UKERC
UK Energy Research Centre

Challenges for the decarbonisation of heat: local gas demand vs electricity supply Winter 2017/2018

Briefing note by Dr Grant Wilson, Dr Ramsay Taylor and Dr Paul Rowley

Summary

This briefing note summarises Great Britain's local gas demand from the 2nd of April 2017 to the 6th of March 2018 and compares this to electrical supply. The data covers the UK cold weather event on the 1st March, providing insights into the scale of hourly energy flows through both networks.

A peak hourly local gas demand of 214 GW occurred at 6pm on the 1st of March, which compared to a peak electrical supply of 53 GW occurring at the same time.

The data highlights a critical challenge – managing the 3-hour difference in demand from 5am to 8am on the local gas network during the heating season. Whilst flexibility in the gas system is provided using a change in pressure to store extra energy in the network to meet increasing demand, the electrical system has no comparable intrinsic equivalent.

The findings add to previous work funded by UKERC on thermal energy storage[i], heat incumbency[ii], and flexibility of electrical systems[iii] to provide insights into the decarbonisation of heat in Britain, helping to inform decision-making, modelling of future networks and highlighting key areas for future research and innovation.

A greater research and innovation focus to reduce the 5am-8am 3-hour difference in heat demand is necessary.

Local gas demand data

Hourly local distribution zone gas data from the four gas network companies: Cadent, Northern Gas Networks, SGN, and Wales and West Utilities, was made available for analysis within the project. This proprietary data was combined to make an hourly aggregated data set for Britain.

The data, provided as units of volume in thousand standard cubic metres of gas (kscm), was converted to units of energy by using a calorific value of 11 kWh (39.6 MJ) per standard cubic metre of gas. This data shows the actual hourly local gas demand from final users connected to the distribution network, including domestic heating, cooking and hot water, small industry, the commercial and service sector, and embedded combined heat and power plants. The local gas demand does not include gas demands directly connected to the high-pressure gas transmission system: interconnectors, power stations, storage and large industrial users.

Electrical supply data

The electrical supply data is available from Elexon and National Grid websites. The Elexon data details the half-hourly values for different types of electrical generation or imports that supply electricity to the electricity transmission system. If the interconnectors are net exporters or pumped storage is charging at any half-hourly period i.e. taking electricity from the system, the value is set to zero rather than a negative value. The sum of electrical supply values will therefore include demand from exports and will be an overestimation of the British electrical demand at these times. The National Grid electrical data has half-hourly estimates for solar photovoltaic and wind generation connected at the electrical distribution level. This 'embedded' generation was added to the Elexon data to give a total value for the electrical supply for each half-hour, which was resampled to hourly data.

Peak characteristics of the local gas and national electricity systems

The characteristics and physical operation of gas and electrical networks are quite different; it is therefore instructive to compare the scale of energy flows through both networks. As most local network demand for gas in Britain is driven by space and water heating, the data provides insights into the challenges of heat decarbonisation, helping to inform decision making and modelling of future networks.

Table 1

	Entire electricity system	Gas demand from local gas networks	Gas to electrical ratio
Peak Daily demand (GWh over a day)	1076 GWh 28-02-2018	3920 GWh 01-03-2018	3.6
Peak Hourly demand (GWh over an hour) See Figures 1 and 2	53 GWh 01-03-2018 18:00	214 GWh 01-03-2018 18:00	4.0
Highest 1-hour difference in demand	+8 GW 14-12-2017 06:00	+61 GW 05-02-2018 06:00	7.6
Highest 3-hour difference in demand See Figure 3	+16 GW 13-11-2017 05:00	+116 GW 28-02-2018 05:00	7.3

Table 1: Summary of peak rates of entire electrical supply and local gas demands, 2nd April 2017 to 6th March 2018.

