Smart Energy Research Lab: Energy use in GB domestic buildings 2022 and 2023

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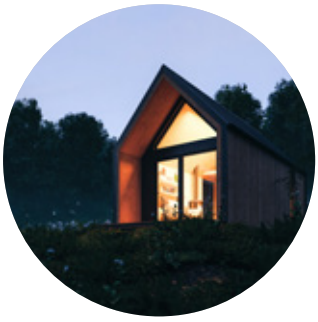

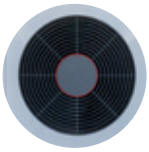

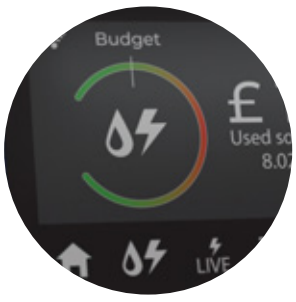

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Energy use in GB domestic buildings 2022 and 2023

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1
Executive summary

This report – Volume 2 of the SERL Statistical Reports Series – describes domestic gas and electricity energy use in Great Britain in 2022 and 2023 based on data from the Smart Energy Research Lab (SERL) Observatory, which consists of smart meter and contextual data from approximately 13,000 homes that are broadly representative of the GB domestic building stock along a range of geographic, building and socio-demographic characteristics.

The report provides an update to the statistics provided in Volume 1 of the SERL Statistical Report Series (Few *et al.*, 2022), which covered 2021 data, and analyses residential energy use in GB in 2022 and 2023 (over the whole year, in each month and half-hourly over the course of the day). Statistics are presented for groups of homes with specific occupant characteristics (number of occupants, tenure), property characteristics (age, size, form, and Energy Performance Certificate (EPC)), heating systems, photovoltaics and electric vehicles, and by weather, region and IMD quintile. Unless otherwise noted, the findings in the report relate to homes in the SERL Observatory that use gas as their main heating source and do not have photovoltaic (PV) electricity generation.

The report also shows how metered residential energy use in GB varies over time from 2021 to 2023.

Key findings include:

1. On average across the whole SERL Observatory sample between 2021 to 2023, electricity and gas use were highest in 2021, when mean external temperature was lower. Average electricity and gas use was slightly lower in 2023 than 2022 on average, and the mean external temperature was very similar in both years.

2. The shapes of mean diurnal profiles were very similar between 2021 and 2023 for homes with gas heating and without PV. Daytime use was slightly higher in 2021 than the following two years.

3. In 2023, the median D-rated home (the GB average) in the SERL Observatory sample used 17% more gas per m^2 and 3% more electricity imports per m^2 than the median C-rated home (the target band for many homes in England, Wales and Scotland by 2035).

4. In 2023, median gas use for homes over 200 m^2 was more than quadruple that for homes less than 50m^2, while electricity imports were more than triple. The mean pattern of electricity use overnight in the largest homes is consistent with significant presence of overnight electric vehicle charging. Mean average overnight lows of electricity use in the largest homes were greater than mean peak use in the smallest homes. Note that floor area is likely to be closely related to occupancy and affluence.

5. Comparing median energy use, detached houses used 49% more gas and 33% more electricity than the average terraced house in 2023. However, after normalising for floor area the proportional difference was much lower, detached homes used 6% more gas per m^2 and 3% less electricity per m^2 than terraced homes.

6. In 2023, homes built between 1900 and 1929, used 31% more gas and 1% less electricity than the newest homes, built since 2003, when comparing median energy use. After normalising for floor area, homes built between 1900 and 1929 use 33% more gas per m^2 than the newest homes, and an equal amount of electricity per m^2.

7. Homes with PV exported a median of 10.0 kWh/day of electricity back to the grid on average in June 2023, and imported 3.4 kWh/day. Meanwhile, in December 2023, households with PV exported only 0.4 kWh/day on average and imported 8.7 kWh/day. The median electricity use for a home without PV was 8.0 kWh/day in December 2023 and 5.8 kWh/day in June 2023.

8. Homes with electric vehicles used a median of 70% more electricity than homes without. The mean electricity profile for homes with electric vehicles showed maximum use at 1 am, with this peak gradually reducing until 6 am, after which the pattern of electricity use was like those homes without electric vehicles.

9. Across the whole SERL Observatory sample the mean annual metered gas use across GB in 2021 was 10% greater and annual electricity use was 2.5% greater than reported by NEED for England and Wales in 2021. However, statistics in NEED are not directly comparable as they are for different time periods (mid-May 2021 to mid-May 2022 for gas, February 2021 to January 2022 for electricity), also the gas figures are weather corrected and NEED data is provided for England and Wales separately from Scotland. Overall, this suggests that the SERL Observatory annual energy consumption is broadly consistent with other national datasets

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2 Introduction

We are delighted to release the first publicly available analysis of the 6th edition of the SERL Observatory data (UKDS SN 8666), with data until the end of 2023. We would like to thank the 13,000+ homes in the SERL Observatory panel, largely representative of the GB domestic population by region and IMD quintile, who have consented to the use of their data for scientific research.

This report is produced by the Smart Energy Research Lab (SERL), a UKRI/EPSRC-funded research project to provide access to gas and electricity smart meter data for the UK research community. More information about SERL, including how to apply to use the data, can be found on our website: www.serl.ac.uk.

This report is the second in a regular series of reports, analyses and aggregated statistics using SERL Observatory data, which we hope will be of interest to academics, government, NGOs and commercial organisations. This data is unique in terms of demonstrating the seasonal and diurnal (within-day) variation of gas and electricity use in British dwellings and how it varies with region, external temperature, occupancy, local deprivation (as measured by Index of Multiple Deprivation), building size, age, form, building efficiency (as measured by Energy Performance Certificates - EPCs), heating system and electric vehicles (EVs). Subject to funding, similar analysis will be updated annually to track changes in domestic energy use over time.

This report provides statistics from 2021 to 2023, a period with significant national and international events: the third national Covid19 lockdown took place between January and March 2021, there were unprecedented rises in domestic energy prices through 2022 including as a result of Russia's invasion of Ukraine in February 2022, and inflation was over 10% in the UK between September 2022 and March 2023. All of these will have had impacts on domestic energy use. The previous report explored energy use in 2021 in detail (Few *et al.*, 2022). This and following reports will provide an indicator of high-level changes in domestic energy use over time. However, we have also conducted and published in depth analysis of the impact of these events on domestic energy use.

In response to the Covid-19 pandemic we issued a tailored questionnaire to SERL participants to understand the impacts of the pandemic on their energy use. This data is available in the SERL Observatory dataset and Huebner *et al.* (2021) provides analysis of the results. Zapata-Webborn *et al.* (2023) undertook counterfactual analysis to quantify the impact of the pandemic on domestic energy use, finding that gas use increased by 5.7% and electricity use increased by 7.8% in the first year of the pandemic on average for homes in England and Wales.

Similarly, SERL has been investigating energy use over the winter 2022/2023. SERL Observatory participants were invited to take part in a follow-up survey in February 2023, tailored to understand the impacts of the rising costs of domestic energy on their consumption. Huebner *et al.* (2023) provides analysis of the questionnaire responses, and the data is available as part of the 6th edition of the SERL Observatory data. Both Zapata-Webborn *et al.* (2024) and McKenna *et al.* (2024b) [forthcoming] used counterfactual modelling to quantify the difference between winter 2021/2022 energy use and winter 2022/2023 energy use, using machine learning and building physics-based models respectively. Both studies found relatively similar changes in energy use, with Zapata-Webborn *et al.* reporting a mean reduction of 7.1% and 11.7% for electricity and gas respectively compared to the previous winter, and McKenna *et al.* reporting a mean reduction of 9.1% and 14.9% for electricity and gas respectively. Moreover, McKenna *et al.* (2024a) [forthcoming] analysed tariff data finding that despite the reduction in gas and electricity use, energy expenditure rose by 60.5% for electricity and 127% for gas.

This report provides a wide range of statistics for different groups within the SERL Observatory sample between 2022 and 2023, similar to that provided in the first report which reported on energy use in 2021 (Few *et al.*, 2022). The aim is to summarise how energy use changes over years, months, days and half-hours in a format others may find useful and to demonstrate the validity and value of the SERL Observatory data. We have tried to provide a range of useful graphical representations, and we welcome recommendations for revisions to the content for future SERL reports (contact info@serl.ac.uk). The following section briefly describes the methods used to derive the data and results found in this

report, and detailed information is provided in the Appendix. Alongside this report we are also releasing a dataset of aggregated statistics and associated documentation, available via the UK Data Service Study Number 8963, which contains far more results than we could include in this report. We are also providing an excel spreadsheet of the statistics which are presented in this report (available via: https://serl.ac.uk/key-documents/reports/).

We anticipate that the results reported here will raise far more questions than they answer, and we encourage researchers to access both the aggregated statistical dataset and the high resolution controlled (secure access) dataset to undertake additional analysis utilising the full set of contextual variables available in the SERL Observatory dataset. The SERL Observatory data is described in detail by Webborn *et al.* (2021), full SERL Observatory documentation is available via UKDS (SN 8666), and details of how to apply to use the data are available on the SERL website.

Only metered gas (i.e. mains gas) and electric energy is reported in our analysis. Many of the homes in the SERL Observatory will use forms of un-metered energy, for example LPG, oil, coal, wood, etc. which are not currently included in the SERL data. In the case of homes with PV, we collect both import and export electricity data, and also calculate net electricity, i.e. the amount the household has imported minus the amount it has exported. Note that while SERL data measures imported and exported electricity in homes that have microgeneration, it does not measure electricity generated. This means that we are unable to calculate the gross electricity demand for these households nor their self-consumption (how much of the electricity they generate is used within their home rather than exported to the grid). For the majority of the analysis presented in this report, we are presenting data from the subset of SERL Observatory homes which have mains gas as their main form of heating and do not have PV in order to aid interpretation of the results.

We recommend care when interpreting the data presented in this report as it has not been weighted to account for sample design and non-response bias, nor normalised with respect to differences in weather. We have normalised energy use by floor area (m^2) and by number of occupants and have presented the normalised statistics alongside energy use statistics in much of the analysis presented here. Where normalised statistics are not presented, they are available in the aggregated statistical dataset that we are releasing alongside this report. Fully accounting for how factors correlate requires more detailed multivariate analysis which is outside the scope of this report but which we have started to publish elsewhere (McKenna *et al.*, 2022).

We are looking to continuously improve the quality of our outputs and we would welcome feedback on potential errors (contact info@serl.ac.uk). Any corrections will be published on our website.

2.1 SERL Observatory dataset and analysis for this report

The SERL Observatory contains smart meter data and linked contextual data for over 13,000 homes in GB. Full details of the Observatory data set are available in Webborn *et al.*, (2021) and full documentation is available via the UKDS (SN 8666). The SERL Observatory is made up of six core datasets:

- electricity and gas smart meter data
- weather data
- SERL survey data (an initial sign-up survey, and occasional follow-up surveys)
- EPC data (for approximately half the sample)
- tariff data
- location data

Participants were recruited in three waves; Figure 1 shows the number of SERL participants over time. For information about the recruitment process see Webborn *et al.* (2021, 2022). Historic smart meter data for up to 12 months prior to recruitment was collected where possible, so the earliest smart meter data dates from August 2018.

The aim was to recruit households in proportions representative of the number of households in different regions of GB and within different Index of Multiple Deprivation (IMD) quintiles. The IMD is an area-based metric which ranks LSOAs (Lower-layer Super Output Areas) from least deprived to most deprived using a range of domains including income, employment, education and health care. The IMD ranking is converted into quintiles, with IMD quintile 1 reporting the most deprived 20% of LSOAs and IMD quintile 5 the 20% least deprived. Figure 2 shows that the 6th edition SERL sample is largely representative of GB regions within 1%, although Wales and Yorkshire are about 3% under- and over-represented respectively. Similarly, Figure 3 shows that the 6th edition SERL sample is representative of IMD quintile, with a maximum deviation of 1.7% over-representation for IMD quintile 2 (second least deprived quintile). Webborn *et al.* (2021) discusses the representativeness of the SERL Observatory sample along other building and sociodemographic characteristics.

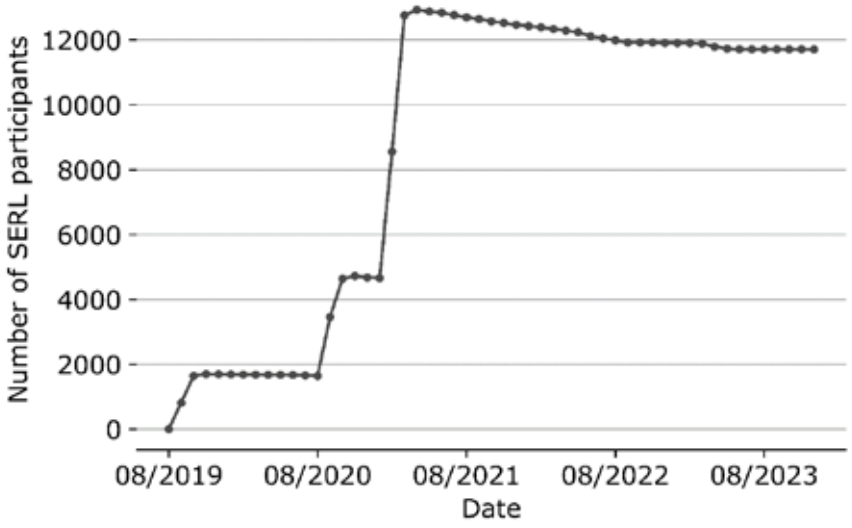


Figure 1. Number of SERL participants over time

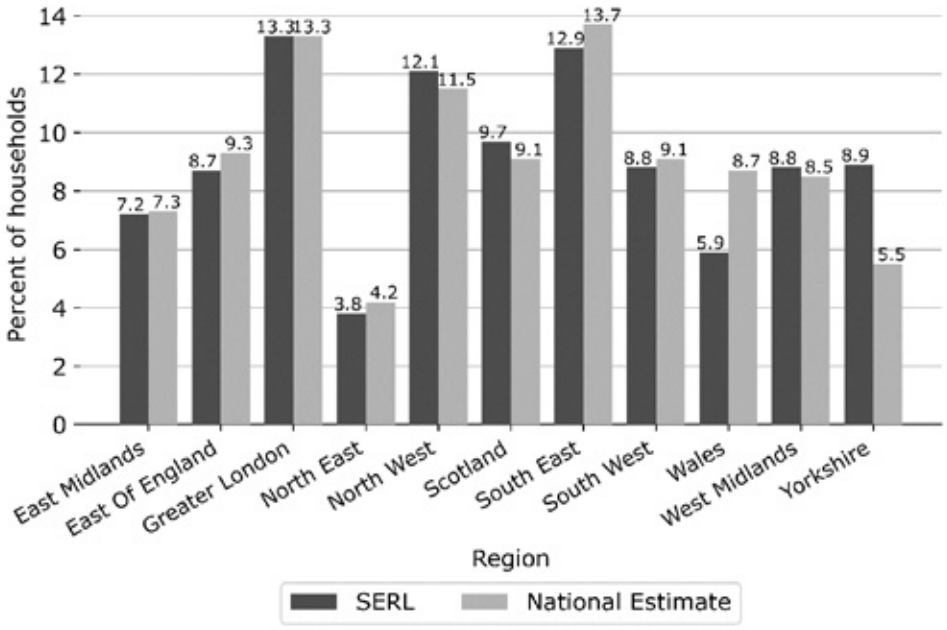


Figure 2. Percentage of SERL Observatory households in each region, compared with a national estimate from Address Base.

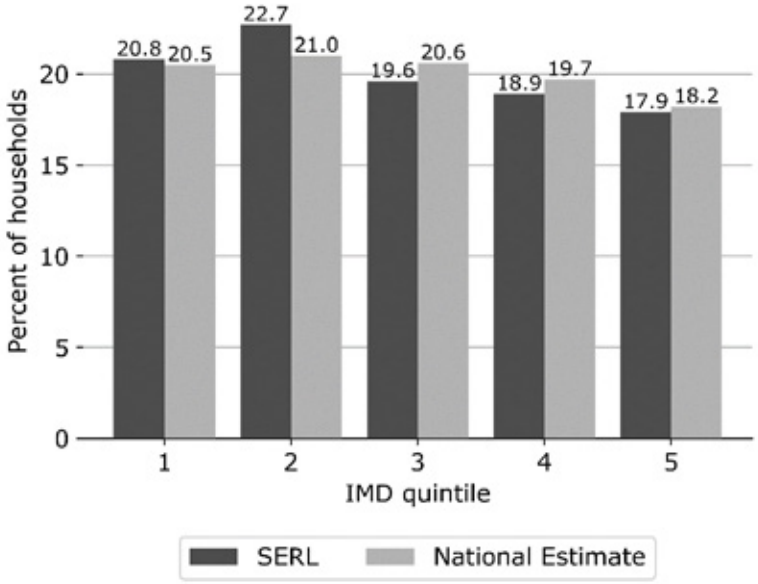


Figure 3. Percentage of SERL Observatory households in each IMD quintile compared with a national estimate from Address Base.

In this report we draw on each of the datasets within the SERL Observatory to provide an overview of energy use by SERL participants. The analysis for this report used the SERL Observatory 6th edition. The majority of the report relates to 2022 and 2023, although some data for 2021 is presented for comparison between the years. We present the energy use for the whole SERL Observatory sample (13,209 homes), as well as broken down into different groups of homes. We first break down by heating system type, separating gas heated (10,560 homes) and electrically heated homes (719 homes), and then by presence of PV (726 homes had PV in 2023). We then segment by key contextual variables including location-based variables (region and IMD quintile), ranges of mean external temperature, EPC variables (energy efficiency rating and floor area), survey variables (building type, building age, central heating system, number of occupants, EV ownership).

- Details of the data processing used to derive the results in this report are available in the Appendix and we will shortly make the code available via the SERL GitHub. However, a brief outline of the process is provided here to explain the process of generating the statistics presented in this report, the following steps were taken:
- Smart meter data underwent standard SERL data quality processing; see the SERL smart meter documentation at UKDS (SN 8666).
- Net electricity use (imports minus exports) was calculated for dwellings where microgeneration is present[1].
- For each household:
  - The mean energy use per month for each fuel was calculated for total daily use as well as use in each half hour, if at least 50% of the data was available.
  - The mean energy use per day and for each half hour for each fuel was calculated for 5°C bands of mean daily external temperature from 5°C to 0°C, to 20°C to 25°C. As above, the mean was calculated only if at least 50% of the data was available for the given temperature band.
  - If the monthly energy use was available for all 12 months, then the mean of these (weighted by number of days in the month) was calculated and reported as the mean annual energy use for the household (over daily and half hourly periods). This ensures that any period of missing data does not unreasonably skew the annual result.
- This provides a distribution of mean energy use per household in the SERL Observatory over different time periods which may be further segmented by selected contextual variables; the statistics presented in this report are drawn from these distributions. For example, the median annual consumption presented below is the median of the mean energy consumption per household in the Observatory.
- Finally, to comply with Statistical Disclosure Control (SDC) requirements that all statistics are based on at least 10 observations. The percentile statistics are the mean of the 10 observations closest to the true percentile value. This affects median, upper, and lower quartile statistics in this report.

