ELECTRICITY SHORTAGES IN IRELAND: PROBABILITY AND CONSEQUENCES[1]

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Introduction

In Ireland electricity demand is at its peak in the winter months, when the days are short and the weather is cold. This causes the likelihood of electricity shortages to peak at the same time. We define a shortage as any instance where demand for electricity is larger than supply. In such cases, the system operator typically implements "load shedding" in order to curb peak demand. This is done by disconnecting sections of consumers for a few hours, while enforcing any interruptible tariff contract previously put in place.[2] This allows electricity to flow undisturbed to the rest of the country. In this paper, we estimate the probability and the consequences of a shortage. We also discuss causes and countermeasures, both short term and long.

The Irish economy has grown very rapidly, and total electricity demand has grown by some 3.6 per cent a year between 1998 and 2005, while peak demand has grown by 5.0 per cent a year.[3] The supply of electricity has had difficulty keeping up. Partly, this is due

[1] We had useful discussions on this subject with Eleanor Denny, Niamh McCarthy, John Fitz Gerald, Michael Kelly, Edgar Morgenroth, Pieter Schipper and Adele Slater. Funding by the Energy Policy Research Centre of the Economic and Social Research Institute (ESRI) is gratefully acknowledged.

[2] Interruptible tariff contracts offer discounts on the cost of electricity to those companies that agree to decrease their use of electricity when requested to do so by the system operator.

[3] ESB at http://www.esb.ie/main/about_esb/grid_growth.jsp and EirGrid at http://www.eirgrid.com/EirgridPortal/DesktopDefault.aspx?tabid=System%20Operations

to the scale of the needed investment, but partly it is also due to existing policy objectives. The Electricity Supply Board of Ireland (ESB) dominates the electricity sector, with 83 per cent of installed generation capacity.[4] The Irish government wants to reduce this dominance without breaking up the ESB, and has been reluctant to approve new ESB power plants. Other companies may hesitate to invest in a market where they would have a small market share of a small and isolated market. When potential entrants are interested, they prefer to invest in base-load capacity that tends to provide higher returns than much needed peak-load capacity. The result is an increasingly tight market – and an increasing probability of shortages.

The Probability of a Shortage

There are 54 power-generating units in Ireland providing about 6,000 MW of installed capacity, in addition to a few combined heat and power units and more than 60 wind farms that contribute about 670 MW of capacity.[5] As with all equipment, power generating units are subject to unexpected mechanical failure, causing unplanned outages. The yearly probability of an unplanned outage can be measured by the Forced Outage Rate (FOR), which is defined as the fraction of time that a unit cannot be used, excluding time spent on scheduled maintenance. For Ireland, the FORs range from 1 per cent to 12 per cent.[6] These are a yearly average of probabilities, however. In practice, at the end of November 2006, 18 per cent of the generation capacity was unavailable because of forced outages.[7] In part this reflects the fact that maintenance and repair efforts reached their historic peak in 2006 in order to enter the winter with a more reliable plant portfolio (EirGrid, personal communication, December 2006).

The probability that no power is generated equals the product of the FORs for all existing plants. This probability is vanishingly small: 1.7 10^{-79}. At the other extreme, the probability that there is full capacity (5,892 MW), excluding wind power, is also small: 8.5 per cent. Wind power has a separate set of problems, not related to mechanical failure, but rather to the variability of wind itself. In the winter of 2006/7, the median wind supply (wind generation is expected to be smaller or equal to this for 50 per cent of the time) is expected to be 283 MW, but it ranges between 51 MW to 556 MW for 80 per cent of the time. For the whole electricity generation system of the Republic of Ireland, the median capacity during the

[4] Department of Enterprise, Trade and Employment at http://www.entemp.ie/publications/trade/2005/electricitymarket.pdf

[5] EirGrid, at http://www.eirgrid.com/EirgridPortal/uploads/Regulation and Pricing/Connected(Wind)Nov06.pdf

[6] Commission for Energy Regulation (CER) and Northern Ireland Authority for Energy Regulation at http://www.allislandproject.org/AIP-SEM-82-05.xls

[7] EirGrid, at http://www.eirgrid.com/EirgridPortal/DesktopDefault.aspx?tabid=SO%20-%20Generation%20System%20Availability&TreeLinkModID=1451&TreeLinkItemID=12

upcoming winter is expected to be 5,990 MW – if all plants are operational.

