6.00PM when most people are at work. On midweek days, in the evening time, the value is highest in summer and lowest in winter. Although electricity use is highest in winter, electricity is valued in terms of time spent on non paid work and thus the amount people are willing to pay per unit of electricity falls. However, the hourly value of electricity will remain high in winter. The continuous lines represent the value of lost load at weekends. Again, the value is lowest during the night and increases between the hours of 5.00AM and 8.00AM. From midday onwards, the value varies by season. At 8.00PM on weekend evenings in summer, the value of lost load reaches an average of €51/kWh when most people are at home but not

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6 Because the value of lost load is defined as loss of time spent on non paid work divided by electricity use, the overall value people are willing to pay for a lost unit of electricity will fall when electricity use, the denominator, increases.
asleep. For the most part, the value of lost load on weekend days exceeds that of midweek days.

**Figure 5. Household value of lost load by season and time of week in ROI (2008)**

Figure 6 shows the evolution of the value of electricity over time for both the hourly value (€/hr) and the value of lost load (€/kWh). The total value of a lost hour of electricity to all three sectors (indicated by the lines on the chart) increased between 2001 and 2008. We estimate the cumulative annual growth rates in the value of a lost hour of electricity in the industrial, commercial and residential sectors as being 6.7%, 1.9% and 4.2% respectively. The bars (and secondary axis) on the chart show the average value of losing 1 kWh of electricity in each of the sectors. The residential values increased only slightly over the period (by 0.8%). This trend is largely due to the stabilisation of wage taxes and saturation of the employment ratio. The industrial value of lost load increased over the period as GVA outgrew electricity use in this sector, however, the commercial value decreased slightly.
5. Discussion

5.1. Current capacity regulations

On 1st November 2007 the trading of wholesale electricity in ROI and NI began on an all-island basis. In this Single Electricity Market (SEM) all electricity generated in or imported into Ireland must be sold into a common pool and all electricity for consumption in Ireland or export to other countries must be purchased from the pool. The SEM replaces the old system in which a central planner would specify a level of capacity (for example, by estimating expected demand plus a reserve margin) thought sufficient to meet a defined standard for system reliability. The aim of the SEM is to allow market forces to ensure that adequate capacity is built in an efficient and timely manner. It is hoped that this will lower prices in the long run.

The market operates on pool arrangements whereby all suppliers pay and generators receive the same System Marginal Price. Generators also receive capacity payments, which are based on annually determined fixed amounts and are ultimately paid for by consumers. The aim of such payments is to increase certainty of revenues, encourage investment and ensure that capacity is made available when it is required. The benefit for generators is that if they make plant available when capacity margins are tight, revenues

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7 The system marginal price is determined by the bid price of the marginal dispatched plant and all dispatched plants receive this price. Dispatched plants are chosen on the basis that all plants are stacked according to their bid, from the cheapest to the most expensive. The cheapest plants that are needed to match demand in each half hour are dispatched.
can be earned which are greater than the short run costs. The level of payments is based on estimates of the tightness of the market and the cost of new peaking capacity. Since this system has been implemented availability of plants has increased slightly in ROI.

Current dispatchable capacity stands at approximately 7,000 MW. Eirgrid (2009) estimates that at times of high demand, surplus capacity is currently about 800 MW. However, Malaguzzi Valeri and Tol (2006) have suggested that forced outages among a small number of ageing generation units could sharply increase the risk of shortages if they were to coincide with peak winter demand. Continued increases in demand (although the recession resulted in decreased demand last year) and planned retirement of old plant have increased the need for investment in new plants over the coming years. According to the energy forecasts of SEAI (Walker et al., 2009), electricity demand is set to increase by 12% between 2008 and 2020.\(^8\) The growing importance of wind generation in the SEM suggests that the system will need more mid-merit and peaking capacity to help meet system reliability goals in future. Peaking plants can be switched on and off relatively easily due to the relatively high level of variable costs to fixed costs that they face. Thus, these plants can be used to meet fluctuating demand. Base load plants, on the other hand, face relatively high fixed costs to variable costs and so, it is most efficient to use them in a continuous way. Mid-merit plants generally produce electricity for several hours at a time but can be shut down and restarted on a daily basis.

5.2. The implications of using the estimated value of lost load

The value placed on lost load should be used to assist decisions regarding investment in new capacity and closure of older, less efficient plants in order to meet the desired supply security. Capacity management is increasingly important as electricity supply and demand become more variable. In Ireland, the growing share of wind power in total generation means that supply is already less predictable than it used to be. The expected growth in interconnection, electric and hybrid vehicles, and smart appliances will further complicate capacity management.