Alongside the energy use data, we also provide normalised energy use statistics. For example, energy use was divided by the household's floor area and by the number of occupants to provide energy use per m^2 and energy use per occupant. The normalised statistics are then calculated in the same way as the energy use statistics. Floor area is available for SERL Observatory participants who have an EPC (8226 households). The number of occupants (available for 12,544 households) is taken from the initial sign-up survey. This means that the sample is different for each of the units and caution in interpreting the results is required as a result.

We provide statistics related to the weather alongside the energy statistics for each group of households. We provide the mean external temperature, mean heating degree days (HDD)[2] to a base temperature of 15.5°C, and mean solar irradiance. These are noted in the report below where they are of particular relevance and are provided within the aggregated data that accompanies this report. The temperature, HDD and solar irradiance are calculated per household using the same time periods as used to calculate the energy statistics.

The smart meter data used as part of this report is originally provided as energy used (or generated) over a half hourly or daily period for electricity, and volume used for gas. We have converted this to kWh/day and mean kWh/h (effectively the power rating) for this report. The time stamps reported are local time and correspond to BST in the summer and GMT in the winter.

Finally, note that the figures presented in this report use fixed y-axis limits for each type of figure. This is to facilitate comparisons between figures across the report.

The aggregated statistics underlying this report are available here: https://serl.ac.uk/reports

The full SERL Observatory data can be accessed by UK researchers following an application process: more details can be found at https://serl.ac.uk/researchers/.

1 Microgeneration was identified on a yearly basis and assumed to be present in homes which exported electricity for at least one half hour period in that year.

2 Heating degree days is a measure of the extent to which external temperature over a given period fell below a level below which central heating is assumed to be required (in the UK, commonly taken to be 15.5°C). The heating degree day values are calculated based on the hourly external temperature data.

3
Annual energy use over time

3.1
Full sample

Table 1 summarises the key energy consumption statistics for all participants in the SERL Observatory between 2021 and 2023. Mean gas use was between 38.7 kWh/day and 29.1 kWh/day. This is larger than the mean electricity import of between 10.1 kWh/day and 8.5 kWh/day, as most dwellings in the UK (and in the SERL Observatory) use gas for space and water heating. Median gas and electricity use is lower than the mean and this reflects the typically skewed distribution of energy use in a sample of dwellings. The sample size for electricity is larger than that for gas in all years. This is partly because there are fewer DCC-enrolled gas smart meters (which we require for collection of gas data) than DCC-enrolled electricity meters, and partly because some dwellings are not on the gas grid and so do not have gas meters.

	Mean	25th percentile	Median	75th percentile	Sample size	Mean external temperature	Mean heating degree days
Units		*kWh/day*			-	*(ºC)*	
Electricity import 2023	8.5	4.7	7.0	10.3	8,830	11.2	5.1
Electricity import 2022	8.8	5.0	7.3	10.7	8,880	11.3	5.1
Electricity import 2021	10.1	5.6	8.3	12.3	10,790	10.4	5.7
Gas 2023	29.1	17.3	26.0	37.0	7,500	11.2	5.1
Gas 2022	30.4	18.4	27.2	38.4	7,590	11.3	5.0
Gas 2021	38.7	24.1	34.8	48.2	7,960	10.4	5.7

Table 1. Summary statistics of the distribution of mean energy consumption per day per participant in years 2021 to 2023.

Changes in domestic energy use over time are related to many complex and interacting factors from the household level up to national and international factors. Over the years 2021 to 2023 there were notable differences in weather, with 2021 being almost 1°C cooler on average in Great Britain than 2022 and 2023. There were also broad societal factors: the beginning of 2021 saw the third national Covid-19 lockdown from January to March, with a gradual easing of lockdown restrictions over spring and summer 2021[3] (House of Commons Library, 2021). In February 2022 Russia launched its full-scale invasion of Ukraine, and domestic energy prices in the UK rose sharply over the latter part of 2021 and through 2022 (House of Commons Library, 2024). This led the UK Government to implement several energy bill support schemes over the winter 2022/2023. Rising energy prices also drove up inflation in the UK, which was over 10% between September 2022 and March 2023 (ONS, 2024). The factors above, and many more, will have affected the ways people used energy in their homes over these three years.

Table 2 compares the annual energy consumption statistics for homes in the SERL Observatory in the years 2021 to 2023 with the most recently published NEED annualised meter data for 2021 (DESNZ, 2023). The only year for which the two datasets overlap is 2021, and in this year the mean gas use is 10.3% larger in the SERL sample than NEED. However, there are several important differences between the datasets:

- NEED gas data for 2021 refers to annualised gas use between mid-May 2021 and mid-May 2022 whereas SERL data for 2021 refers to the calendar year.
  - Note that mean SERL metered gas use in 2022 (the first 4.5 months of which are included in NEED 2021) was 13.2% lower than NEED 2021.
- NEED gas data is corrected for weather so that years can be compared, SERL data is not.
- NEED gives statistics for England and Wales separately from Scotland, whereas SERL includes Scottish homes which generally experience colder weather than England and Wales.

	Data source	Mean	25th percentile	Median	75th percentile
Units	–			*kWh/year*	
Gas	SERL 2023	10,610	6,310	9,490	13,510
Gas	SERL 2022	11,110	6,700	9,910	14,020
Gas	SERL 2021	14,120	8,810	12,720	17,590
Gas	NEED 2021	12,800	7,700	11,500	16,400
Electricity import	SERL 2023	3,110	1,730	2,250	3,770
Electricity import	SERL 2022	3,200	1,810	2,660	3,910
Electricity import	SERL 2021	3,690	2,050	3,030	4,500
Electricity	NEED 2021	3,600	1,800	2,800	4,300

Table 2. Summary energy use for all homes in the SERL Observatory in 2021-2023 compared to NEED 2021 energy use statistics for England and Wales

3 Health is a devolved matter in the UK and each nation had slightly different lockdown dates and restrictions.

Although the SERL and NEED data cannot be directly compared, given the differences between the datasets the values are in reasonable agreement.

The mean imported electricity is 2.5% larger for the SERL sample than NEED for 2021. NEED electricity data for 2021 is annualised for the period February 2021 to January 2022, whereas the SERL data covers the 2021 calendar year. Table 2 reports electricity import statistics for both the SERL and NEED data but note that some of the homes will have solar PV so for these homes the imported electricity is not the same as the total electricity used in the home (electricity exports and net electricity use also are available for the SERL homes).

We note that NEED data has been shown to be in good agreement with other data sources (BEIS, 2021), suggesting that SERL would also show good agreement with these data sources. For comparison, in 2021 Ofgem used a medium Typical Domestic Consumption Value (TDCV) of 12,000 kWh/year for gas and 2,900 kWh/year for electricity profile class 1[4] (ofgem.gov.uk, 2022). In 2023 these were updated to 11,500 kWh/year for gas and 2,700 kWh/year for electricity (ofgem.gov.uk, 2023).

3.2 Monthly energy use between 2021 and 2023

Figure 4 shows the median of the daily mean energy use per participating household in each month between January 2021 and December 2023, alongside the mean external temperature and solar irradiance. Households included in this figure have gas central heating and do not have PV. Gas use varies substantially by month, with consistently high gas use in winter and lower gas use in summer months, as expected for this group of homes as they use gas as their main form of space heating. Summer gas use is likely associated with hot water heating and cooking and may also include some space heating.

The overall highest monthly gas use occurred in January 2021 with median daily use of 74.4 kWh/day, which also corresponds with the lowest mean daily temperature of 3.6°C. Early January 2021 also saw the beginning of the third Covid-19 lockdown across GB. The overall lowest monthly gas use occurred in August 2022 with median daily use of 4.5 kWh/day, which corresponds with the highest mean temperature of 18.5°C.

Monthly electricity use shows far smaller variation than for gas. Nonetheless, electricity use is also higher in winter months and lower in summer months. Higher use in winter may be associated with increased electricity use for electric supplementary heating, increased lighting, increased preparation of hot meals and hot drinks, and possibly increased indoor activities. Lower electricity use in the summer also indicates that use of electric air conditioners remains relatively uncommon in GB homes. The overall highest median electricity use coincided with that for gas, in January 2021 at 9.7 kWh/day. Meanwhile, the overall minimum median electricity use of 5.8 kWh/day occurred in June 2023.

The monthly statistics presented here show that electricity and gas use vary considerably over time across the SERL Observatory sample. Gas use in particular shows a strong relationship with external temperature. However, this does not fully explain differences in energy use between years, for example January 2022 and 2023 had very similar temperature and solar irradiance, but both gas and electricity use were lower in January 2023 than January 2022. It should also be noted that this analysis presents all

4 Electricity profile class 1 is domestic unrestricted customers, not on Economy 7 meters.

homes for which sufficient data is available in each month, it does not require that the same households contribute to every month. Detailed analysis to understand how much of the change in energy use is due to variations in weather conditions and how much can be attributed to other factors is an active area of research.

Several analyses of the SERL Observatory data have explored this, both in relation to the impact of Covid-19 (Zapata-Webborn *et al.*, 2023) and the rising energy prices in the winter of 2022/2023 (McKenna *et al.*, 2024b; Zapata-Webborn *et al.*, 2024).

Table 3 below presents minimum and maximum energy consumption values for each year presented in Figure 4 left.

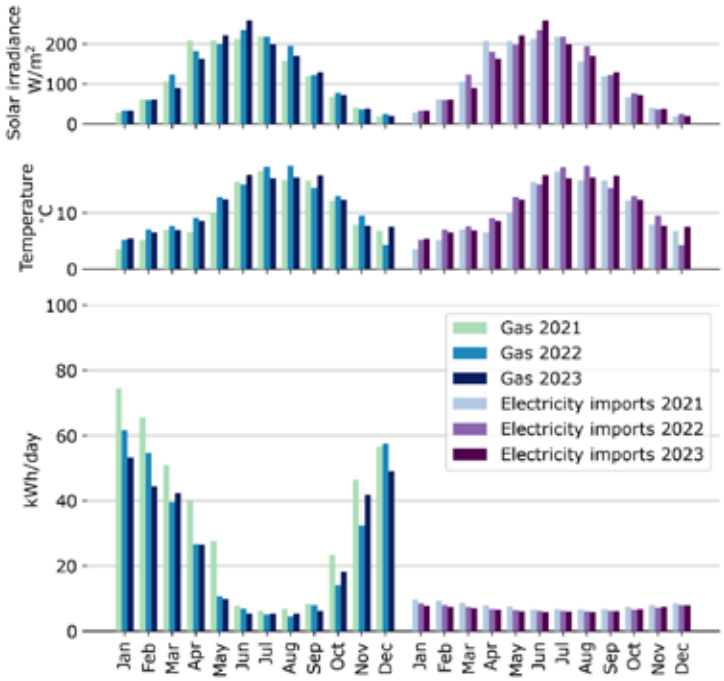


Figure 4 Median gas and electricity imports per day in each month from January 2021 to December 2023 for homes in the SERL Observatory with gas heating and without PV.

Quantity	Minimum	Month for min. value	Temp. for min. value	Maximum	Month for max. value	Temp. for max. value	Year
Electricity	6.6 kWh/day	June	15.5 °C	9.7 kWh/day	January	3.5 °C	2021
Electricity	6.0 kWh/day	August	18.4 °C	8.5 kWh/day	January	5.2 °C	2022
Electricity	5.8 kWh/day	June	16.8 °C	7.9 kWh/day	December	7.5 °C	2023
Gas	6.2 kWh/day	July	17.5 °C	74.4 kWh/day	January	3.6 °C	2021
Gas	4.5 kWh/day	August	18.5 °C	61.7 kWh/day	January	5.2 °C	2022
Gas	5.4 kWh/day	August	16.4 °C	53.3 kWh/day	January	5.5 °C	2023

Table 3 Summary statistics for Figure 4

3.3 Annual energy use within external temperature bands between 2021 to 2023

In all years 2021 to 2023, both gas and electricity use increased with decreasing external temperature (Figure 5). Across both electricity and gas, for almost all temperature bands, energy use was greatest in 2021 and lowest in 2023. The 10°C to 15°C temperature band was the only exception, where gas use was lowest in 2022. Note that slightly different samples will have contributed to the statistics in each year, as participants are included in the years for which they have sufficient data. Also note that the average temperature within a band is usually the mid-point of the band, but for the warmest and coolest bands the average may be skewed toward milder temperatures if there were relatively few days of very warm or very cold weather in the year. Nonetheless, the results suggests that energy use was considerably greater in 2021 than the following years on days with similar temperatures, possibly associated with the third national Covid-19 lockdown between January and March 2021. The 'cost-of-living crisis' and higher domestic energy costs likely contributed to decreased energy use in both 2022 and 2023. As noted above, further analyses of the change in energy use over time has been published using the SERL Observatory has been published (McKenna *et al.*, 2024b; Zapata-Webborn *et al.*, 2023, 2024).

For all years, gas use increased steeply with decreasing temperature. Gas use increased by more than 15 times (1400%) from days with average temperatures between 20 °C and 25 °C to days with average temperatures between -5 °C and 0°C in all years. Electricity use also increased between the same temperature bands, however only by between 30% and 50%. The homes presented in this analysis use gas boilers as their main heating source, and the strong temperature dependence of gas demand is largely due to its use for space heating; gas use on warmer days is associated with cooking, hot water heating and some residual space heating. Increased electricity consumption on colder days may be partly due to shorter daylight hours resulting in increased lighting use in the winter.

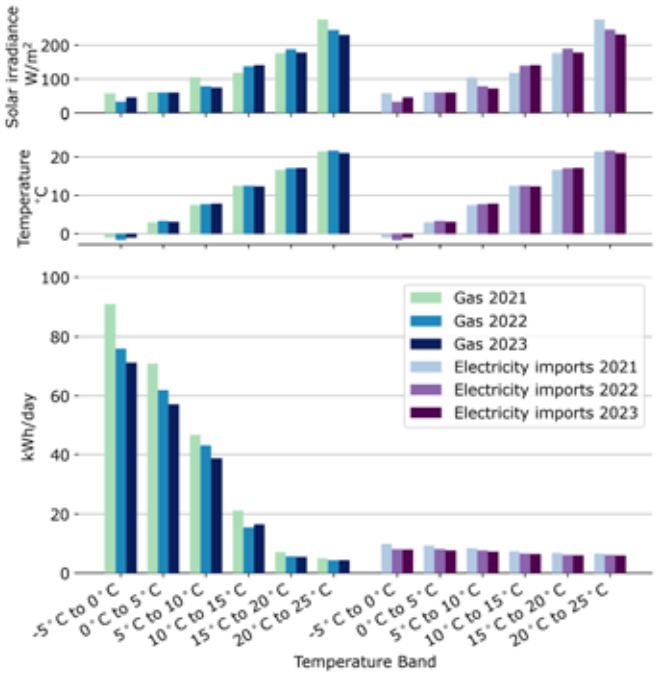


Figure 5 Median gas and electricity imports per day for days falling within different ranges of mean external temperature for homes in the SERL Observatory with gas heating and without PV, for years 2021 to 2023.

Table 4 presents minimum and maximum energy consumption values for each year and temperature band presented in Figure 5.

Quantity	Minimum	Temp. band for min. value	Maximum	Temp. band for max. value	Year
Electricity	6.6 kWh/day	20 °C to 25 °C	9.8 kWh/day	-5 °C to 0 °C	2021
Electricity	6.1 kWh/day	20 °C to 25 °C	8.2 kWh/day	0 °C to 5 °C	2022
Electricity	5.9 kWh/day	20 °C to 25 °C	8.0 kWh/day	-5 °C to 0 °C	2023
Gas	5.0 kWh/day	20 °C to 25 °C	90.9 kWh/day	-5 °C to 0 °C	2021
Gas	4.3 kWh/day	20 °C to 25 °C	75.9 kWh/day	-5 °C to 0 °C	2022
Gas	4.4 kWh/day	20 °C to 25 °C	71.2 kWh/day	-5 °C to 0 °C	2023

Table 4 Summary statistics for Figure 5

3.4 Diurnal energy use between 2021 and 2023

Figure 6 shows the median of the mean gas use in each half hour per household in years 2021 to 2023. The overall shape is very similar in all years, with a steep rise in gas consumption from 06:00 until the morning peak at around 07:30. This is followed by a decrease through the day, with a very small peak around 12:30, possibly associated with lunch time cooking. There is then a shallower rise than the morning increase, up to an early evening peak, at around 18:00, which is of similar magnitude to the morning peak. Gas use decreases after this to very close to zero overnight, from midnight until about 05:00. 2022 and 2023 show very similar median gas consumption throughout the day, along with very similar temperature profiles. 2021 shows higher median gas consumption from early morning, around 06:00, to late evening, around 23:00. The temperature was notably cooler in 2021, which will have significantly contributed to the increased daytime gas use. As noted above, the impact of Covid-19 lockdowns, the cost-of-living crisis, and other factors will also have affected the use of energy in homes throughout this period.

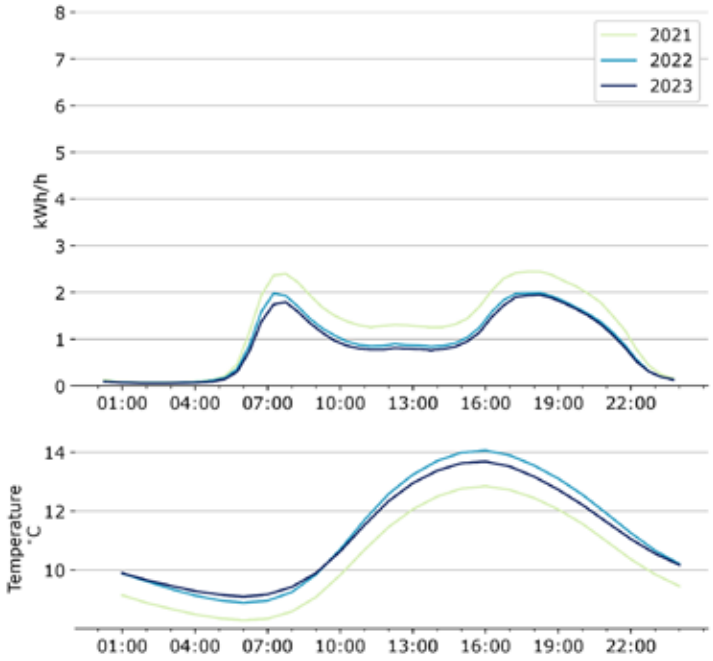


Figure 6 Profiles of median gas use for homes in the SERL observatory with gas central heating and without PV in years 2021 to 2023.

Table 5 presents minimum and maximum energy consumption values for the years presented in Figure 6.