Given the FORs and the existing capacity, we can compute the probability that the electricity supply exceeds any given demand *D*. We do this through a Monte Carlo analysis, which allows us to calculate the probability we are interested in by simulating what happens in reality given the information we have on the probability of forced outages. In each run there is a different realisation of the (uncertain) levels of power generation and wind generation that will be available. The probability of supply exceeding demand is then calculated as the average of all the Monte Carlo runs. In mathematical (and more concise) form, this can be expressed as follows:

$$P(C > D) = \frac{1}{MC}\sum_{i=1}^{MC} I\left\{\left(W_i + \sum_{j=1}^{N} C_j \cdot I\left\{U_{i,j} > FOR_i\right\}\right) > D\right\} \quad (1)$$

where *C* is total available capacity, *D* is demand, *MC* is the number of Monte Carlo runs, indexed by i, *W* is the wind power, *N* is the number of plants, indexed by j, *U* is a random number uniformly distributed between 0 and 1, and C_j is the capacity of plant *j*; $I\{\cdot\}$ is the indicator function, $I\{\text{true}\}=1$ and $I\{\text{false}\}=0$.[8]

The results are shown in Figure 1, as a function of the size of demand. The winter 2006/2007 peak demand will probably be around 5,000 MW. If we assume that 200 MW of electricity will be imported from Northern Ireland, 4,800 MW will need to be generated in the Republic of Ireland. The probability of supply exceeding 4,800 MW equals 99.91 per cent when all plants are available. This is a reassuringly high probability.

Unfortunately, not all power plants are fully operational. Ireland's generation plant portfolio is older than average, which leads to one of the lowest average availability rates in Europe. One of the ageing oil-fired units at Poolbeg is in extensive maintenance.[9] This reduces capacity by 240 MW, or 3.5 per cent of total installed capacity (including maximum wind). The other two steam units at Poolbeg (220 MW, 3.3 per cent of total installed capacity), the units at Great Island (216 MW, 3.3 per cent of capacity) and at Tarbert (589 MW, 9.1 per cent of capacity) are old and historically unreliable – although they are supposed to work at times of high demand and are operational in December 2006 (EirGrid, personal communication, 2006).

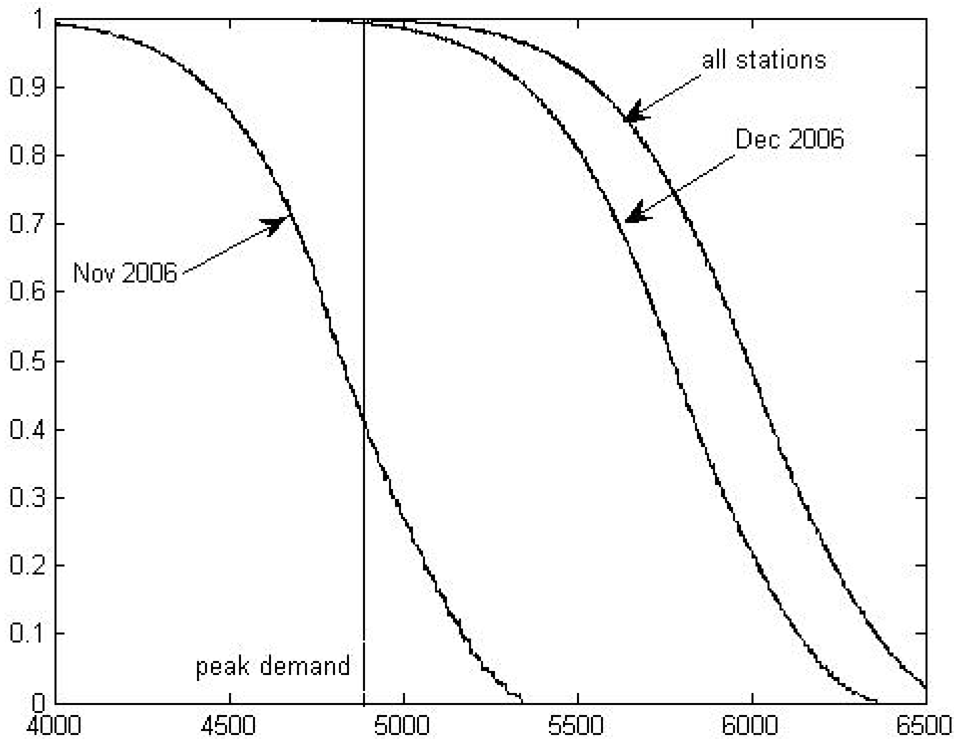
Figure 1 also shows the survival probabilities (i.e. the probability that no shortage will occur) of total capacity if availability of plants is limited. If a 240 MW peak plant is out, the probability that

[8] Wind and other sources of electricity are included simultaneously in the Monte Carlo analysis. The empirical probability density function of wind is approximated by the 20 mid-points of the 5th percentile ranges, each occurring with a 1/20th chance.