Our results show that the weighted average value of lost load in ROI is €12.9/kWh. This indicates that the €10/kWh set by CER & NIAUR is too low for short term loss of load.

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\(^8\) Despite forecasted decreases in demand between 2008 and 2012, the average annual growth rate for both electricity and total energy is estimated to be 0.9% between 2008 and 2020.
(several hours). The average value of lost load in NI in 2007 was €4/kWh for the industrial sector, €13/kWh for the commercial sector and €18/kWh for the residential sector. In contrast, in ROI in 2008, the average value of lost load was around €4/kWh for the industrial sector, €14/kWh for the commercial sector and €24.6/kWh for households. The residential value is an average, brought down by the very low values which occur during the night. It can reach values over €60/kWh, usually at weekends when most people are at home. Between the hours of 6.00PM and 9.00PM on midweek days, when brown-outs are most likely, hourly values of electricity are at their highest; between €41 million and €45 million. In 2008, peak electricity demand occurred at 5.00PM on 15th December. At this time, the average value of lost load was €15.2/kWh but it was even higher at €35/kWh between 8.00AM and 9.00AM that day. Thus, the peak value of lost load and peak electricity demand do not occur simultaneously. This opens some opportunities for peak shifting to minimise the damage of brown-outs.

The estimate for NI suffers from a lack of detailed data on residential electricity use and time use. The average VoLL we have estimated for NI may be an overestimate, as the incorporation of detailed data on residential electricity use for ROI has resulted in a downward revision of the weighted average value of lost load compared to that estimated by Tol (2007).

At present, during a brown-out, it is policy to shut off electricity in residential areas first, and in industrial estates later. As the value of lost load is highest in the residential sector, in both NI and ROI (during the relevant hours), this policy may be reconsidered. However, the decision as to which sector will be subject to rationing should depend on the day and time at which the shortage occurs. During the hours of 1.00AM and 6.00AM the value of a lost hour of electricity in the industrial and commercial sectors is much higher than it is in the residential sector.

6. Conclusion

In this paper, we use a simple version of the production function approach to estimate the short term value of lost load in NI for the period 2000-2007 and in ROI for the period 2001-2008. We find that:

- VoLL differs by sector and is highest in the residential sector in both ROI and NI
- VoLL differs substantially by time of day and week
More detailed data for ROI enables us to show that VoLL also differs by time of year. The value of a lost hour of electricity is driven by electricity demand in that hour. The peak VoLL and peak electricity demand do not occur simultaneously. VoLL in ROI has increased between 2001 and 2008 and is currently higher than the Regulator assumes it to be.

These results come with a number of caveats. More detailed data on electricity use per type of user in NI would enable us to deliver more accurate results. It would be good to test the validity of our results based on the production function approach with estimates based on contingent valuation and contingent choice methods as well as with estimates based on observed black-outs. Our estimates are valid only for short interruptions of the power supply. Longer interruptions, while much more unlikely, may well be disproportionally damaging. All this is deferred to future research.

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Sean Lyons, Laura Malaguzzi Valeri, Pat McCullen and Gerry White had excellent comments on an earlier version of this paper. Financial support by ESBI is gratefully acknowledged. All errors and opinions are ours.

References


ONS, 2010a. ASHE Results. Office for National Statistics  


### Appendix


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### A2. Sample data for Northern Ireland: 2007

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<tr>
<th>Northern Ireland 2007</th>
<th>Industrial and Commercial demand (gWh) *</th>
<th>Industrial and Commerical Voll (€)*</th>
<th>Residential demand (gW)</th>
<th>Residential Voll (€)</th>
<th>Average VoL° Northern Ireland (€)</th>
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<td><strong>Distribution of electricity demand</strong></td>
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<tr>
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<td>3490</td>
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<td>1082</td>
<td>13</td>
<td>11</td>
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<td>Midweek evening</td>
<td>521</td>
<td>4</td>
<td>864</td>
<td>26</td>
<td>17</td>
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<tr>
<td>Midweek night</td>
<td>695</td>
<td>4</td>
<td>491</td>
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<td>Weekend day</td>
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<td>346</td>
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<td>Weekend night</td>
<td>134</td>
<td>4</td>
<td>196</td>
<td>0</td>
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*The Industrial and Commercial figures were estimated twice, once with UK shares and once with ROI shares as exact data for NI do not exist. The figures shown here represent an average of the two results.
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