Quantity	Minimum	Time of min. value	Temp. for min. value	Maximum	Time of max. value	Temp. for max. value	Year
Gas	0.08 kWh/h	02:30	8.7 °C	2.45 kWh/h	18:00	12.1 °C	2021
Gas	0.07 kWh/h	03:00	9.1 °C	1.99 kWh/h	18:30	13.1 °C	2022
Gas	0.06 kWh/h	02:30	9.5 °C	1.95 kWh/h	18:30	12.7 °C	2023

Table 5 Summary statistics for Figure 6

Figure 7 shows the median of the mean electricity use in each half hour per participant in years 2021 to 2023. The overall patterns are very similar for each year. Median electricity use increases from an overnight low at about 04:30 to a steady morning consumption between about 07:30 and 09:00. This is followed by a slight rise between about 12:00 and 14:00, possibly associated with lunch time cooking. Median electricity use then falls slightly in the early afternoon, before rising steeply to peak use at around 18:30. Following the peak, electricity use reduces gradually over the evening and into the early hours of the next morning.

The median electricity profile is very similar for 2022 and 2023, alongside a very similar temperature profile for these two years. 2021 shows higher electricity consumption from early morning, around 07:30, until approximately midnight. 2021 was cooler than the other two years, and this may have had an impact, alongside the impact of the Covid-19 lockdowns and cost-of-living crisis over this period.

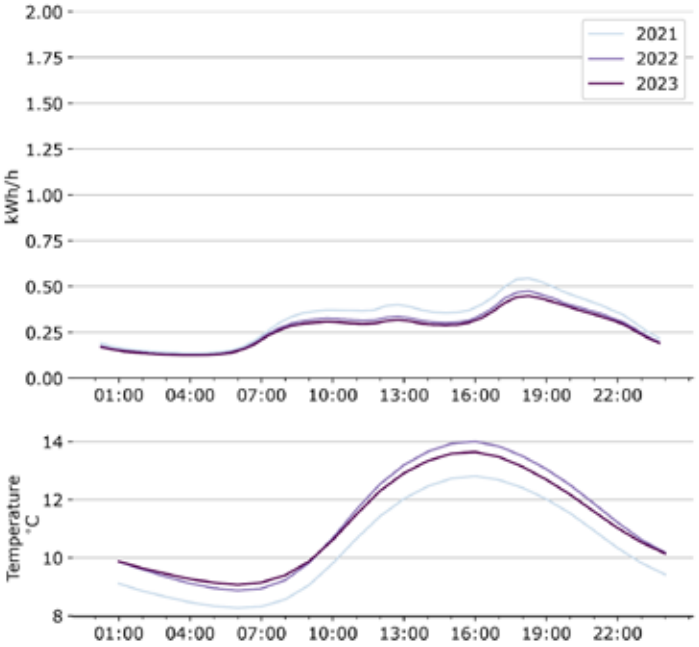


Figure 7 Profiles of median electricity imports for homes in the SERL observatory with gas central heating and without PV in years 2021 to 2023

Table 6 below presents minimum and maximum energy consumption values for the years presented in Figure 7 above.

Quantity	Minimum	Time of min. value	Temp. for min. value	Maximum	Time of max. value	Temp. for max. value	Year
Electricity	0.14 kWh/h	04:30	8.3 °C	0.54 kWh/h	18:30	12.0 °C	2021
Electricity	0.13 kWh/h	04:30	9.0 °C	0.48 kWh/h	18:30	13.0 °C	2022
Electricity	0.13 kWh/h	04:30	9.1 °C	0.45 kWh/h	18:30	12.7 °C	2023

Table 6 Summary statistics for Figure 7

4
Energy use in 2023

4.1
Annual energy use

4.1.1
Annual energy use by region

Figure 8 presents median daily gas and electricity consumption per home for 2023 by region. Median gas consumption is similar between most regions, although the South West and Wales have notably lower consumption. Median electricity consumption is similar between all the regions. There is not a clear relationship between the coolest regions and energy consumption, even for gas, the primary space heating fuel in these homes. The South West, for example, has the highest mean external temperature and the lowest median gas consumption; however Scotland, which has the lowest mean external temperature, has a middling median gas consumption (the fifth lowest). Similarly, there is no clear pattern for electricity consumption in different regions, Scotland has the lowest electricity imports and the South East has the highest. Differences between regions are likely to be a result of combinations of differences between building types, floor areas, affluence, weather and other factors.

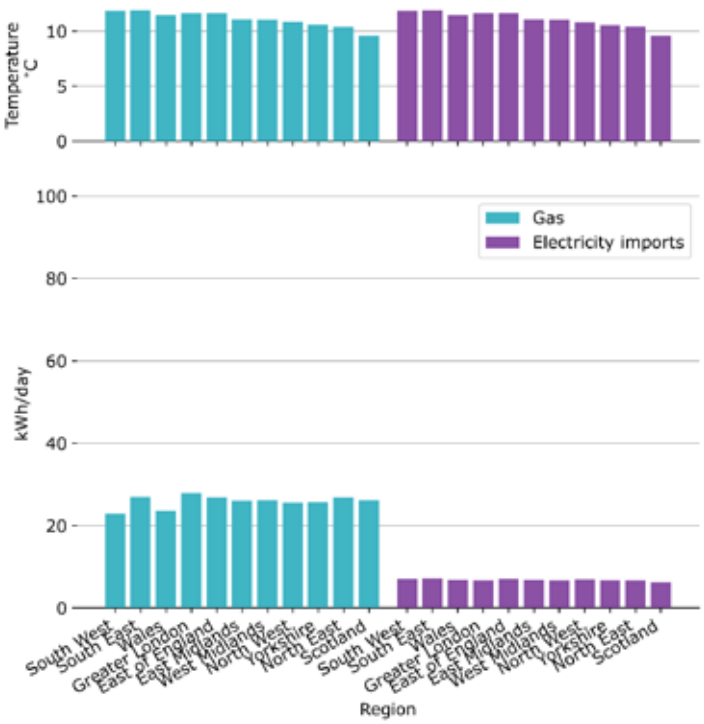


Figure 8. Median consumption of gas and electricity imports for homes in the SERL Observatory within different regions of Great Britain. Bars are arranged from left to right from the highest to lowest mean external temperature in 2021 (for consistency with volume one of the SERL statistical report). These homes have gas central heating and do not have PV. The upper plot shows the mean daily external temperature for the sampled homes in each region.

Table 7 below presents minimum and maximum energy consumption values by region as presented in Figure 8 above.

Quantity	Minimum	Region with min. value	Temp. for min. value	Maximum	Region with max. value	Temp. for max. value	Year
Electricity	6.3 kWh/day	Scotland	9.6 °C	7.2 kWh/day	South East	11.9 °C	2021
Gas	22.8 kWh/day	South West	11.9 °C	27.9 kWh/day	Greater London	11.6 °C	2022

Table 7 Summary statistics for Figure 8

4.1.2
Annual energy use by IMD (Index of Multiple Deprivation) quintile

Both electricity and gas consumption increase with higher IMD (i.e., lower deprivation) quintiles in 2023, see Figure 9. Decreasing deprivation shows a strong trend with increasing gas consumption both per household and per occupant. When gas consumption is calculated per m^2 of floor area however, the relationship to deprivation is relatively weak. This suggests that much of the increase in gas use in less deprived areas is largely associated with homes having higher floor areas. There is a similar trend of decreasing deprivation with increasing electricity use and electricity use per person, but no clear relationship with electricity use per m^2.

As noted in Section 2.1, normalised statistics relate to different sample of households due to the availability of contextual data (floor area is available for approximately half the sample, and number of occupants for over 95%). As a result care should be taken in comparing the results for different units.

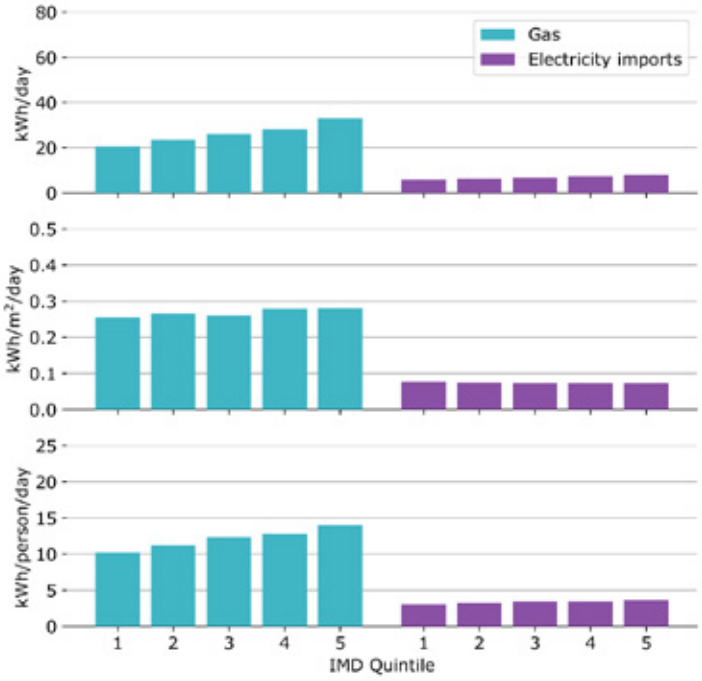


Figure 9 Median consumption of gas and electricity imports for homes in the SERL Observatory by IMD quintile in 2023. These homes have gas central heating and do not have PV.

Table 8 below presents minimum and maximum energy consumption values for the IMD quintiles presented in Figure 9 above.

Quantity	Minimum	IMD quintile for min. value	Maximum	IMD quintile for max. value
Electricity	5.9 kWh/day	1	8.0 kWh/day	5
Electricity	0.07 kWh/m^2/day	3, 4, 5	0.08 kWh/m^2/day	1
Electricity	3.1 kWh/person/day	1	3.6 kWh/person/day	5
Gas	20.6 kWh/day	1	33.0 kWh/day	5
Gas	0.26 kWh/m^2/day	1	0.28 kWh/m^2/day	5
Gas	10.2 kWh/person/day	1	14.0 kWh/person/day	5

Table 8 Summary statistics for Figure 9

4.1.3
Annual energy use by EPC energy efficiency rating

Approximately 60% of the SERL Observatory sample have an EPC and for these homes, gas use decreases with improving EPC energy efficiency rating according to all metrics in this analysis (Figure 10). Homes rated F & G are an exception to this trend per household and per m², however, it should be noted that the sample is relatively small (90 F & G-rated homes), and that the majority of F & G-rated homes use fuels other than gas for central heating[5]. Since the figure below includes only gas centrally heated homes, the F & G homes in this group may be unusual.

Electricity imports increase from band C to E for electricity use per household and per occupant, while bands C to E have very similar electricity use per m². Groups A & B, and F & G, have the lowest and highest electricity use per occupant respectively, but do not follow a clear trend with efficiency rating across the other metrics. Groups A & B, and F & G, have the joint lowest electricity use per m², and fall in the middle of the groups for electricity use per household. However, it should be noted that most A & B-rated homes have PV, whereas those presented in these figures do not, so these A&B homes may be unusual. As above, the F & G homes may be unusual because they have gas central heating while most would not have this form of heating. The sample sizes are also small for both of these groups (170 for A & B, and 100 for F & G).

Table 9 below presents minimum and maximum energy consumption values for the EPC bands presented in Figure 10 above.

The average home in GB is D-rated (DHSG, 2020; ONS, 2021) while the government ambition is for as many homes as possible to reach at least a C-rating by 2035 in England and Wales (HMG, 2017). In Scotland the ambition is for social housing to reach at least a B-rating by 2032 and for other homes to reach a C-rating by 2033 (Scottish Government, 2021). The median D-rated home in the SERL Observatory sample used 33% more gas per household and 19% more electricity imports per household than the median C-rated home in 2023. Note that the energy efficiency rating is based on cost per m², so the comparing the energy use normalised by floor area is particularly important in this case. After adjusting for floor area, the median D-rated home in the SERL Observatory sample used 17% more gas per m² and 3% more electricity imports per m² than the median C-rated home in 2023. This difference between metrics reflects that D-rated homes are on average larger than C-rated homes. See Few *et al.* (2023) for analysis of the difference between EPC-modelled and metered energy use in the SERL Observatory sample, which shows that there is a significantly smaller change in metered energy use than the modelled change in energy use between EPC bands.

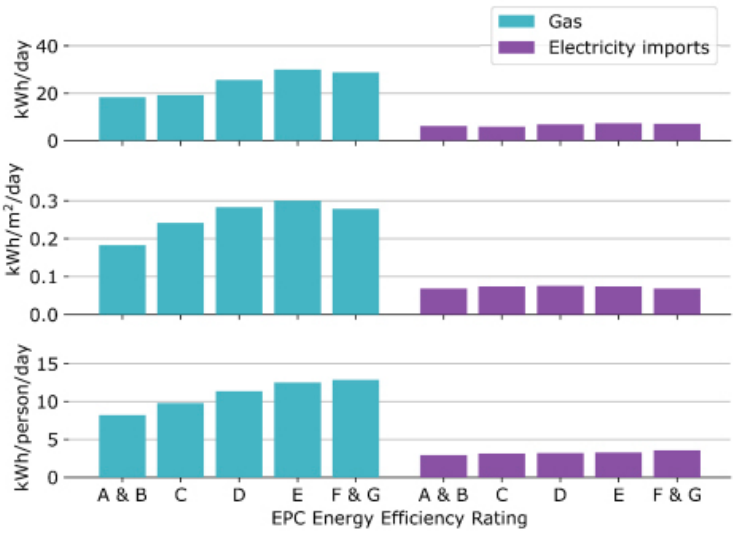


Figure 10 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2023 by EPC energy efficiency rating. These homes have gas central heating and do not have PV.

Quantity	Minimum	EPC rating with min. value	Maximum	EPC rating with max. value
Electricity	5.8 kWh/day	C	7.4 kWh/day	E
Electricity	0.07 kWh/m²/day	A & B, F & G	0.08 kWh/m²/day	D
Electricity	2.9 kWh/person/day	A & B	3.6 kWh/person/day	F & G
Gas	18.2 kWh/day	A & B	29.9 kWh/day	E
Gas	0.18 kWh/m²/day	A & B	0.30 kWh/m²/day	E
Gas	8.2 kWh/person/day	A & B	12.9 kWh/person/day	F & G

Table 9 Summary statistics for Figure 10

5 The EPC energy efficiency rating is based on cost per m², and gas is the cheapest fuel, meaning that the lowest bands are skewed towards homes using fuels other than gas.

4.1.4
Annual energy use by floor area

Median electricity and median gas use per household increased significantly with floor area in our sample (Figure 11) (note that floor area is only available for homes with an EPC record – approximately 60% of the sample). Gas use for homes over 200 m² was more than quadruple that for homes less than 50 m², while electricity imports more than tripled between the same groups. Electricity and gas use per occupant also increased significantly with floor area band. There was a decrease in electricity and gas use per m² with floor area showing that the relationship is not linear, although for gas it is very similar for all bands with floor area up to 150 m². Homes over 200 m² used 22% less gas per m² and 41% less electricity imports per m² than homes with floor area less than 50 m². Floor area is strongly correlated with number of occupants, IMD quintile and building type.

Table 10 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 11 above.

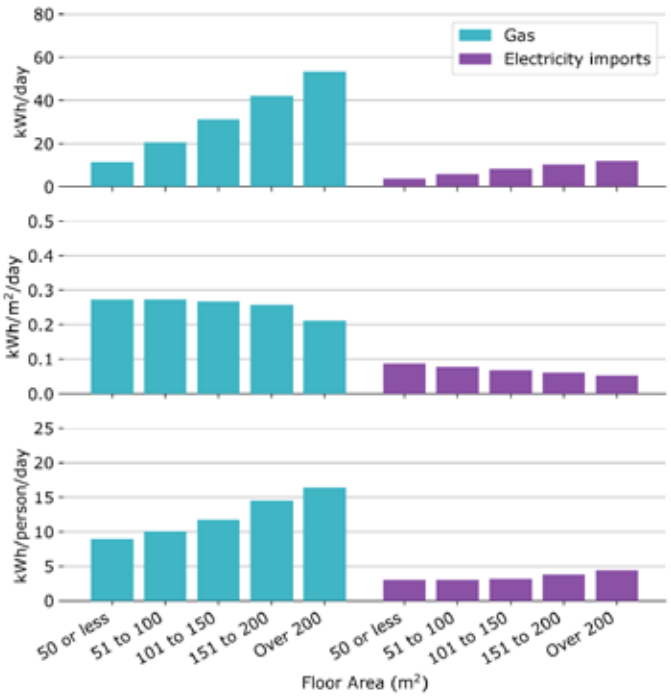


Figure 11 Median consumption of gas and electricity imports for homes in the SERL by floor area in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Floor area with min. value	Maximum	Floor area with max. value
Electricity	3.7 kWh/day	50 m² or less	12.0 kWh/day	Over 200 m²
Electricity	0.05 kWh/m²/day	Over 200 m²	0.09 kWh/m²/day	50 m² or less
Electricity	3.0 kWh/person/day	51 m² to 100 m²	4.4 kWh/person/day	Over 200 m²
Gas	11.5 kWh/day	50 m² or less	53.5 kWh/day	Over 200 m²
Gas	0.21 kWh/m²/day	Over 200 m²	0.27 kWh/m²/day	51 m² to 100 m²
Gas	8.9 kWh/person/day	50 m² or less	16.4 kWh/person/day	Over 200 m²

Table 10 Summary statistics for Figure 11

4.1.5
Annual energy use by building type

Gas and electricity use showed the same pattern with different building types (Figure 12), both per home and per occupant. The median gas use in detached homes was 49% greater than that in terraced homes, and 33% greater for electricity. However, different building types correlate strongly with floor area and number of occupants. The proportional difference between different building types reduces significantly when normalising for floor area, for example detached homes used 6% more gas per m^2 and 3% less electricity than terraced homes. Purpose-built flats showed the lowest use per m^2, while converted flats and shared houses showed the largest gas use per m^2, although it should be noted that the sample for this is relatively small (90 households).

Table 11 below presents minimum and maximum energy consumption values for the building types presented in Figure 12 above.

