# Impact on distribution losses of changing the domestic single rate demand profile


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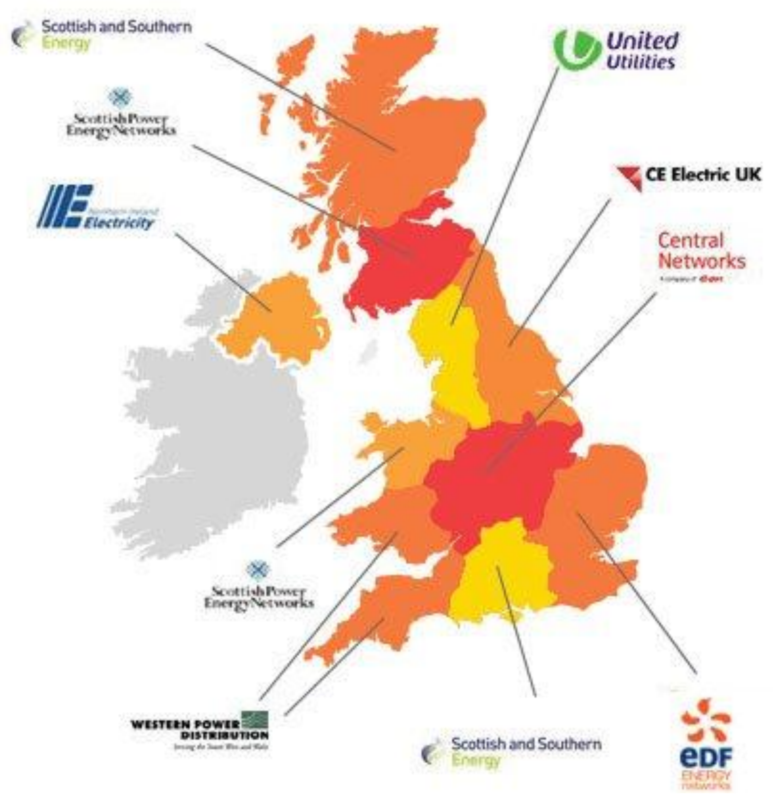


**Figure 1. Distribution Network Operator areas (Energy Networks Association)**

**An electricity distribution system loses a proportion of the electrical energy passing through it before that energy can be delivered to customers. Reducing network losses reduces the environmental impact of the energy system and the network operators have a regulatory incentive to do this. So new loss reduction strategies are always of interest.**

**Since the variable component of losses varies as the square of the current, a less peaked and more even demand for power through the day can be expected to bring a reduction in losses. This will occur even without an absolute reduction in energy demand. However no published research could be identified which determined the scale of this effect.**

**A new spreadsheet model has thus been created to provide a first approximation. The model calculates the reduction in distribution losses caused by delaying a proportion of peak demand from the domestic single-rate customer class. The overall effect seems surprisingly small, calling into question the benefits of seeking to change profile shapes specifically in order to reduce distribution losses.**

Losses may be defined simply as the difference between units entering and units exiting (distributed by) the network. By this definition losses on the United Utilities network accounted for 6.46% of units distributed in 2000/01 and 5.49% in 2004/05.

The variable or resistive component of losses at a given voltage level is proportional to the square of the power ie

$$\text{resistive losses} \propto \int [P(t)]^2 dt, \text{ or } \propto \sum_t [P(t)]^2,$$

where the power $P$ may take different values in each half-hour time period $t$.

The main domestic customer group of single-rate customers has a strong daily peak and was associated with nearly 42% of electricity distributed but more than 56% of all losses in 2000/01 on the United Utilities network. The model investigates the effect of altering the power consumption profile for this customer class. Unless the value of the reduction is truly significant, it is not worthwhile to consider in detail what technical, regulatory and behavioural changes might be needed to cause the change in profile shape.