Figure 1

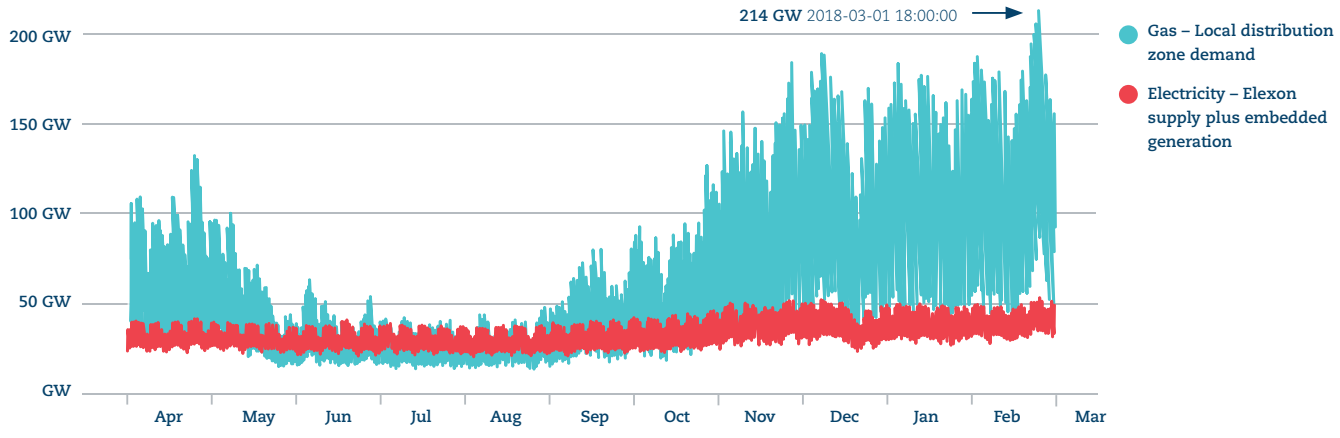

Figure 1: Britain's hourly local gas demand and electrical system supply, 2nd April 2017 - 6th March 2018.

Figure 2

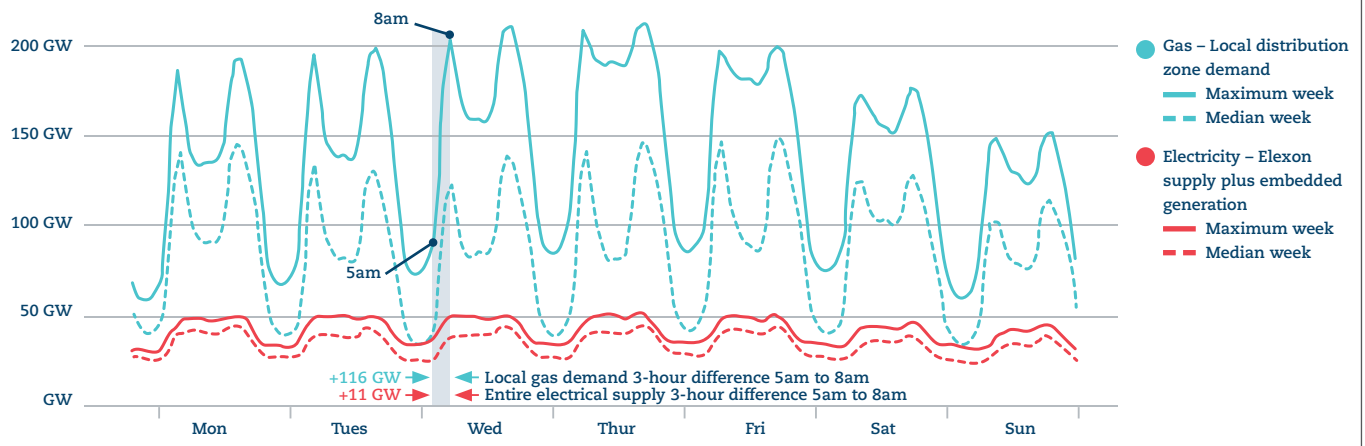

Figure 2: Britain's local gas demand and electrical system supply - median and maximum demand weeks. The week dating 22nd to 28th January is the median demand week for the 2017–2018 heating season. The week dating 26th February to 5th March represents the maximum demand week of the 2017–2018 heating season.