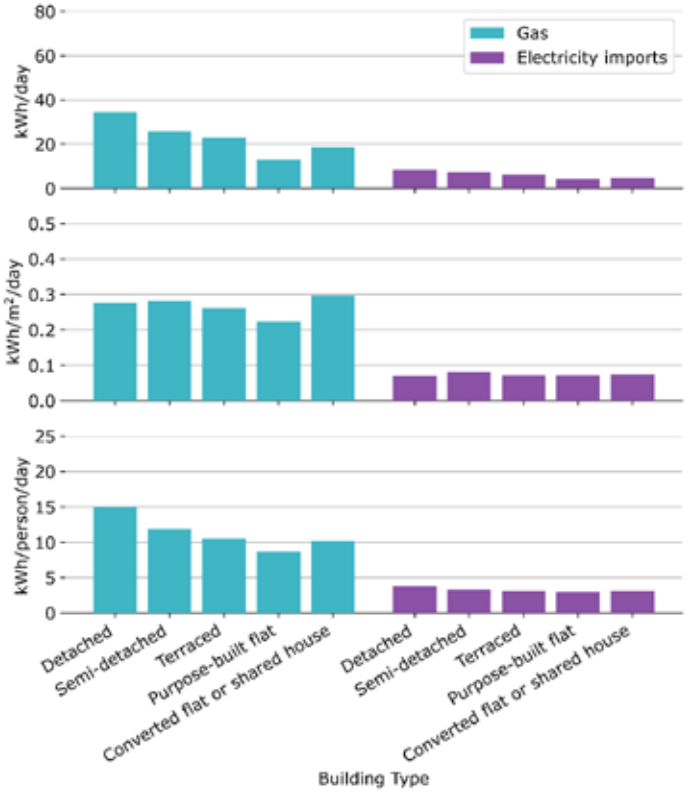


Figure 12 Median consumption of gas and electricity imports for homes in the SERL Observatory by building type[6] in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Building type with min. value	Maximum	Building type with max. value
Electricity	4.3 kWh/day	Purpose-built flat	8.4 kWh/day	Detached
Electricity	0.07 kWh/m^2/day	Detached	0.08 kWh/m^2/day	Semi-detached
Electricity	3.0 kWh/person/day	Purpose-built flat	3.8 kWh/person/day	Detached
Gas	12.9 kWh/day	Purpose-built flat	34.4 kWh/day	Detached
Gas	0.22 kWh/m^2/day	Purpose-built flat	0.30 kWh/m^2/day	Converted flat or shared house
Gas	8.7 kWh/person/day	Purpose-built flat	14.9 kWh/person/day	Detached

Table 11 Summary statistics for Figure 12

6 Categories in this figure are based on participant responses to the following question: "B1. What type of accommodation do you live in? Tick one answer only". Some small categories have been merged for SDC reasons.

4.1.6 Annual electricity use by central heating system

As expected, homes with any type of electric central heating (electric radiators, electric storage radiators or other electric) used more electricity than homes without for all metrics, see Figure 13. However, the proportional difference is much greater for electricity per m^2, which likely reflects the higher prevalence of electric heating in flats, particularly electric radiators and electric storage heaters, which will have relatively small floor areas. Homes with gas boilers, gas boiler plus other and oil, solid fuel or biomass all have very similar electricity import for all metrics. This is expected since these homes do not use any form of electric heating as their main heating source. Note that the gas boiler group is by far the largest group, with over 7,000 households contributing to the kWh/day statistic (reflecting the prevalence of this type of heating). The rest are all less than 500 households and the other electric and district or community groups are less than 100.

Table 12 below presents minimum and maximum energy consumption values for the central heating systems presented in Figure 13 above.

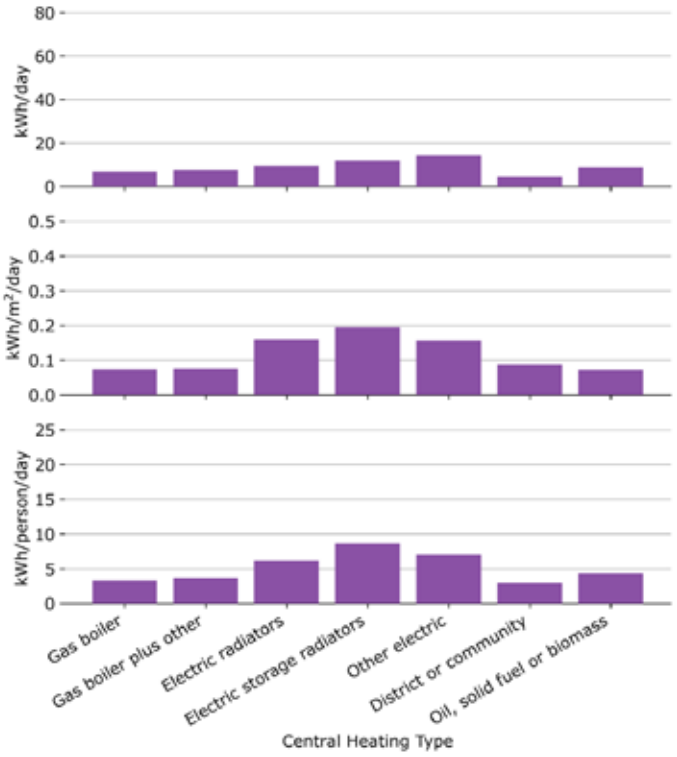


Figure 13 Median consumption of electricity imports for homes in the SERL observatory by central heating system[7] in 2023. These homes do not have PV.

Quantity	Minimum	Central heating type with min. value	Maximum	Central heating type with max. value
Electricity	4.6 kWh/day	District or community	14.4 kWh/day	Other electric
Electricity	0.07 kWh/m^2/day	Oil, solid fuel or biomass	0.20 kWh/m^2/day	Electric storage radiators
Electricity	3.0 kWh/person/day	District or community	8.6 kWh/person/day	Electric storage radiators

Table 12 Summary statistics for Figure 13

7 Categories in this figure are based on participant responses to the following question: "A3. What type of central heating does your accommodation have? By central heating we mean a central system that generates heat for multiple rooms. Tick all that apply whether or not you use it'. Most participants chose only one type of heating, but those that chose multiple forms have been grouped either as 'gas boiler plus other' in this figure, or as 'other mix' in the aggregated statistics provided alongside this report. Some small categories have been grouped for this figure.

4.1.7
Annual energy use by year of building construction

In general, older properties use more gas than modern ones according to all energy metrics in our analysis (Figure 14). Median energy use in homes built between 1900 and 1929 was 31% greater for gas and 1% less for electricity than that in the newest homes, built since 2003. After normalising for floor area, median gas use per m^2 in homes built between 1900 and 1929 was 33% greater than that for homes built since 2003, electricity use per m^2 was equal in these age bands. Homes built before 1950 have very similar gas use per m^2, while homes built after this have lower gas use per m^2. Building Regulations were introduced in 1965 and have been progressively tightened since then. The trends are different for gas use per occupant, which may be associated with differences in typical property sizes, types and occupancy. The most modern homes, built since 2003, show the lowest gas use according to all metrics in this analysis, suggesting higher efficiency in this group. Electricity use shows relatively little variation and no clear pattern with construction age band according to the metrics in our analysis.

Table 13 below presents minimum and maximum energy consumption values for the construction year bands presented in Figure 14 above.

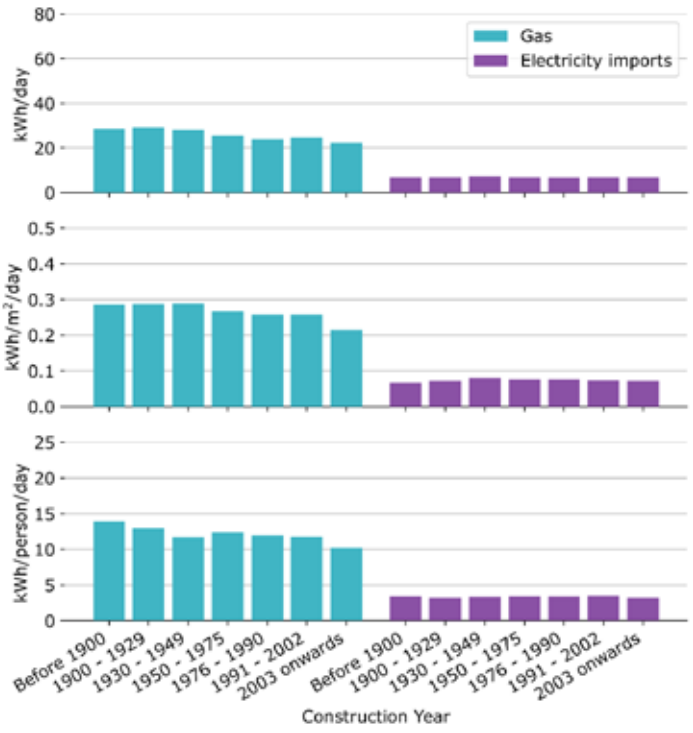


Figure 14 Median consumption of gas and electricity imports for homes in the SERL observatory by construction year bands[8] in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Construction year with min. value	Maximum	Construction year with max. value
Electricity	6.7 kWh/day	1976 - 1990	7.3 kWh/day	1930 - 1949
Electricity	0.07 kWh/m^2/day	Before 1900	0.08 kWh/m^2/day	1930 - 1949
Electricity	3.2 kWh/person/day	2003 onwards	3.5 kWh/person/day	1991 - 2002
Gas	22.2 kWh/day	2003 onwards	29.2 kWh/day	1900 - 1929
Gas	0.22 kWh/m^2/day	2003 onwards	0.29 kWh/m^2/day	1930 - 1949
Gas	10.2 kWh/person/day	2003 onwards	13.9 kWh/person/day	Before 1900

Table 13 Summary statistics for Figure 14

8 Categories in this figure are based on participant responses to the following question: "B9. Approximately when do you think your accommodation was built? Tick one answer only."

4.1.8
Annual energy use by number of occupants

Both gas and electricity use increase with number of occupants (Figure 15). For both gas and electricity, an increase of 1 in the number of occupants shows the greatest increase in energy use when the occupant number increases from 1 to 2, with median gas use increasing by 8.3 kWh/day, and electricity use by 3.2 kWh/day. Gas use per m^2 continues to increase with increasing occupant numbers, even though gas use is largely driven by space heating in the UK. This may be because each additional occupant also requires hot water, which is also largely provided by gas in the UK. Electricity use per m^2 increases with increasing occupant numbers. Gas and electricity use per occupant decrease with increasing occupant numbers, showing that each additional occupant does not increase energy use by the same amount as the one before.

Table 14 below presents minimum and maximum energy consumption values by number of occupants as presented in Figure 15 above.

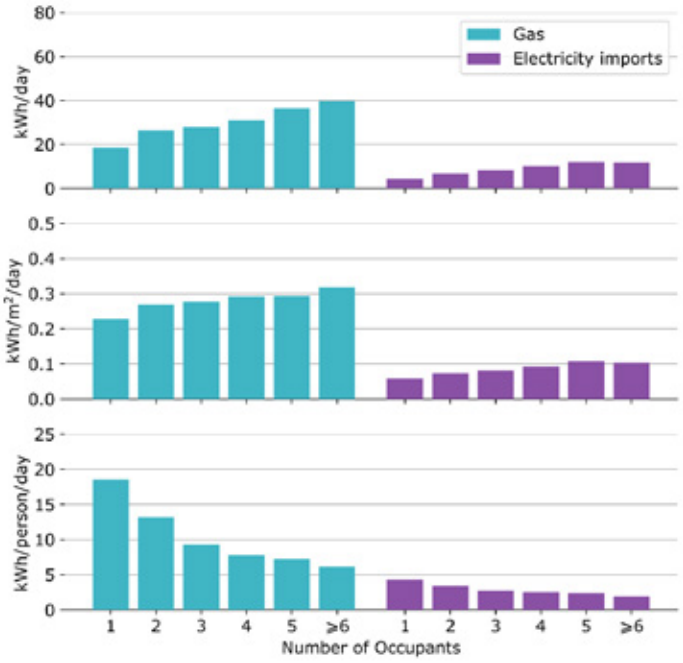


Figure 15 Median consumption of gas and electricity imports for homes in the SERL Observatory by number of occupants[9] in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Number of occupants with min. value	Maximum	Number of occupants with max. value
Electricity	4.2 kWh/day	1	12.1 kWh/day	5
Electricity	0.06 kWh/m^2/day	1	0.11 kWh/m^2/day	5
Electricity	1.9 kWh/person/day	≥6	4.2 kWh/person/day	1
Gas	18.5 kWh/day	1	39.8 kWh/day	≥6
Gas	0.23 kWh/m^2/day	1	0.32 kWh/m^2/day	≥6
Gas	6.2 kWh/person/day	≥6	18.5 kWh/person/day	1

Table 14 Summary statistics for Figure 15

9 Categories in this figure are based on participant responses to the following question: "C1. How many people currently live in your household, including you? Please include all those who are there regularly, even if not every day, including children who live away from home during term time." Large numbers have been grouped into one category for SDC reasons.

4.1.9
Annual energy use by tenure

Homes that are owned outright or with a mortgage and rent-free homes use the most gas by all metrics in this analysis, and have the greatest electricity use and electricity use per person (Figure 16). Gas use per m^2 is similar in all homes of all tenures except those that are part-owned, part-rented which show lower use per m^2. Part-own part-rent is a relatively new form of tenure and so these homes are possibly more modern and efficient buildings.

Homes that are private or social rent have the lowest electricity use per household and per occupant but have similar electricity use to part-own part-rent per m^2. Tenure is likely to be associated with affluence and this may affect the trends for these types of homes.

Note that the rent-free and part-own part-rent groups are both small, with 30 and 50 households in each category respectively for the electricity imports per day statistic. The statistics for these groups are therefore less reliable than the other categories, which all have over 500 or more households.

Table 15 below presents minimum and maximum energy consumption values by tenure as presented in Figure 16 above.

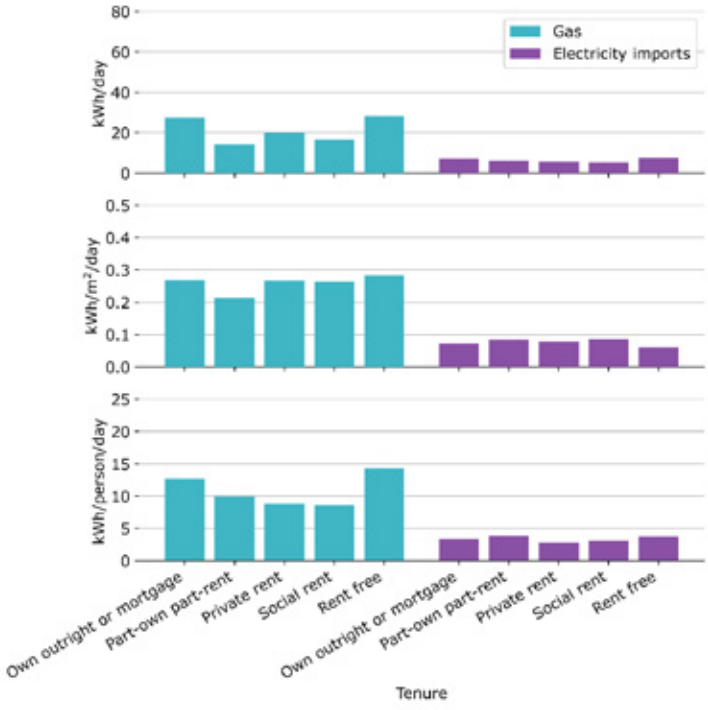


Figure 16 Median consumption of gas and electricity imports for homes in the SERL observatory by tenure[10] in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Tenure with min. value	Max	Tenure with max. value
Electricity	5.2 kWh/day	Social rent	7.5 kWh/day	Rent free
Electricity	0.06 kWh/m^2/day	Rent free	0.09 kWh/m^2/day	Social rent
Electricity	2.8 kWh/person/day	Private rent	3.8 kWh/person/day	Part-own part-rent
Gas	14.2 kWh/day	Part-own part-rent	28.4 kWh/day	Rent free
Gas	0.21 kWh/m^2/day	Part-own part-rent	0.28 kWh/m^2/day	Rent free
Gas	8.6 kWh/person/day	Social rent	14.3 kWh/person/day	Rent free

Table 15 Summary statistics for Figure 16

10 Categories in this figure are based on participant responses to the following question: "B4. Do you (or your household) own or rent this accommodation? Tick one answer only". Some small categories have been merged for SDC reasons.

4.1.10
Annual electricity use by electric vehicle ownership

The median home with an EV used 100% more electricity and 15% more gas than the median home without in 2023 (Figure 17). The gas use per m^2 and per occupant are marginally higher for homes with EVs, which may because households with an EV are likely to be more affluent than those without. As expected, homes with electric vehicles show significantly higher electricity imports per m^2 and per occupant, reflecting the additional electricity load associated with the EV.

Note that this analysis is based on the household's response to a question about EVs when they signed up to be part of the SERL Observatory, between August 2019 and February 2021, so some households who initially answered that they did not have an EV may have subsequently acquired one. As part of our follow-up survey in 2022, we asked again if households had an EV as well as asking how many; future analysis will investigate this updated information.

Table 16 below presents minimum and maximum energy consumption values by EV ownership status as presented in Figure 17 above.

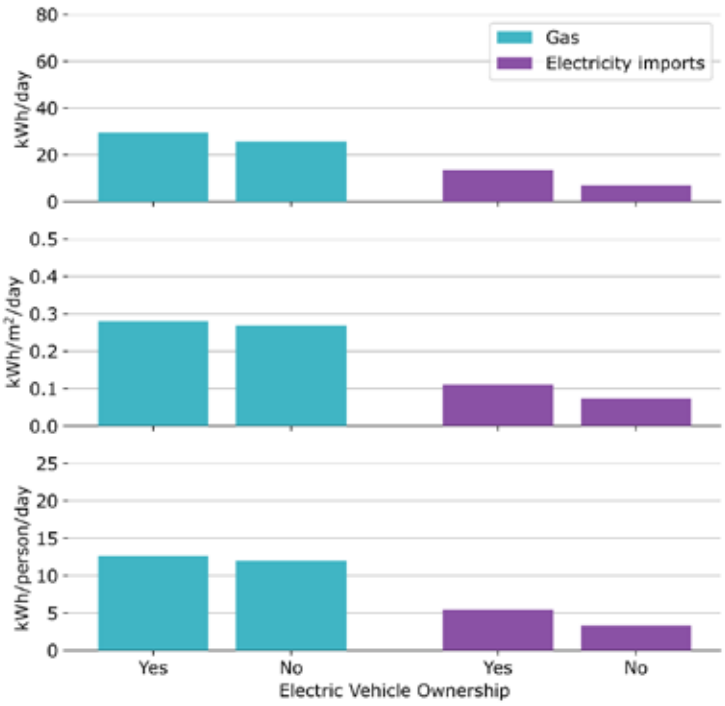


Figure 17 Median consumption of gas and electricity imports for homes in the SERL observatory by electric vehicle ownership[11] in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	EV ownership status with min. value	Maximum	EV ownership status with max. value
Electricity	6.7 kWh/day	No	13.4 kWh/day	Yes
Electricity	0.07 kWh/m^2/day	No	0.11 kWh/m^2/day	Yes
Electricity	3.3 kWh/person/day	No	5.4 kWh/person/day	Yes
Gas	25.7 kWh/day	No	29.5 kWh/day	Yes
Gas	0.27 kWh/m^2/day	No	0.28 kWh/m^2/day	Yes
Gas	12.0 kWh/person/day	No	12.6 kWh/person/day	Yes

Table 16 Summary statistics for Figure 17

11 Categories in this figure are based on participant responses to the following question: "C5. Does your household have a plug-in electric vehicle? This does not include hybrid cars which are not plugged-in to charge. Tick one answer only".