[9] The other two steam units that were also under maintenance (*The Irish Times*, 3 November 2006) are now back in operation (Kelly, personal communication, 2006).

available supply will be sufficient to cover expected demand falls to 99.5 per cent. With 460 MW out, this chance falls to 98.5 per cent, and with 580 MW out, to 95.8 per cent. In the event that 1,260 MW of ageing plants (equivalent to the size of Poolbeg, Great Island and Tarbert together) could not be switched on, this probability would decrease to 53.5 per cent. That is, the probability of a shortage would be 47 per cent.

Figure 1: Survival Probability as a Function of Demand for Electricity Supply in the Republic of Ireland



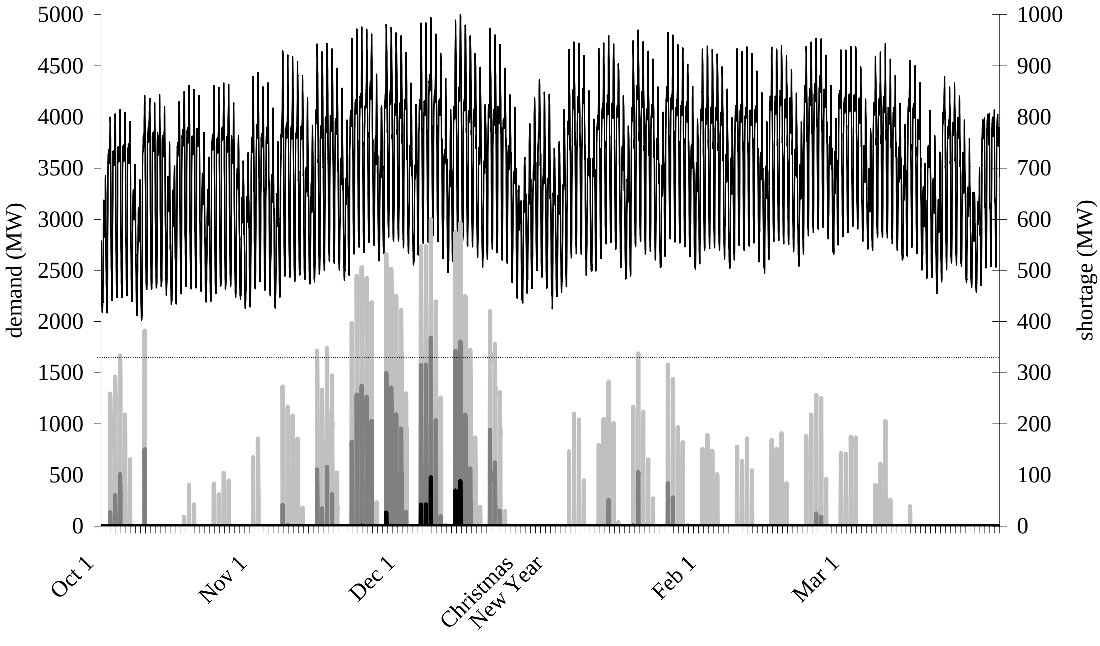
Note: "All stations": all stations available; "December 2006": without the largest Poolbeg steam unit, the situation in December 2006"; "November 2006": without the Poolbeg (steam), Great Island and Tarbert stations, the situation in November 2006. For comparison, the likely peak demand in 2006 (minus imported electricity) is also shown.

The Consequences of a Shortage

Figure 2 shows a hypothetical scenario of electricity demand for the winter of 2006/2007. It also shows the amount of shortage for six different cases: a mildly pessimistic scenario, interacted with three levels of wind, and a very pessimistic outage scenario, again interacted with the three wind levels. The three wind levels are low (wind is expected to be lower than this amount for only 10 per cent of the time), middle (wind is expected to be lower than this amount for 50 per cent of the time) and high (wind is expected to be lower than this amount for 90 per cent of the time).

In the top panel, all stations except Poolbeg (steam), Great Island and Tarbert are operational, so we are also along the line that denotes the most pessimistic scenario in Figure 1 (with Poolbeg, Great Island and Tarbert out of order, but all other plants operational). In terms of generation availability this is equivalent to having Tarbert available, but other plants of the same size out of order. Figure 2 shows that, with all stations except the three ageing ones of Poolbeg (steam), Great Island and Tarbert, there is a good chance of getting through the winter without shortages – provided that the wind blows when demand peaks. Even with a low level of wind the largest shortage is 120 MW, an amount that may easily be imported. In this scenario, there are 8 hours at risk of a shortage.