*Rita Shaw is a Research Engineer on the Engineering Doctorate Programme in Environmental Technology supported by the EPSRC. The supervisors for the work are Mike Kay at United Utilities and Tim Jackson at RESOLVE in the University of Surrey. United Utilities holds a DNO licence to own and operate the electricity network serving 2.2 million customers from 132kV to 230V in the north west of England.*

The model combines historical data on assumed losses for three voltage bands (LV, HV and EHV), actual network power flows and the national consumption profiles of the domestic single-rate customer class. Power flow data series were set up for forty-eight half-hour periods on each of fifteen representative days. The fifteen representative days covered weekday, Saturday and Sunday for five 'seasons'.

Figure 2 shows the type of profile change analysed by the model – for the time periods which reach 90% of the maximum expected power demand, the top 10% is delayed by 8.5 hours. The scale of the delay and delay time are however both chosen variables in the model. The percentage reduction in variable losses after the profile shift is given by the percentage change in the area under the curve in Figure 3. At LV, a simplifying assumption is made that different circuits serve different customer types. Thus the overall shape of the power flow at LV for domestic-single rate customers is approximately given by the consumption profile. At HV and EHV, account is taken of the effect on the total power flow of serving other customer classes apart from domestic single-rate.

For each generic voltage level for a year, the percentage reduction in variable losses is found by comparing the sum of the squares of the typical power flows for the year. In each case the variable losses will be proportional to the sum of the power flows over the 48 half-hour periods $t$ and then weighted by a factor $w_i$ according to the frequency of occurrence of each of the 15 profiles $i$ through the year. Thus *at each given voltage level*, the percentage reduction in variable losses between power series $P_A$ and $P_B$ is given by

$$\frac{\sum_i^{15} w_i \sum_t^{48} P_{Ait}^2 - \sum_i^{15} w_i \sum_t^{48} P_{Bit}^2}{\sum_i^{15} w_i \sum_t^{48} P_{Ait}^2}.$$

The percentage reductions at each generic voltage level are then applied to the total variable losses at each generic voltage level to find the overall loss reduction (Table 1).

From the model, the feasible net loss reduction appears small, even if the methodology is likely to slightly underestimate the effect. Delaying by 4 hours 15% of the energy demanded by these customers in peak periods would reduce total network losses by 0.8% or 13 GWh on the United Utilities network in 2000/01. This is equivalent to delaying nearly 5% of all the energy delivered to the domestic single-rate customer class or 2% of the energy delivered to all customer classes. If the United Utilities network is assumed representative of Great Britain, the scaled-up energy saved would be around 160 GWh per year. This is equivalent to the output of generation capacity of 37MW operating at 50% load factor, or around £10m per year at 7p/kWh spread over around 20 million households on single-rate tariffs.

Note. The analysis presented here has concentrated on distribution losses, but a flatter domestic demand profile would also reduce the required amount of peak generation, distribution and transmission network capacity, the operational costs of generation and transmission system electrical losses.