4.2
Monthly energy use in 2023

4.2.1
Monthly energy use by EPC energy efficiency rating

Gas consumption by month varied by EPC energy efficiency rating (Figure 18). January 2023 was the coldest month of the year (averaging 5.5 °C), and median gas consumption in F & G-rated homes was almost twice that of A & B-rated homes. The difference in median gas consumption between EPC ratings reduces considerably over the summer months when average temperatures are above 15 °C (June to September), although each of the bottom four bands continues to use more gas than the top 3 bands, possibly because of lower boiler efficiency for hot water. As mentioned in the preceding section, F & G-rated homes are often heated by fuels other than gas, so the sample presented in this analysis is unusual compared to typical F & G homes. The sample size for A & B and F & G rated homes is much smaller than for the other bands, 140 and 90 homes respectively, compared to over 500 for all other bands, and the results for these bands are therefore less reliable than the middle bands. Note that figures normalised by floor area and by occupant are available in the aggregated statistics dataset which accompanies this report.

Table 17 below presents minimum and maximum gas consumption values for the EPC bands presented in Figure 18 above.

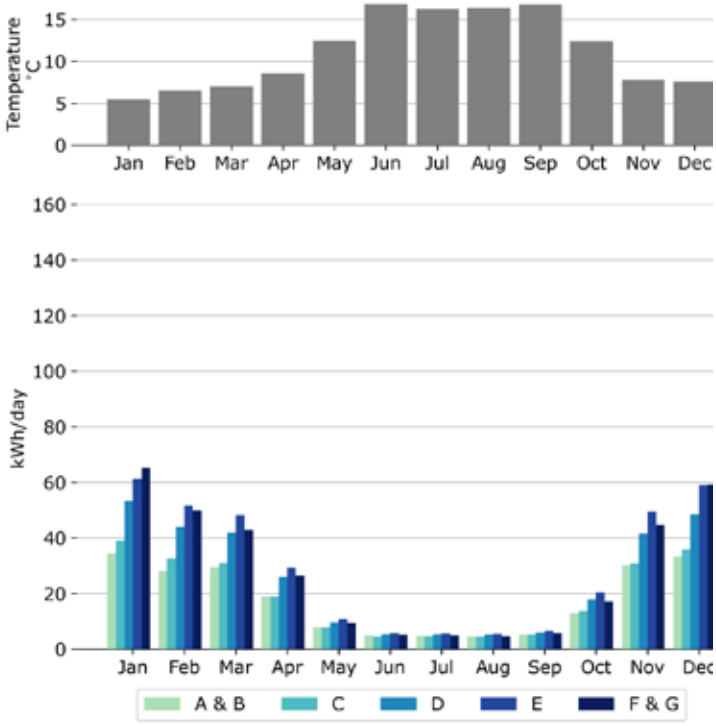


Figure 18 Median gas consumption per day for homes in the SERL Observatory sample by month and EPC energy efficiency rating in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value	EPC band
Gas	4.6 kWh/day	August	16.4 °C	34.4 kWh/day	January	5.5 °C	A & B
Gas	4.6 kWh/day	June	16.8 °C	39.0 kWh/day	January	5.5 °C	C
Gas	5.2 kWh/day	August	16.4 °C	53.3 kWh/day	January	5.5 °C	D
Gas	5.5 kWh/day	August	16.4 °C	61.3 kWh/day	January	5.5 °C	E
Gas	4.7 kWh/day	August	16.3 °C	65.1 kWh/day	January	5.5 °C	F & G

Table 17 Summary statistics for Figure 18

Electricity use also varied by month and EPC rating (Figure 19), although by less than the variation in gas consumption, with homes in the four lowest bands using notably more electricity than the most efficient three bands in all months of 2023. Note that in general, A & B-rated homes have solar PV, whereas the sample presented in these figures do not have PV and so are unusual compared to typical A & B homes. Additionally, the sample size for A & B and F & G rated homes is much smaller than for the other bands, 180 and 110 homes respectively, compared to over 600 for all other bands, the results for these bands are therefore less reliable than the middle bands.

Table 18 below presents minimum and maximum electricity consumption values for the EPC bands presented in Figure 19 above.

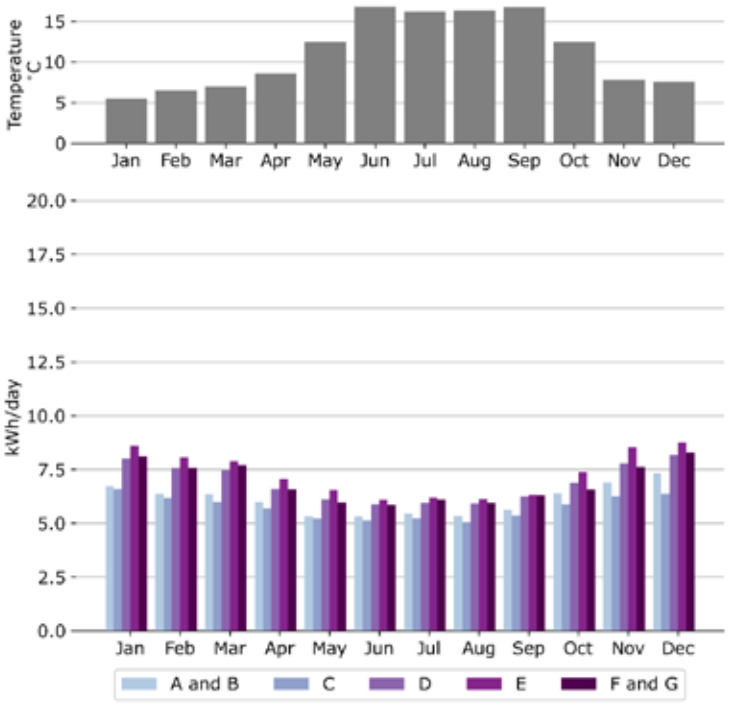


Figure 19 Median consumption of electricity imports per day for homes in the SERL Observatory sample by month and EPC energy efficiency rating in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value	EPC band
Electricity	5.3 kWh/day	May	12.4 °C	7.3 kWh/day	December	7.7 °C	A & B
Electricity	5.1 kWh/day	August	16.3 °C	6.6 kWh/day	January	5.5 °C	C
Electricity	5.9 kWh/day	June	16.8 °C	8.2 kWh/day	December	7.5 °C	D
Electricity	6.1 kWh/day	June	16.9 °C	8.8 kWh/day	December	7.6 °C	E
Electricity	5.9 kWh/day	June	16.8 °C	8.3 kWh/day	December	7.6 °C	F & G

Table 18 Summary statistics for Figure 19

4.2.2
Monthly energy use by floor area

Gas use by month varied by floor area (Figure 20). January 2023 was the coldest month of the year (5.5 °C), and median gas consumption in homes over 200 m² was almost five times larger than in homes of 50 m² or less. Smaller homes continued to use less gas over the summer months, and in the warmest month of the year (June, 16.8 °C), the smallest homes used almost a quarter of the gas that the largest used. Summer gas use is likely to be largely related to water heating (with some residual space heating) and it is likely that larger homes have more occupants and therefore have greater hot water demand than smaller homes (note that energy statistics normalised by m² and occupant number are available in the statistical dataset that accompanies this report).

Table 19 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 20 above.

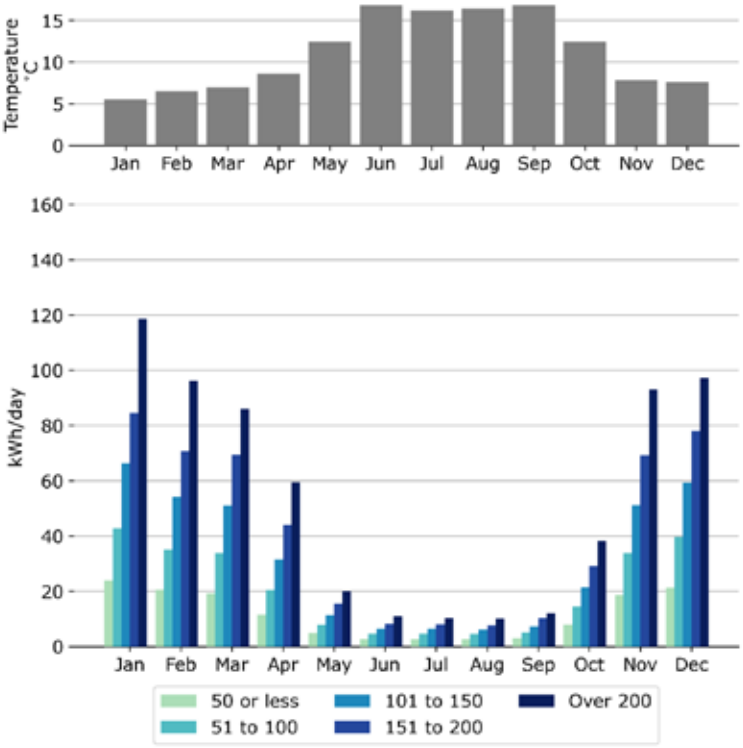


Figure 20 Median gas consumption per day for homes in the SERL Observatory sample by month and floor area in 2023. These homes have gas central heating and do not have PV.

Quantity	Min.	Month with min. value	Temp. for min. value	Max.	Month with max. value	Temp. for max. value	Floor area band
Gas	2.7 kWh/day	July	16.3 °C	23.9 kWh/day	January	5.5 °C	50 m² or less
Gas	4.5 kWh/day	August	16.3 °C	42.8 kWh/day	January	5.5 °C	51 m² to 100 m²
Gas	6.1 kWh/day	August	16.4 °C	66.4 kWh/day	January	5.6 °C	101 m² to 150 m²
Gas	7.6 kWh/day	August	16.4 °C	84.5 kWh/day	January	5.6 °C	151 m² to 200 m²
Gas	10.2 kWh/day	August	16.4 °C	118.7 kWh/day	January	5.6 °C	Over 200 m²

Table 19 Summary statistics for Figure 20

Electricity demand also varied by month and floor area (Figure 21), although by less than the variation in gas consumption, with smaller homes consuming less electricity. In January 2023 the median electricity use in homes smaller than 50 m² was less than a third of that in homes larger than 200 m². In the warmest month, June 2023, the smallest homes again had a median consumption almost a third of the largest homes.

Table 20 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 21 above.

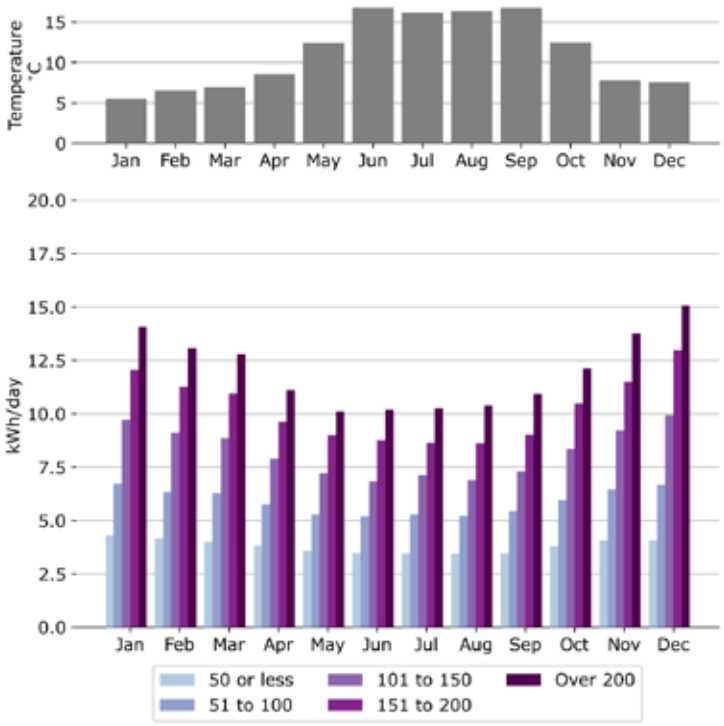


Figure 21 Median consumption of electricity imports per day for homes in the SERL Observatory sample by month and floor area in 2023. These homes have gas central heating and do not have PV.

Quantity	Min.	Month with min value	Temp. for min. value	Max.	Month with max. value	Temp. for max. value	Floor area band
Electricity	3.4 kWh/day	August	16.4 °C	4.3 kWh/day	January	5.5 °C	50 m² or less
Electricity	5.2 kWh/day	June	16.8 °C	6.7 kWh/day	January	5.4 °C	51 m² to 100 m²
Electricity	6.8 kWh/day	June	16.8 °C	9.9 kWh/day	December	7.6 °C	101 m² to 150 m²
Electricity	8.6 kWh/day	August	16.3 °C	13.0 kWh/day	December	7.6 °C	151 m² to 200 m²
Electricity	10.1 kWh/day	May	12.4 °C	15.1 kWh/day	December	7.6 °C	Over 200 m²

Table 20 Summary statistics for Figure 21

4.2.3 Monthly electricity imports and exports for homes with PV

Figure 22 shows the monthly median electricity imports and exports for homes in the SERL Observatory which have solar PV. Note that imported electricity is the amount of electricity taken from the grid, and export is the amount exported back to the grid. The means the amount of self-generated electricity used by the household is not known. The figure shows a very clear pattern in which electricity exports are strongly correlated with mean solar irradiance (as expected).

Note that due to activities associated with migrating our data infrastructure very few export electricity readings were collected in February 2023 and so these results are not shown in the figure.

Table 21 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 22 above.

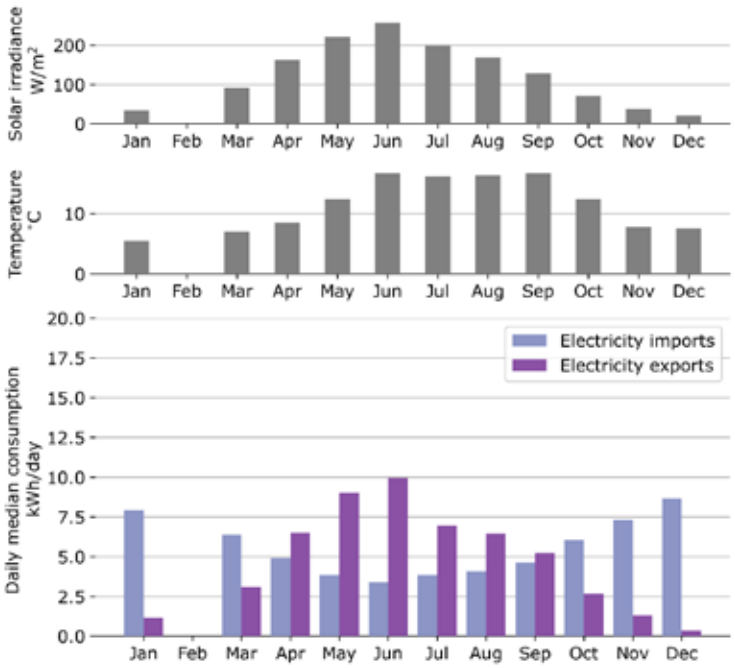


Figure 22 Median electricity imports and exports per day for homes in the SERL Observatory sample by month in 2023. These homes have gas central heating and PV.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value	Floor area band
Electricity imports	3.4 kWh/day	June	16.7 °C	8.7 kWh/day	December	7.5 °C	50 m² or less
Electricity exports	0.4 kWh/day	December	7.5 °C	10.0 kWh/day	June	16.7 °C	51 m² to 100 m²

Table 21 Summary statistics for Figure 22

4.3
Diurnal energy use in 2023

4.3.1
Full sample

Gas consumption over the course of the day (Figure 23) shows two main peaks, in the morning and evening, with little overnight consumption and moderate levels during the day between the peaks[12]. The median morning peak occurs at 08:00 whilst the, slightly higher, afternoon peak occurs at 18:30. Daytime usage falls to below half the morning peak; a very slight peak centred on 12:30 can be observed, possibly associated with lunchtime cooking and washing-up. Overnight usage falls close to zero, suggesting that at least half the sample does not use its central heating overnight.

For the 25th percentile, the morning peak occurs slightly later at 08:30, and is only around 40% of the median peak, while its afternoon peak is almost 60% of the median. The 75th percentile meanwhile shows a larger morning rather than evening peak – the morning peak is over double the median, while the afternoon peak is just over 50% larger than the median. Overnight usage is also low, although at its lowest the 75th percentile usage is 3.6 times larger than the lowest median usage.

Table 22 below presents minimum and maximum energy consumption values for the quartiles presented in Figure 23 above.

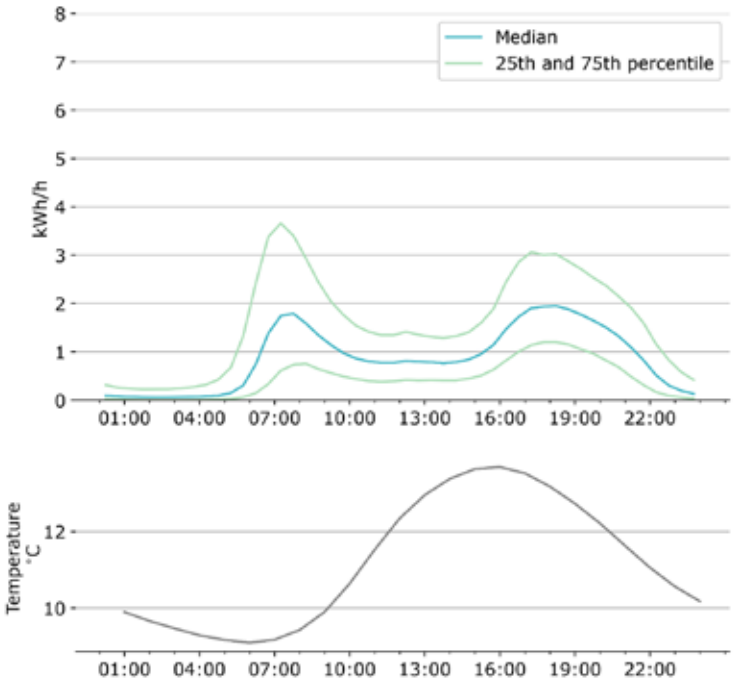


Figure 23 Quartiles of gas consumption for SERL Observatory participants in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Quartile
Gas	0.06 kWh/h	02:30	1.95 kWh/h	18:30	Median
Gas	0.01 kWh/h	03:00	1.20 kWh/h	18:30	25th
Gas	0.23 kWh/h	02:00	3.66 kWh/h	07:30	75th

Table 22 Summary statistics for Figure 23

12 The median and quartiles presented here are drawn independently for each half hour from the distribution of the mean energy use per household for that period. For statistical disclosure control, the median and quartile values shown are the mean of the 10 values closest to the median or quartile. Note that the value for each half hour is not necessarily drawn from the same 10 dwellings.

Electricity use across the day shows a different profile to gas (Figure 24), generally flatter, with a rise in the morning from the overnight lows then a levelling off until an evening increase that peaks at 18:30. Demand then gradually declines into the early hours of the next day, reaching the minimum at 04:00. A slight peak near the middle of the day, at around 13:00, can again be discerned.

The 25th and 75th percentiles show very similar profiles to the median, simply scaled lower or higher. The 25th centile peak demand is about two thirds that of the median, while the 75th centile peak demand is 1.5 times that of the median.

Table 23 below presents minimum and maximum energy consumption values for the quartiles presented in Figure 24 above.