Median gas demand week

Figure 2 shows two gas demand weeks - the week beginning Monday the 22nd of January 2018 is the median demand week over the October 2017 to March 2018 heating season. It also depicts the week beginning Monday the 26th of February 2018 that had the maximum weekly local gas demand of the heating season.

Looking at Figure 2 the hourly local gas demand profile has the following characteristics:

- a rapid increase in demand from 5am to 8am each day;
- a morning peak at 8am and an evening peak at 6pm or 7pm, with a pronounced trough across the middle of the day;
- the width of the evening peak is wider than the morning peak;
- the demand falls away sharply to an overnight minimum at 3am; and
- at weekends, the morning and evening peaks can be less than weekdays; the trough across the middle of the day may also be less pronounced.

Maximum gas demand week

The 'Beast from the East' is the popular name given to the cold weather event in Britain that lasted from late February into early March 2018. This weather event subjected a number of the local gas distribution zones to a 1 in 20-year demand. For the others, it represented the peak demand of the 2017/2018 heating season. The British peak hourly local gas demand of 214 GW took place at 6pm on March 1st (Figure 1 and Figure 2).

Earlier that day, National Grid (the gas system operator) forecast that total gas demands could outstrip supplies; there was a risk that the pressure in the gas transmission system could drop below the safety limit by the end of the gas day (5am on March 2nd). It therefore issued a Gas Deficit Warning for the first time since 2008 alerting the market to this risk. The forecast drop in pressure was averted as market players brought more gas onto the system and withdrew less gas from the system than was originally forecast.

During the week beginning February 26th, the Monday and Tuesday had a typical working day hourly cold weather local gas demand profile. By Wednesday, the peak demands had continued to increase, and the trough over the middle of the day (11am to 3pm) was less pronounced. Peak demand occurred at 6pm on Thursday March 1st, with the 8am and 6pm peaks at almost the same level as the day before (approximately a 4 GW increase). However, the trough over the middle of the day was much shallower than the other weekdays; in addition, the overnight minimum had increased to 86 GW. This combination meant that the overall daily demand for this Thursday was the highest of the heating season at 3920 GWh and was the day that National Grid issued the gas deficit warning.

On Friday March 2nd, there was a similar shallower trough profile as Thursday, but the morning and evening peaks were smaller than the previous two days. The demands over the weekend were lower still.

Two potential factors could explain the shallower troughs on Thursday and Friday:

1. The cold weather meant that buildings were losing heat more rapidly. Gas heating systems were providing greater amounts of heat to maintain a particular internal temperature. In more moderate conditions heat loss from buildings takes longer, and heating systems can therefore lower their output for greater periods of time.
2. School and business closures caused by the disruption to transport from snow meant that more people were at home, and heating would be required throughout the day.

3-hour difference in demand

The 3-hour difference in demand represents the change in demand over a 3-hour period e.g. if the gas demand at 5am is 80 GW and at 8am it is 150 GW then the 3-hour difference in demand is +70 GW. For local gas demand the 5am to 8am period is nearly always the greatest 3-hour difference in demand for each day. Wednesday the 28th of February had the heating season's highest 3-hour difference for local gas demand at +116 GW, values are summarised in Table 2.

Table 2

	5am value GW	8am value GW	3-hour difference GW
Local gas demand	89	205	+116
Entire GB electrical supply	38	49	+11

Table 2: The 2017/2018 heating season's peak 3-hour local gas difference in demand, Wednesday 28th of February 2018

The 3-hour difference in demand was investigated further to see if the peak values were atypical of the heating season. In Figure 3, the 3-hour differences from 5am to 8am are shown for each day from April 2nd 2017 to March 6th 2018. The analysis shows the 3-hour difference in demand is above +60 GW for 82% of the days, above +80 GW for 61% and above +100 GW for 24% of the days from October to March. In comparison, the highest value for the electrical 3-hour supply difference is +16 GW (5am-8am on November 13th) and is above +12 GW for 86 % of the days.