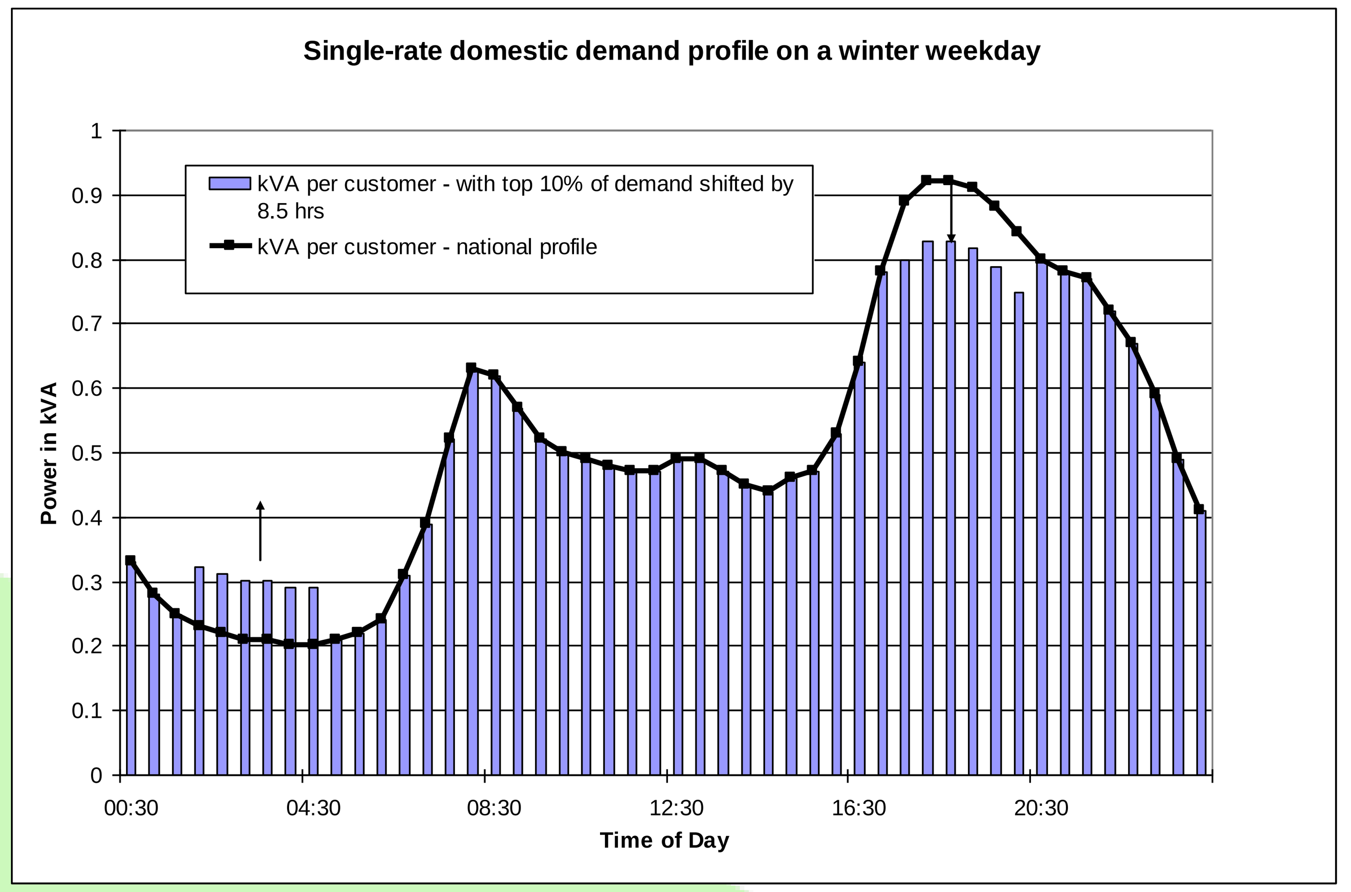


**Figure 2. National demand profile for single-rate domestic customers, with delay applied to a proportion of peak demand**