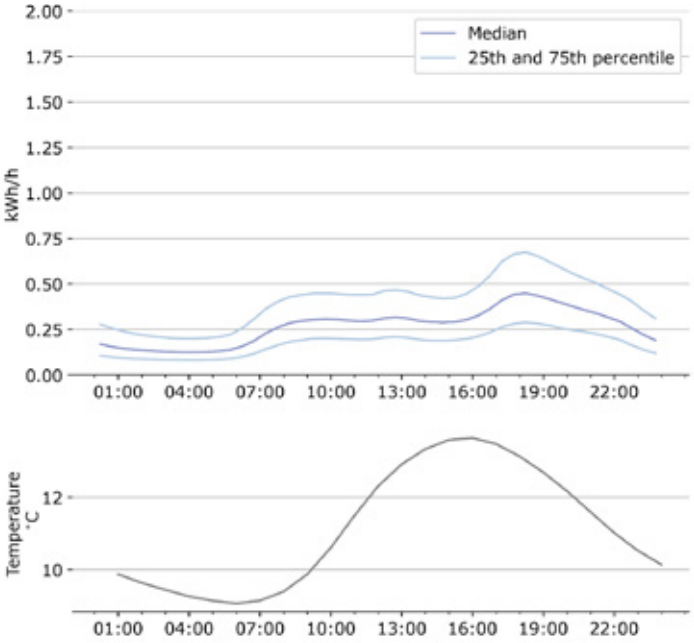


Figure 24 Quartiles of electricity imports for SERL Observatory participants in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Quartile
Electricity	0.13 kWh/h	04:30	0.45 kWh/h	18:30	Median
Electricity	0.08 kWh/h	04:30	0.29 kWh/h	18:30	25th
Electricity	0.20 kWh/h	04:00	0.68 kWh/h	18:30	75th

Table 23 Summary statistics for Figure 24

4.3.2
Diurnal energy use by temperature band

In Figure 25, half-hourly gas consumption is plotted by daily mean external temperature band. This shows the strong relationship between external temperature and gas use across the day for these gas centrally-heated homes. Morning and evening peaks are evident across all the temperature bands, even the 20 °C to 25 °C band mostly associated with the summer period. This suggests that hot water use in the mornings and evenings may in part drive these peaks. Gas use between the peaks is a smaller proportion of peak usage at lower temperatures. A small spike in use is also evident around midday, potentially for cooking and washing up.

The morning peak in gas demand is over nine times higher in the coldest temperature band shown (-5 °C to 0 °C) than in the warmest band (20 °C to 25 °C), while the evening peak is nearly 12 times higher.

Night-time use is relatively low at all temperatures, although the lowest mean usage in the -5 °C to 0 °C temperature band is still nearly 60% higher than peak usage in the 20 °C to 25 °C band. This suggests that there is a significant increase in the proportion of homes using night-time space heating as temperatures get colder.

Table 24 below presents minimum and maximum energy consumption values for the quartiles presented in Figure 25 above.

The fact that the gas profiles for 15 °C to 20 °C and 20 °C to 25 °C bands are similar suggests that this is mostly not space heating but hot water and cooking gas use. This is consistent with the use of a 15.5 °C degree-day base temperature for UK homes, i.e. space heating will normally come on when the outside temperature drops below 15.5 °C.

It is interesting to compare the median peak gas demand during the coldest period (-5 °C to 0 °C) of 5.7 kW to the capacity of gas boilers, which tends to range from 12 kW to 35 kW depending on the number of rooms, heat loss and, for combi-boilers, the number of bathrooms. This means that even during cold spells, many boilers will have to significantly modulate their output and/or cycle on and off, which can impact their efficiency (Bennett *et al.*, 2019).

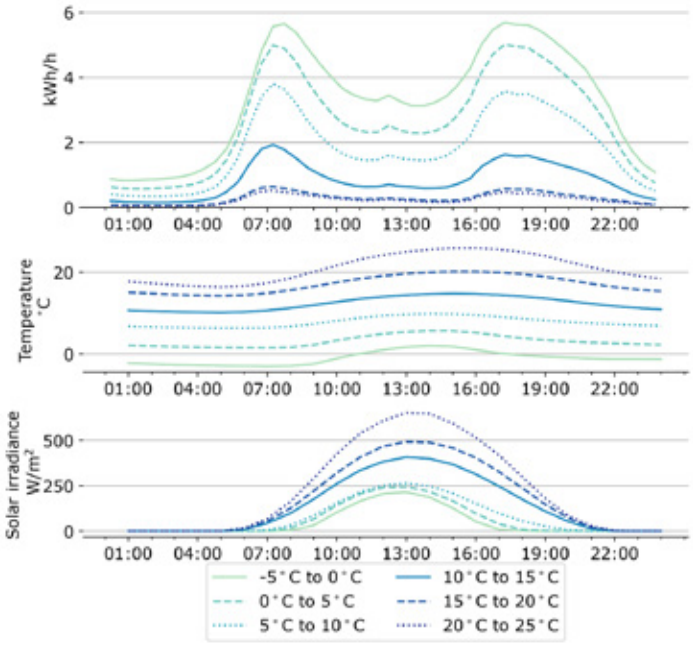


Figure 25 Mean gas consumption by temperature band in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Temperature band
Gas	0.83 kWh/h	01:00	5.69 kWh/h	17:30	-5 °C to 0 °C
Gas	0.57 kWh/h	02:00	5.02 kWh/h	17:30	0 °C to 5 °C
Gas	0.34 kWh/h	02:30	3.80 kWh/h	07:30	5 °C to 10 °C
Gas	0.16 kWh/h	02:30	1.93 kWh/h	07:30	10 °C to 15 °C
Gas	0.05 kWh/h	02:30	0.64 kWh/h	07:30	15 °C to 20 °C
Gas	0.04 kWh/h	02:30	0.52 kWh/h	07:30	20 °C to 25 °C

Table 24 Summary statistics for Figure 25

The net electricity profiles (Figure 26) for all the temperature bands show similar overall shapes, beginning to rise from an overnight low at around 05:00 or 05:30 then staying relatively flat until rising again to an evening peak at 18:30. Demand then declines slowly through the evening and night until the overnight low. Across all bands, a slight rise in usage in the early afternoon is observed, perhaps due to cooking for lunch.

Differences in demand are proportionally higher during the day than overnight, with peak demand over 60% higher in the -5 °C to 0 °C temperature band than in the 20 °C to 25 °C band.

The variation that is observed between temperature bands could be the result of various factors, including increased use of supplementary electric heating, lighting, and energy-using appliances for indoor activities in the colder winter months.

Table 25 below presents minimum and maximum energy consumption values for the temperature bands presented in Figure 26 above.

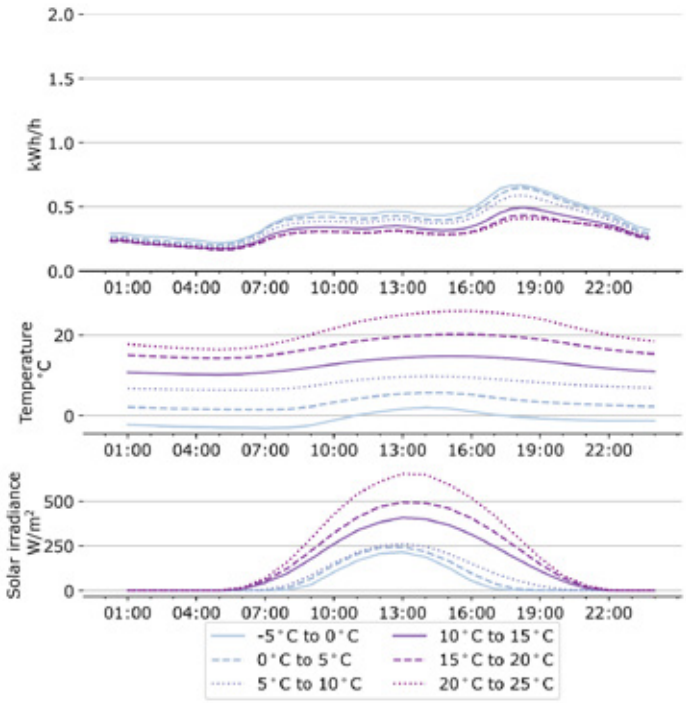


Figure 26 Mean electricity imports by temperature band in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Temperature band
Electricity	0.22 kWh/h	05:00	0.67 kWh/h	18:30	-5 °C to 0 °C
Electricity	0.20 kWh/h	05:00	0.65 kWh/h	18:30	0 °C to 5 °C
Electricity	0.19 kWh/h	05:00	0.59 kWh/h	18:30	5 °C to 10 °C
Electricity	0.17 kWh/h	05:00	0.49 kWh/h	18:30	10 °C to 15 °C
Electricity	0.17 kWh/h	05:30	0.43 kWh/h	18:30	15 °C to 20 °C
Electricity	0.17 kWh/h	05:30	0.41 kWh/h	18:30	20 °C to 25 °C

Table 25 Summary statistics for Figure 26

4.3.3
Diurnal energy use by deprivation quintile

In Figure 27, mean gas consumption is presented for households segmented by the Index of Multiple Deprivation (IMD) quintile of the areas in which they are located. The figure shows that over the whole day mean gas consumption increases with IMD quintile (i.e. with reducing deprivation). Peak usage, particularly in the morning, varies most, whilst usage during the daytime and overnight varies little. In IMD quintiles 1 and 2 (most deprived areas), the evening peak is higher than the morning; for quintiles 3 to 5, the morning peak is higher. Peak demand in IMD quintile 5 (in the morning) is twice the peak demand in IMD quintile 1 (in the evening). A smaller midday spike becomes more prominent as IMD increases, being barely present in IMD quintile 1.

Table 26 below presents minimum and maximum energy consumption values for the IMD quintiles presented in Figure 27 above.

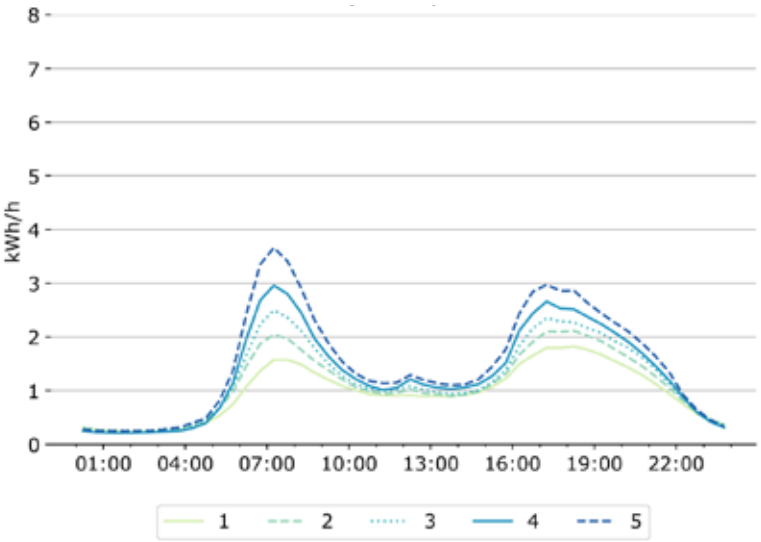


Figure 27 Mean gas consumption by IMD quintile in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	IMD quintile
Gas	0.24 kWh/h	02:30	1.82 kWh/h	18:30	1
Gas	0.24 kWh/h	02:00	2.11 kWh/h	18:30	2
Gas	0.25 kWh/h	02:30	2.50 kWh/h	07:30	3
Gas	0.21 kWh/h	02:00	2.96 kWh/h	07:30	4
Gas	0.25 kWh/h	02:00	3.66 kWh/h	07:30	5

Table 26 Summary statistics for Figure 27

Figure 28 shows electricity consumption by IMD quintile. The typical electricity profile for the full sample is broadly present across all IMD bands, with the morning peak being relatively small, of a similar order to the daytime usage up until the late afternoon, when it begins to rise to an evening peak at 18:30. Across the day, mean electricity usage is generally higher as the IMD quintile increases. A slight morning peak is visible in IMD quintiles 3 to 5 that is absent in quintiles 1 and 2.

IMD quintile 5, the least deprived, has a distinctly higher overnight demand than the other bands, with a small peak at 01:00. This is a pattern consistent with EV charging profiles (see section 4.3.10), and its presence in IMD quintile 5 may be due to EV ownership being higher among higher income households.

Table 27 below presents minimum and maximum energy consumption values for the IMD quintiles presented in Figure 28 above.

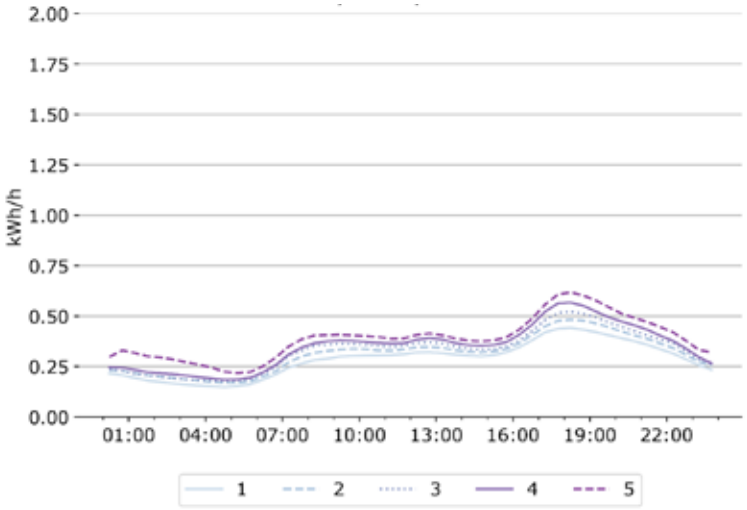


Figure 28 Mean electricity imports by IMD quintile in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	IMD quintile
Electricity	0.15 kWh/h	05:00	0.44 kWh/h	18:30	1
Electricity	0.17 kWh/h	05:00	0.48 kWh/h	18:30	2
Electricity	0.18 kWh/h	05:00	0.52 kWh/h	18:30	3
Electricity	0.18 kWh/h	05:00	0.57 kWh/h	18:30	4
Electricity	0.22 kWh/h	05:30	0.62 kWh/h	18:30	5

Table 27 Summary statistics for Figure 28

4.3.4
Diurnal energy use by EPC band

Figure 29 presents mean gas usage by EPC energy efficiency rating. The general picture is of household gas usage being lower across the day for homes with higher EPC ratings, however there are significant nuances. The morning peak in gas demand among the most energy efficient homes (bands A & B) is substantially higher than it is for band C, and thereafter bands A, B and C have broadly similar demand profiles. The demand profile normalised by floor area shows a clearer difference with homes in bands A & B showing lower consumption per m^2 throughout the day.

The difference in household demand between bands C, D and E is more substantial, and present throughout the daytime, but minimal overnight. The difference between these bands is also clear in the profile normalised by floor area. Bands F & G have similar demand to band E, except that F & G's morning peak is slightly later and slightly higher. This difference remains in the profile normalised by floor area, but the evening peak for F & G homes is notably lower than that for E-rated homes.

Table 28 below presents minimum and maximum energy consumption values for the EPC bands presented in Figure 29 above.

As noted previously, care should be taken in interpreting the differences between bands as there are important contributing factors to consider: the sample includes only homes with gas central heating, however most F & G rated homes are not gas heated, and those that are gas heated are more likely to have inefficient gas systems such as old system boilers rather than combi boilers. This could explain the lower night-time gas use in F & G-rated homes (there is no combi boiler keep-warm function) and later start to their morning rise in demand, as hot water use in the morning in these homes would come from the store rather than immediately using gas to heat the water as would happen with a combi boiler. Sample sizes are also small for both the A & B and F & G groups.

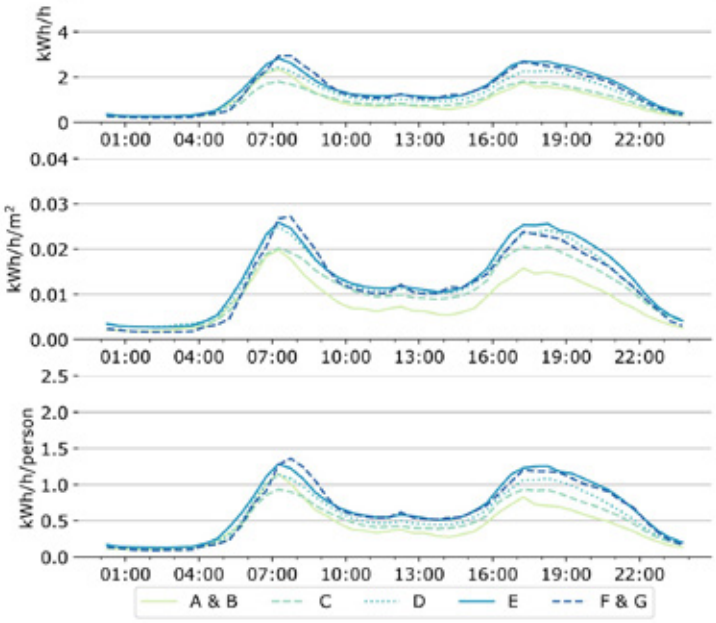


Figure 29 Mean gas consumption by EPC energy efficiency rating in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	EPC band
Gas	0.23 kWh/h	01:30	2.35 kWh/h	07:30	A & B
Gas	0.23 kWh/h	03:00	1.80 kWh/h	17:30	C
Gas	0.25 kWh/h	02:00	2.43 kWh/h	07:30	D
Gas	0.28 kWh/h	02:30	2.83 kWh/h	07:30	E
Gas	0.20 kWh/h	02:30	2.95 kWh/h	08:00	F & G
Gas	0.002 kWh/h/m^2	01:30	0.020 kWh/h/m^2	07:30	A & B
Gas	0.003 kWh/h/m^2	03:00	0.021 kWh/h/m^2	18:30	C
Gas	0.003 kWh/h/m^2	02:00	0.025 kWh/h/m^2	07:30	D
Gas	0.003 kWh/h/m^2	02:30	0.026 kWh/h/m^2	07:30	E
Gas	0.002 kWh/h/m^2	02:30	0.027 kWh/h/m^2	08:00	F & G
Gas	0.10 kWh/h/person	02:00	1.15 kWh/h/person	07:30	A & B
Gas	0.11 kWh/h/person	03:00	0.93 kWh/h/person	17:30	C
Gas	0.12 kWh/h/person	02:00	1.14 kWh/h/person	07:30	D
Gas	0.13 kWh/h/person	03:00	1.28 kWh/h/person	07:30	E
Gas	0.09 kWh/h/person	02:30	1.36 kWh/h/person	08:00	F & G

Table 28 Summary statistics for Figure 29

Figure 30 presents mean electricity use by EPC rating. Electricity use is higher with lower EPC bands across the whole day between bands C and F & G. Bands F & G are unusual in having particularly higher overnight demand, from around 01:00. This could be due to a small proportion of them using economy seven electric heating as a secondary heating source, which could be one of the factors contributing to a low EPC rating for homes with gas central heating. The profile normalised by floor area shows that bands F & G have higher electricity use per m^2 throughout the day, while all other bands show very similar energy use per m^2 at all times.