Figure 3

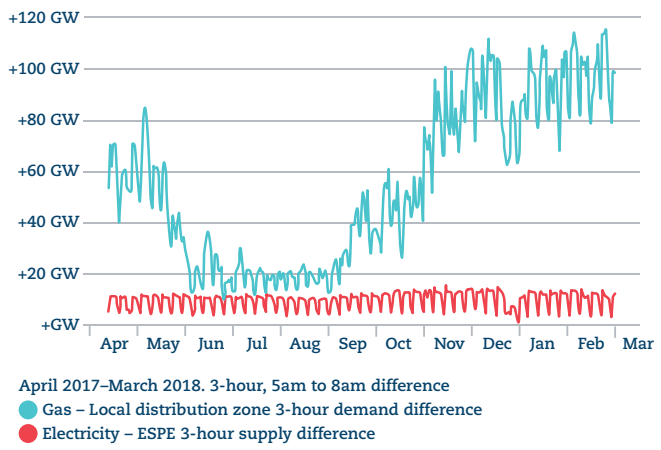

Figure 3: Britain's 3-hour difference in demand/supply, 5am - 8am, 2nd April 2017 to 6th March 2018

Potential policy and research implications

This research illustrates the scale of the increase in demand from Britain's local gas networks in comparison to that of the entire electrical supply over the 3-hour period from 5am to 8am. The difference of this local gas demand at over +100 GW for nearly 25% of days during the heating season highlights a formidable challenge to be addressed in the transition to decarbonise heat.

The significant difference in demand is currently met through a change in pressure within the higher pressure tiers of the gas system. Gas pipeline infrastructure has the capacity for significant levels of inherent energy storage by increasing the overnight gas pressure. This allows additional gas to be stored closer to final end users, ready for the sharp increase in their demand at 5am each morning. In comparison, the electrical grid has no inherent means of storing electricity within the delivery infrastructure itself (the electrical cables).

An obvious implication is that if heat demand was simply shifted from the gas network to the electrical network, this would transfer much of these differences in demand to the electrical grid too, representing a significant challenge.

This analysis highlights the increasing importance of measures that target and reduce the 5am-8am difference in local gas demand, which is predominantly driven by the demands for heat. Increasing insulation in new builds and greater amounts of retrofit insulation would help reduce this demand regardless of the type of lower-carbon heating systems adopted. Previous UKERC research and progress reports from the Committee on Climate Change[iv] has consistently highlighted the many advantages of decreasing heating demand, and this research suggests an additional wider system benefit.

Alongside reduced overall demand, thermal storage of various kinds will undoubtedly play a much greater role in future systems to help smooth the difference in demand, as will other technical solutions such as hybrid heat-pumps using renewable gas and hydrogen based technologies. However, as a multi-disciplinary challenge, the concurrency of heat demand or thermal routines[iv] from a behavioural perspective also needs to be further explored.

More detailed evidence is required to better understand what types of behavioural and technological interventions can help to mitigate the scale of the 5am to 8am difference in demand, and what their relative advantages and disadvantages are. This requires an increased focus and funding for the wider research and innovation community to help address these key questions.

About UKERC
The UK Energy Research Centre (UKERC) carries out world-class, interdisciplinary research into sustainable future energy systems. It is a focal point of UK energy research and a gateway between the UK and the international energy research communities.Our whole systems research informs UK policy development and research strategy. UKERC is funded by The Research Councils Energy programme.

www.ukerc.ac.uk **Follow us @UKERCHQ** 10 Princes Gardens, London SW7 1NA ukercpressoffice@ukerc.ac.uk +44 (0) 207 594 1574

[i] Eames, P., Loveday, D., Haines, V. and Romanos, P. (2014) The Future Role of Thermal Energy Storage in the UK Energy System: An Assessment of the Technical Feasibility and Factors Influencing Adoption - Research Report (UKERC: London)
[ii] Woodman, B., Lowes, R. (2018) Incumbency in the UK heat sector: Implications for policy (UKERC: London)
[iii] Bell, K., Hawker, G. (2016) Security of electricity supply in a low-carbon Britain (UKERC: London)
[iv] Committee on Climate Change. (2018) Reducing UK emissions 2018 Progress Report to Parliament
[v] Hanmer, C., Shipworth, M., Shipworth, D. et al. Energy Efficiency (2018). https://doi.org/10.1007/s12053-018-9632-x