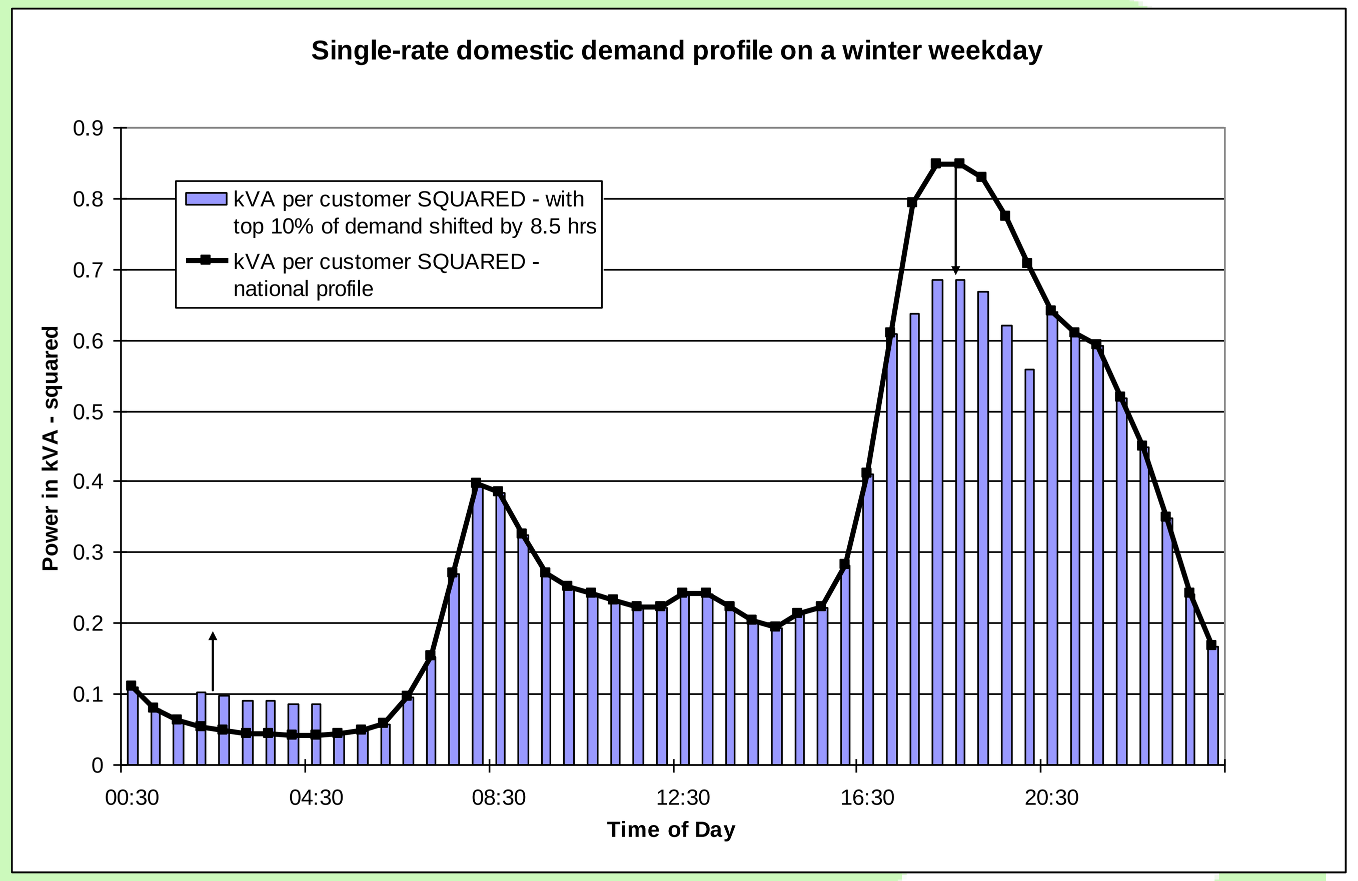


**Figure 3. Square of the national demand profile for single-rate domestic customers, with delay applied to a proportion of peak demand**

| | ORIGINAL Fixed GWh | ORIGINAL Variable GWh | ORIGINAL Total GWh | NEW Variable GWh | NEW Total GWh | NEW Reduction GWh |
|---|---|---|---|---|---|---|
| **EHV** | 105 | 339 | 444 | 337 | 442 | 2 |
| **EHV (DG)** | 0 | 76 | 76 | 76 | 76 | 0 |
| **HV** | 75 | 283 | 358 | 281 | 355 | 2 |
| **LV** | 229 | 475 | 703 | 466 | 695 | 8 |
| **Total** | **409** | **1172** | **1581** | **1159** | **1568** | **13** |
| | | | *Reduction* | 13 | 13 | |
| | | | *Reduction* | 1.1% | 0.8% | |

**Table 1. Predicted effect on 2000/01 losses of a change in profile shape for domestic single-rate customers where the top 15% of peak demand is delayed by 4 hours. Losses are allocated by network voltage, rather than by customer group.**