A & B-rated properties have slightly higher demand than C-rated homes across the day, particularly into the late evening and overnight. Normalised by floor area, demand is slightly higher in A & B-rated homes compared to C-rated homes overnight, and then falls slightly below the other bands from mid to late morning, and again falls below the rest of the bands through the late afternoon peak. However, many A & B-rated homes achieve their rating by having rooftop solar panels, and homes with PV are excluded from this figure, so the profile is unlikely to be typical of A & B-rated homes.

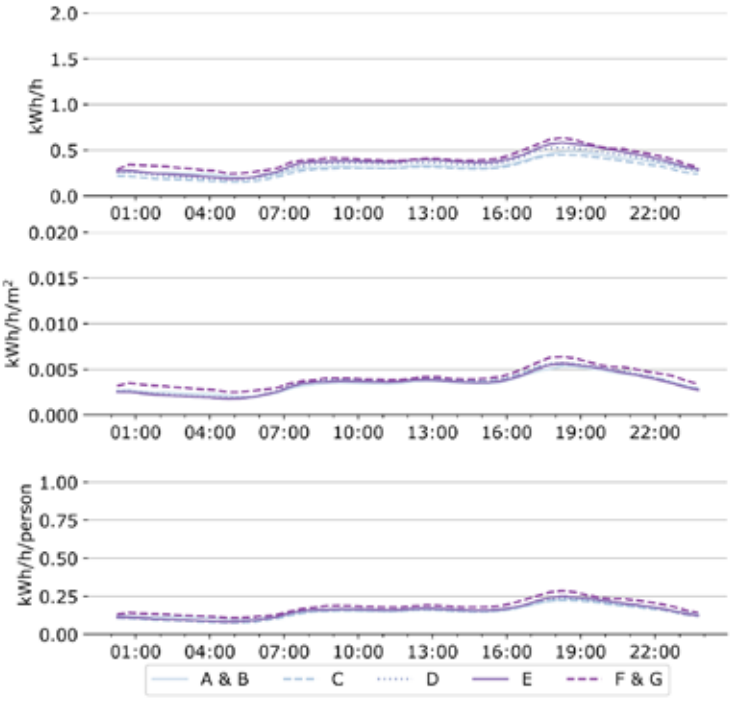


Figure 30 Mean electricity imports by EPC energy efficiency rating in 2023. These homes have gas central heating and do not have PV.

Table 29 below presents minimum and maximum energy consumption values for the EPC energy efficiency rating presented in Figure 30 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	EPC band
Electricity	0.20 kWh/h	06:00	0.49 kWh/h	19:00	A & B
Electricity	0.15 kWh/h	05:00	0.45 kWh/h	18:30	C
Electricity	0.18 kWh/h	05:00	0.53 kWh/h	18:30	D
Electricity	0.19 kWh/h	05:00	0.58 kWh/h	18:30	E
Electricity	0.24 kWh/h	05:00	0.63 kWh/h	18:30	F & G
Electricity	0.002 kWh/h/m^2	05:30	0.005 kWh/h/m^2	18:30	A & B
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	C
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	D
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	E
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	F & G
Electricity	0.10 kWh/h/person	05:30	0.23 kWh/h/person	19:00	A & B
Electricity	0.08 kWh/h/person	05:00	0.22 kWh/h/person	18:30	C
Electricity	0.08 kWh/h/person	05:00	0.24 kWh/h/person	18:30	D
Electricity	0.08 kWh/h/person	05:00	0.25 kWh/h/person	18:30	E
Electricity	0.11 kWh/h/person	05:00	0.29 kWh/h/person	18:30	F & G

Table 29 Summary statistics for Figure 30

4.3.5 Diurnal energy use by floor area band

Mean gas consumption throughout the course of the day varies substantially by floor area (Figure 31), with the greatest variation occurring during the morning and evening peak periods. A midday peak also becomes more prominent as floor area increases. The morning peak is 6.3 times higher in homes over 200 m² than in homes of 50 m² or less, and the evening peak 5.4 times higher. The morning peak time is half an hour earlier in the larger homes (07:00 compared to 07:30). The evening peak occurs an hour earlier in the larger homes (17:30 vs 18:30).

The lunchtime peak is very prominent in bigger homes and almost absent in homes of 50 m² or less, which are likely to be small flats, more likely with single occupants who are out during the day, leaving the home unoccupied.

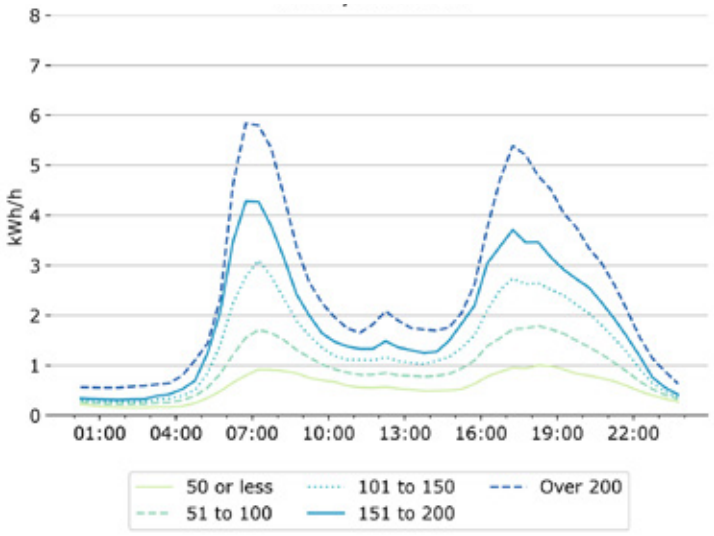


Figure 31 Mean gas consumption by floor area in 2023. These homes have gas central heating and do not have PV.

Table 30 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 31 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Floor area band
Gas	0.16 kWh/h	02:30	1.00 kWh/h	18:30	50 m² or less
Gas	0.22 kWh/h	02:00	1.79 kWh/h	18:30	50 m² to 100 m²
Gas	0.27 kWh/h	02:30	3.10 kWh/h	07:30	101 m² to 150 m²
Gas	0.31 kWh/h	02:00	4.28 kWh/h	07:00	151 m² to 200 m²
Gas	0.55 kWh/h	01:30	5.84 kWh/h	07:00	Over 200 m²

Table 30 Summary statistics for Figure 31

Electricity use also varies substantially by floor area (Figure 32). Although the increase is generally more consistent throughout the day than is the case for gas demand, there are some nuances. In particular, overnight demand from larger homes shows a peak from 01:00 that is a similar size to their morning peaks, unlike in smaller homes. Slight morning and lunchtime peaks also become more apparent in larger homes. One possible reason for the large early morning peaks in larger homes may be higher levels of EV charging, with EV ownership and larger homes both more common among more affluent and bigger households. Larger homes are also more likely to be houses rather than flats, with space for EV charging. Off-peak rate electric storage heaters may also be more commonly used as secondary heating in larger homes, and so also contribute to the early morning peaks.

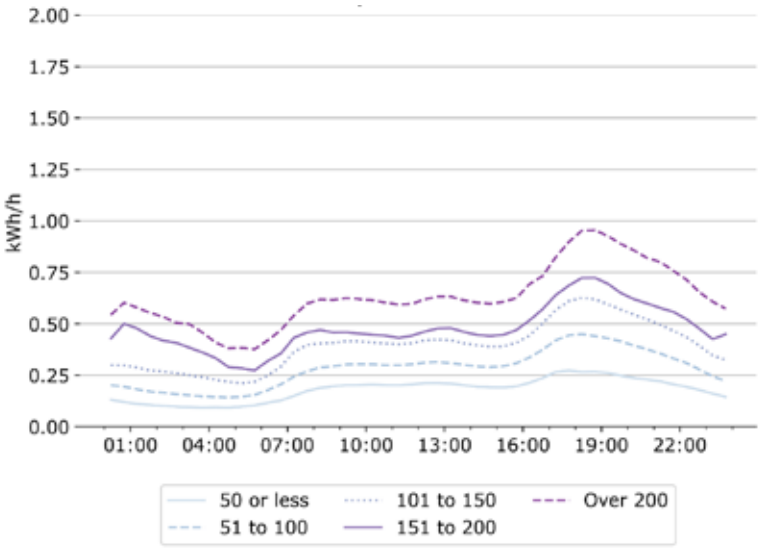


Figure 32 Mean electricity imports by floor area in 2023. These homes have gas central heating and do not have PV.

Table 31 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 32 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Floor area band
Electricity	0.09 kWh/h	05:00	0.27 kWh/h	18:00	50 m^2 or less
Electricity	0.14 kWh/h	05:00	0.45 kWh/h	18:30	51 m^2 to 100 m^2
Electricity	0.21 kWh/h	05:30	0.63 kWh/h	18:30	101 m^2 to 150 m^2
Electricity	0.27 kWh/h	06:00	0.72 kWh/h	19:00	151 m^2 to 200 m^2
Electricity	0.38 kWh/h	06:00	0.96 kWh/h	19:00	Over 200 m^2

Table 31 Summary statistics for Figure 32

4.3.6 Diurnal energy use by building type

Mean gas usage varies substantially throughout the daytime between the main building types present in Figure 33, particularly during the morning and evening peaks. Purpose-built flats have substantially lower usage than other building types throughout the day, whilst detached homes have by far the highest usage, especially during the morning peak, with the evening peak in particular occurring earlier. Detached houses also have the most pronounced midday peak, whilst the peak is almost absent in flats. Correlations between building type, floor area, occupancy levels, energy efficiency and other factors means a range of these factors will contribute to the observed patterns in demand.

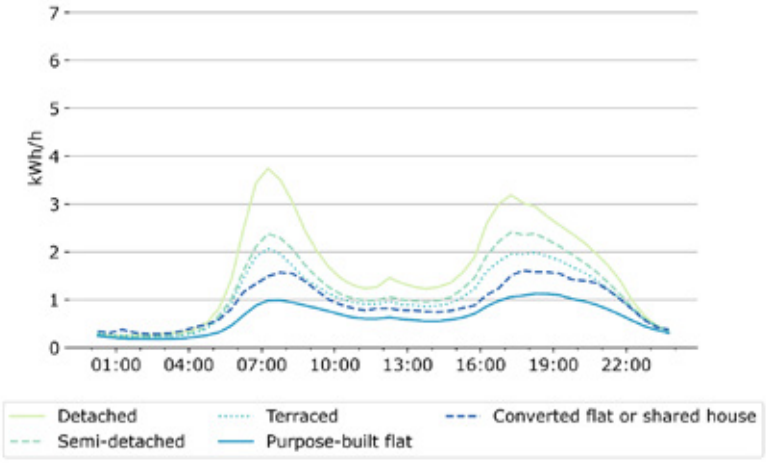


Figure 33 Mean gas consumption by building type in 2023. These homes have gas central heating and do not have PV.

Table 32 below presents minimum and maximum energy consumption values for the building types presented in Figure 33 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Building type
Gas	0.26 kWh/h	01:30	3.74 kWh/h	07:30	Detached
Gas	0.22 kWh/h	02:00	2.41 kWh/h	17:30	Semi-detached
Gas	0.24 kWh/h	03:00	2.07 kWh/h	07:30	Terraced
Gas	0.18 kWh/h	03:00	1.13 kWh/h	18:30	Purpose-built flat
Gas	0.28 kWh/h	03:00	1.61 kWh/h	18:00	Converted flat or shared house

Table 32 Summary statistics for Figure 33

Electricity demand varies more consistently over the day with building type than does gas demand (Figure 34), although there is most variation in the evening peak. The order of building type with demand is the same as for gas, with purpose-built flats having the lowest mean demand and detached houses the highest. A spike in demand from 01:00 is observable for detached houses. This again may be due to higher levels of EV charging in this group, with detached houses being more likely to be owned by more affluent households, and more likely to have space for EV charge-points.

Table 33 below presents minimum and maximum energy consumption values for the building types presented in Figure 34 above.

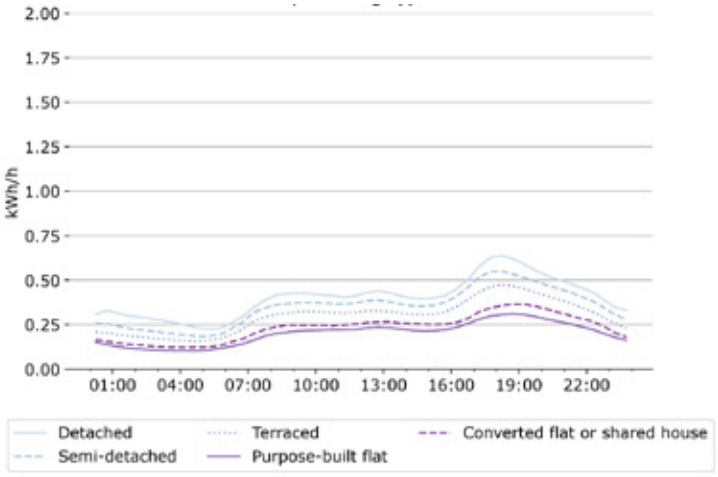


Figure 34 Mean electricity imports by building type in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Building type
Electricity	0.23 kWh/h	05:30	0.64 kWh/h	18:30	Detached
Electricity	0.18 kWh/h	05:00	0.55 kWh/h	18:30	Semi-detached
Electricity	0.16 kWh/h	05:00	0.47 kWh/h	18:30	Terraced
Electricity	0.10 kWh/h	05:00	0.31 kWh/h	19:00	Purpose-built flat
Electricity	0.12 kWh/h	04:30	0.36 kWh/h	19:00	Converted flat or shared house

Table 33 Summary statistics for Figure 34

4.3.7
Diurnal electricity use by heating system

The type of heating system has a substantial impact on homes' electricity demand profiles, as seen in Figure 35, which includes homes with all types of heating system.

Four of the categories are for central heating systems that do not use electricity as the fuel source: gas boilers, gas boilers plus other, district or community heating, and oil, solid fuel or biomass heating. These all show similar shapes of profile through most of the day, with the main difference being in the level of demand. This is likely down to differences in the characteristics of these groups, such as average floor area and number of occupants. The oil, solid fuel and biomass group also has an overnight peak in demand that is consistent with EV ownership as seen in other sections of the report, or may be due to use of supplementary electric storage heaters in some of the homes.

Among homes with electric central heating systems, demand profiles vary substantially by technology, consistent with what would be expected for each type. Homes with electric storage radiators show a large overnight peak in demand: this is the time of day when storage radiators normally use electricity to build up their heat store for use during the daytime, taking advantage of off-peak electricity rates. While the off-peak period varies by supplier and region, it is normally between 10pm and 8am. Homes with electric radiators show a similar profile to homes with non-electric heating, particularly the oil, solid fuel or biomass group.

Table 34 below presents minimum and maximum energy consumption values for the central heating types presented in Figure 35 above.

This is likely to be due to differences in average floor area and number of occupants, although a higher morning peak might be expected. Homes with 'other' electric heating have by far the highest electricity use across the daytime, in particular having high morning and evening peaks, as well as higher overnight use than all groups except for those with electric storage heaters. The 'other electric' group is likely to include homes with heat pumps, but may include additional forms of electric heating. High day and night usage in the other electric group is consistent with the presence of heat pumps, and homes with heat pumps are less likely to be flats than those with electric radiators or electric storage radiators, which could account for the overall higher electricity use in this group. The afternoon rise begins earlier in the other electric group than in the rest of the groups shown. Due to the range of electric heating options available in the survey, it is also possible that response errors may account for some of the differences between groups observed.

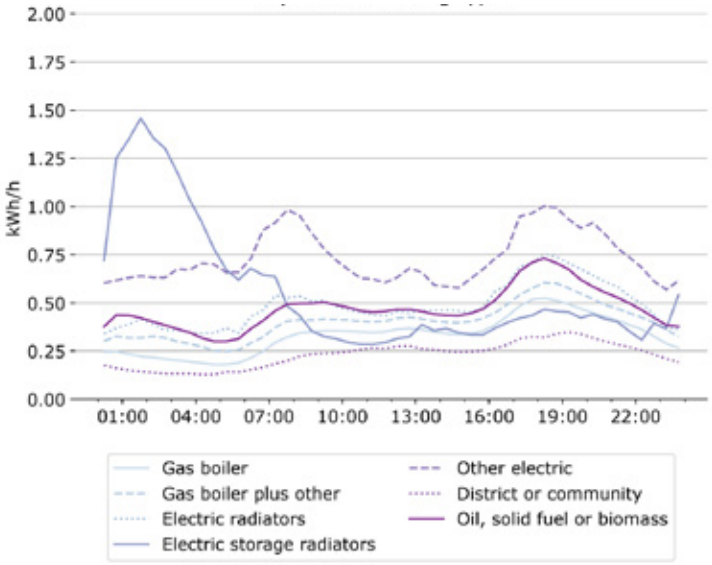


Figure 35 Mean electricity imports by central heating system in 2023. These homes do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Central heating type
Electricity	0.18 kWh/h	05:00	0.52 kWh/h	18:30	Gas boiler
Electricity	0.25 kWh/h	05:30	0.60 kWh/h	18:30	Gas boiler plus other
Electricity	0.34 kWh/h	00:30	0.75 kWh/h	18:30	Electric radiators
Electricity	0.29 kWh/h	11:30	1.46 kWh/h	02:00	Electric storage radiators
Electricity	0.57 kWh/h	23:30	1.00 kWh/h	18:30	Other electric
Electricity	0.13 kWh/h	04:30	0.35 kWh/h	19:30	District or community
Electricity	0.30 kWh/h	05:00	0.73 kWh/h	18:30	Oil, solid fuel or biomass
Electricity	0.28 kWh/h	05:00	0.55 kWh/h	18:30	None

Table 34 Summary statistics for Figure 35

4.3.8 Diurnal energy use by number of occupants

Although gas consumption across the day correlates with number of occupants (Figure 36), above two occupants the increases with each additional person are relatively small or only at certain times of day. The difference in peaks is greatest between 1 and 2 occupants. Homes with 2 and 3 occupants have very similar profiles throughout the day. Homes with 4, 5 and 6 or more occupants have similar morning peaks (higher than for 2 occupants), and demand that diverges to differing degrees across the rest of the day. The morning and evening peaks for 6 or more occupants are both around 1.9 times higher than for one occupant. The morning peak occurs an hour earlier for homes with 6 or more occupants (at 07:00 vs 08:00). The evening peak for 6 or more occupants spans 17:30 to 18:30, and is at 18:30 for 1 occupant.

Table 35 below presents minimum and maximum energy consumption values for the occupant bands presented in Figure 36 above.

The observed patterns are likely due to a range of interacting factors that influence gas demand differently across the day, including the tendency of larger households to live in larger homes that require more space heating to reach a given indoor temperature, an increasing likelihood of homes being occupied during the day as the number of occupants increases, and variation in how much of the home is heated at different times.