Figure 2: Hypothetical Electricity Demand (line, left axis) and Potential Electricity Shortage (bars, right axis) in the Republic of Ireland for Winter 2006/7



Note: In the top panel, all power generating units except Great Island, Tarbert, and the steam units at Poolbeg are operational. In the bottom panel, all of Poolbeg (including the CCGT plant) is switched off together with Great Island and Tarbert. Shortages are shown for three different levels of wind: low (10th percentile, light grey), middle (50th percentile, dark grey), and high (90th percentile, black). The import capacity for electricity from Northern Ireland is 330 MW.

In the bottom panel, all of Poolbeg – including its Combined Cycle Gas Turbine (CCGT) plant – is out, as well as Great Island and Tarbert.[10] That is, we are around the median along the most pessimistic line shown in Figure 1. In this scenario, with an additional big power plant out of order, even the strongest winds and maximum electricity imports on the interconnector will not prevent a shortage. The shortage may go up to 600 MW, while the

[10] We take the Poolbeg CCGT plant as representative of any large (480 MW) plant. This scenario is identical to one where the Poolbeg CCGT plant is operational but any other 480 MW plant (or combination of plants) is out of order.

interconnector capacity is only 330 MW. In this case there are 166 hours at risk of shortage with low winds, 72 hours with middle winds, and 5 with high winds. With low winds, the shortage exceeds the maximum interconnector capacity for 43 hours; with medium winds, for 1.5 hours.

What would be the consequences of a shortage? In the current market, there would be limited changes in the price of electricity. Most of the consequences would derive from the unavailability of electricity. Electricity demand peaks in the late afternoon/early evening, as it gets dark and people are still at work or shopping while others have started cooking. A benign shortage would be limited in time and space; some people would be inconvenienced, a few businesses would be interrupted, and shopkeepers would grumble about lost custom. In the most pessimistic scenario, the model has shortages for up to 5.5 hours. Hospitals and large businesses have historically received priority dispatch, so they would not be affected. Households, small business, and – importantly – traffic signals are the most likely to be disrupted.

Discussion and Conclusion

What could be done to avoid this? The probability of a shortage depends crucially on the power units in Poolbeg, Great Island and Tarbert. If these work, as is the case in early December 2006, chances are there will be no shortages. Maintenance of these units is therefore a great priority. Agreements between the Commission for Energy Regulation and the ESB, aimed at reducing the ESB's market power, will likely involve the closure of the Poolbeg steam plants, Great Island and Tarbert by 2010.[11] However, until reliable alternatives to these plants are built and commissioned, they need to be kept in good working order. The alternative is to have a substantial risk of a shortage.

The capital cost of replacing 1,200 MW of peaking capacity is currently estimated to be around €480 million.[12] This level of investment would allow the system to be consistently on the right-most line in Figure 1. It is also likely to be smaller than the cost of shortages to the Irish economy, although quantifying these costs precisely is difficult.

Given the need for new and reliable generation capacity in Ireland, it is paramount that the new All-Island market provide the correct incentives for new investment, particularly in peak capacity, and that permission to build be granted. However, it should be noted that this might further enhance the market power of the ESB. The Irish government clearly prefers a decrease in ESB's market share, and is therefore considering two alternative solutions: forcing the ESB to divest some of its generation capacity or dividing it into two or three separate businesses.

[11] CER, press release, 29 November 2006.

[12] Assuming a cost of €40 per kW of installed capacity, in line with the assumptions made in the All Island Project.

However, this does not affect the coming winter, and not even the winter after that. The only alternative to increasing supply is to reduce demand. The Power-of-One campaign may be successful in this. It would probably be more effective, however, if in the short term the system operator were able to call on large offices and factories to curb their demand in periods of extremely high demand. This could be done fairly easily by reducing the temperature inside buildings by one or two degrees centigrade for a few hours, or having the cooling units in supermarkets run more intensively at off-peak times. For next winter, more interruptible power contracts may be put in place. In addition, the North-South interconnector should be available to be used to its maximum extent.

EirGrid has contingency plans in place for controlled power interrupts that were initially set up in the 1970s and 1980s, when rolling black-outs were more common. Such contingency plans should also prepare the population to deal with cases of shortages lasting a few hours, so as to minimise accidents and disruptions. In the past the system operator warned in advance those segments of the population (and areas of the country) that were at highest risk of losing power and this is still likely to happen in the event of imminent power cuts. Crucial services (e.g., hospitals) should be encouraged to check their back-up power generation. Finally, special instructions on how to deal with non-functioning traffic lights should be prepared. Currently there are no such instructions, which is likely to lead to traffic chaos in cities, in the event of power outages.