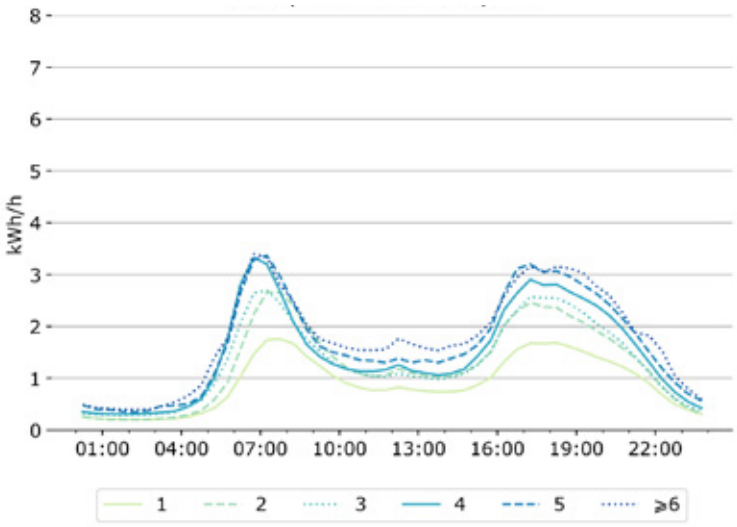


Figure 36 Mean gas consumption by number of occupants in 2023. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Number of occupants
Gas	0.21 kWh/h	02:30	1.75 kWh/h	08:00	1
Gas	0.20 kWh/h	02:00	2.66 kWh/h	08:00	2
Gas	0.28 kWh/h	02:00	2.70 kWh/h	07:30	3
Gas	0.31 kWh/h	02:00	3.33 kWh/h	07:00	4
Gas	0.34 kWh/h	02:30	3.37 kWh/h	07:30	5
Gas	0.39 kWh/h	02:00	3.40 kWh/h	07:00	≥6

Table 35 Summary statistics for Figure 36

In contrast to gas usage, electricity usage differs more substantially with the number of occupants (Figure 37) and, broadly, more consistently across the day (with the exception of homes with 6 or more occupants compared to those with 5). Evening peak electricity usage in homes with six or more occupants is 2.8 times higher than in homes with one occupant, but occurs at the same time, as do the minimum values for these groups.

This pattern could be accounted for by the types of activities which use electricity. Unlike gas usage, where space heating is largely shared by the occupants, more electricity-using activities are per-person, e.g. heating water for laundry, hot drinks and (in some cases) washing; personal electronic devices; lighting of more rooms; etc.

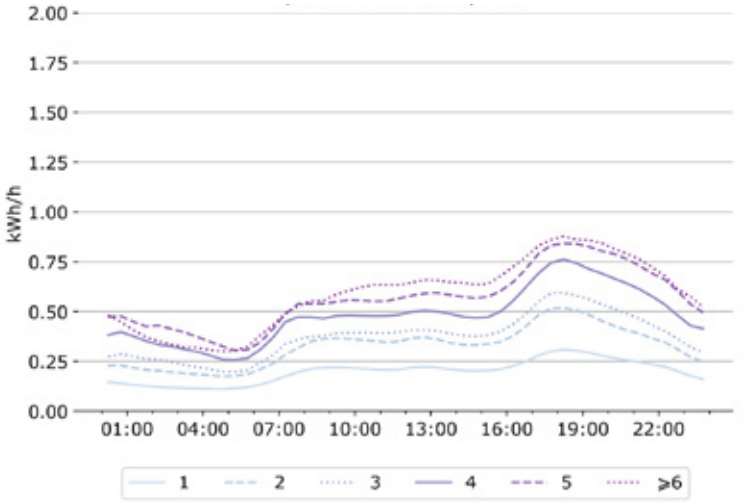


Figure 37 Mean electricity imports by number of occupants in 2023. These homes have gas central heating and do not have PV.

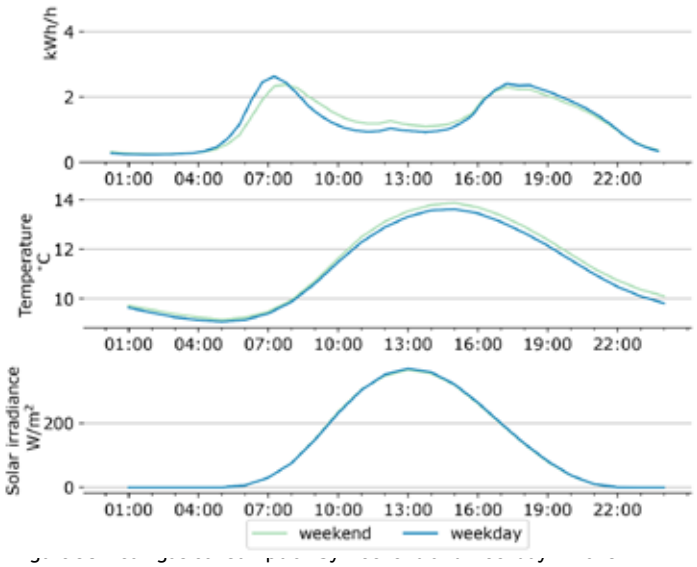
Table 36 below presents minimum and maximum energy consumption values for the occupant numbers presented in Figure 37 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Number of occupants
Electricity	0.11 kWh/h	05:00	0.31 kWh/h	18:30	1
Electricity	0.18 kWh/h	05:00	0.52 kWh/h	18:30	2
Electricity	0.20 kWh/h	05:30	0.59 kWh/h	18:30	3
Electricity	0.26 kWh/h	05:30	0.76 kWh/h	18:30	4
Electricity	0.30 kWh/h	05:30	0.84 kWh/h	18:30	5
Electricity	0.30 kWh/h	05:00	0.88 kWh/h	18:30	≥6

Table 36 Summary statistics for Figure 37

4.3.9
Diurnal energy use by day of the week

Both gas and electricity usage show small variations between weekdays and weekends, with the differences being similar for both fuel types (Figure 38 and Figure 39). Compared to weekdays, weekend morning peaks in usage occur slightly later and progress into slightly higher daytime usage, before converging to very similar evening peaks and overnight usage patterns. In the case of electricity, the morning peak at weekends continues on as a gradual rise in demand through the morning, merging with the slight midday peak. This is likely an effect of typical Monday to Friday working patterns, with more households getting up later and staying home during the day at weekends, hence using more energy.

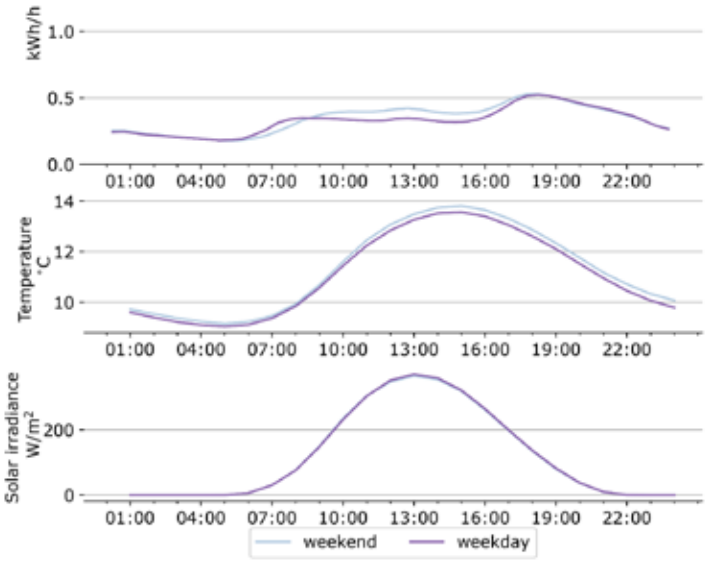


These homes have gas central heating and do not have PV.

Table 37 below presents minimum and maximum energy consumption values by weekend and weekday as presented in Figure 38 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Period
Gas	0.25 kWh/h	02:30	2.38 kWh/h	08:00	Weekend
Gas	0.23 kWh/h	02:00	2.63 kWh/h	07:30	Weekday

Table 37 Summary statistics for Figure 38



These homes have gas central heating and do not have PV.

Table 38 below presents minimum and maximum energy consumption values by weekend and weekday as presented in Figure 39 right.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Period
Electricity	0.18 kWh/h	05:30	0.53 kWh/h	18:00	Weekend
Electricity	0.18 kWh/h	05:00	0.52 kWh/h	18:30	Weekday

Table 38 Summary statistics for Figure 39

4.3.10 Diurnal electricity use by EV ownership

Throughout the day, households with electric vehicles have a higher mean electricity use than those without (Figure 40). Here, households who own EVs are identified based on their responses to the SERL recruitment survey between 2019 and 2021. For most of the day the mean profile is similar in shape, although the evening peak for EV owners is slightly later and proportionally higher than other daytime differences. The main difference between the two groups is overnight from approximately midnight until around 06:00, when the EV group shows a peak in usage that reaches levels substantially higher than at any other time of the day. This is most likely due to automated charging periods for the electric vehicles.

In addition to EV charging during the day, the higher electricity usage among the EV group at other times of the day could be due to differences in other characteristics between the two groups: EV owning households in the sample are on average more affluent, live in homes with larger floor areas, and have higher numbers of occupants.

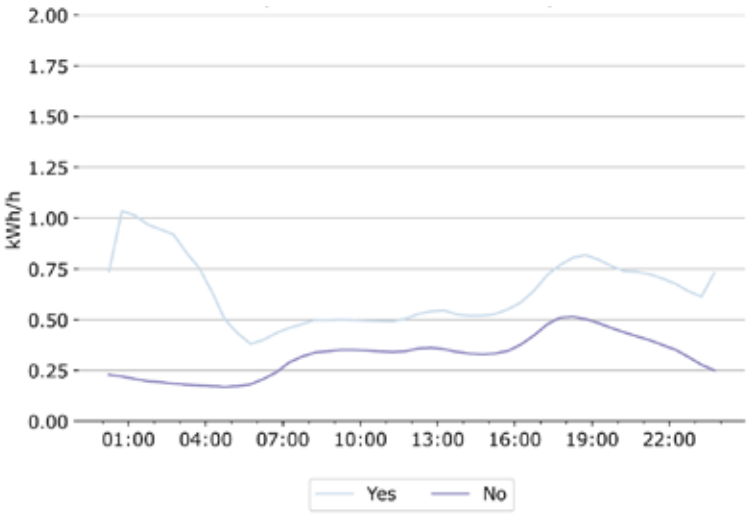


Figure 40 Mean electricity imports by electric vehicle ownership in 2023. These homes have gas central heating and do not have PV.

Table 39 below presents minimum and maximum energy consumption values by EV ownership status as presented in Figure 40 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	EV ownership
Electricity	0.38 kWh/h	06:00	1.03 kWh/h	01:00	Yes
Electricity	0.17 kWh/h	05:00	0.51 kWh/h	18:30	No

Table 39 Summary statistics for Figure 40


Budget
14:42
£1.26
Used so far today :
8.02 kWh
LIVE
OK

5
Energy use in 2022

This section provides the equivalent analysis to Section 4 for 2022. The absolute values are different, but the trends in energy use between different groups of households are very similar to those found for 2023. It should be noted that slightly different households are included in the statistics for both years, because of variable data availability over time.

5.1
Annual energy use in 2022

5.1.1
Annual energy use by region

Figure 41 presents median daily gas and electricity consumption per home for 2022 by region (note that the equivalent figure for 2023 is Figure 8). Median gas consumption is similar across most regions, although the South West and Wales have notably lower consumption. Median electricity consumption is similar between all regions. There is no clear relationship between the coolest regions and the energy consumption even for gas, the primary space heating fuel in these homes. The South East for example has the highest mean external temperature and the third highest median gas consumption, while Scotland has the lowest mean external temperature but the fourth highest median gas consumption. Similarly, there is no clear pattern for electricity consumption in different regions, Scotland has the lowest electricity imports and the South East has the highest. Differences between regions are likely to be a result of combinations of differences between building types, floor areas, affluence, weather and other factors.

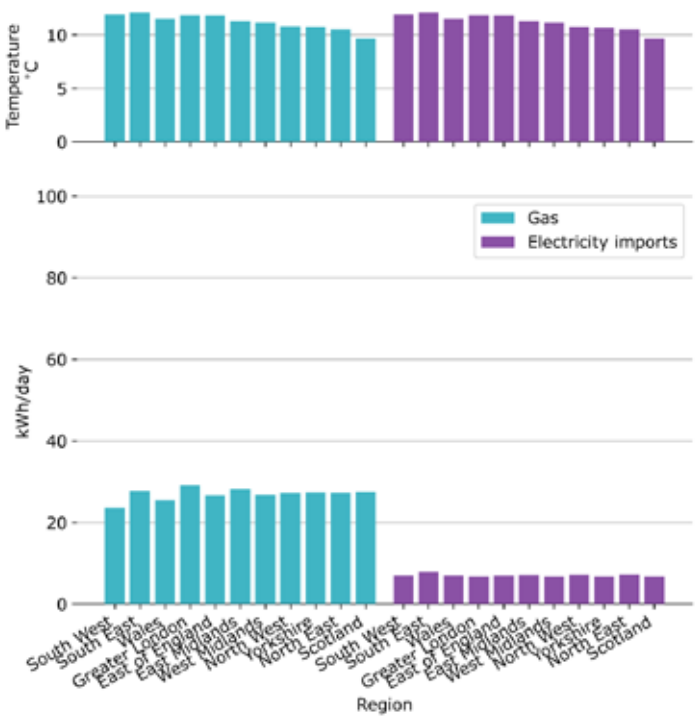


Figure 41. Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 within different regions of Great Britain. These homes have gas central heating and do not have PV. Bars are arranged from left to right from the highest to lowest mean external temperature in 2021 (for consistency with the previous SERL statistical report).

Table 40 below presents minimum and maximum energy consumption values by region as presented in Figure 41 above.

Quantity	Minimum	Region with min. value	Temp. for min. value	Maximum	Region with max. value	Temp. for max. value
Electricity	6.7 kWh/day	Scotland	9.7 °C	7.9 kWh/day	South East	12.1 °C
Gas	23.6 kWh/day	South West	11.9 °C	29.1 kWh/day	Greater London	11.9 °C

Table 40 Summary statistics for Figure 41

5.1.2 Annual energy use by IMD (Index of Multiple Deprivation) quintile

Both electricity and gas consumption increase with higher IMD (i.e., lower deprivation) quintiles in 2022, see Figure 42 (note that the equivalent figure for 2023 is Figure 9). Decreasing deprivation shows a strong trend with increasing gas consumption and increasing gas consumption per occupant, but a relatively weak relationship with gas consumption per m^2. This suggests that much of the increase in gas use in less deprived areas is largely associated with increasing floor areas. There is a similar trend of decreasing deprivation with increasing electricity use and electricity use per person, but no clear relationship with energy use m^2.

As noted in Section 2.1, normalised statistics relate to different sample of households due to the availability of contextual data (floor area is available for approximately 60% of the sample, and number of occupants for over 95%). As a result, care should be taken in comparing the results for different units.

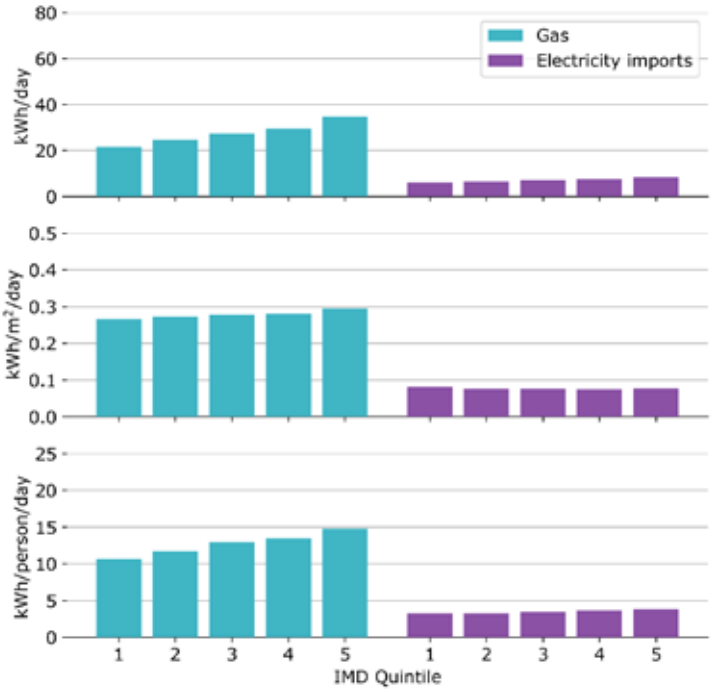


Figure 42 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 within different IMD (Index of Multiple Deprivation) quintiles. These homes have gas central heating and do not have PV.

Table 41 below presents minimum and maximum energy consumption values for the IMD quintiles presented in Figure 42 above.

Quantity	Minimum	IMD quintile for min. value	Maximum	IMD quintile for max. value
Electricity	6.2 kWh/day	1	8.4 kWh/day	5
Electricity	0.08 kWh/m^2/day	4	0.08 kWh/m^2/day	1
Electricity	3.3 kWh/person/day	1	3.8 kWh/person/day	5
Gas	21.7 kWh/day	1	34.6 kWh/day	5
Gas	0.27 kWh/m^2/day	1	0.30 kWh/m^2/day	5
Gas	10.7 kWh/person/day	1	14.8 kWh/person/day	5

Table 41 Summary statistics for Figure 42

5.1.3 Annual energy use by EPC energy efficiency rating

Approximately 60% of the SERL Observatory sample have an and for these participants gas use decreases with improving EPC energy efficiency rating according to all metrics in this analysis, see Figure 43 (note that the equivalent for 2022 is Figure 10). Homes rated F & G are an exception to this trend for gas use and gas use per m^2. However, it should be noted that the sample is relatively small (90 F & G-rated homes), and that the majority of F & G-rated homes use fuels other than gas for central heating. Since the figure below includes only gas centrally heated homes, the F&G homes in this group may be unusual.

Electricity use and electricity use per occupant increases from band C to E, while bands C to E have very similar electricity use per m^2. Groups A & B, and F & G, have the lowest and highest electricity use per occupant respectively, and fall in the middle of the groups for electricity use per household. However, it should be noted that most A & B-rated homes have PV whereas those presented in these figures do not, so these homes may be unusual compared to most A & B homes. As above, the F & G homes may be unusual because they have gas central heating while most homes in these bands would not have this form of heating. The sample sizes are also small for both these groups (180 for A & B, and 100 for F & G).

Table 42 below presents minimum and maximum energy consumption values for the EPC bands presented in Figure 43 above.

The average home in GB is D-rated (DHSG, 2020; ONS, 2021) while the government ambition is for as many homes as possible to reach a C-rating by 2035 (HMG, 2017). In Scotland the ambition is for social housing to reach at least a B-rating by 2032 and a C-rating for other homes and by 2033 (Scottish Government, 2021). The median D-rated home in the SERL Observatory sample used 31% more gas per day and 17% more electricity imports per day than the median C-rated home in 2022. However, note that the energy efficiency rating is based on cost per m^2, so the comparing the energy use normalised by floor area is particularly important in this case. After adjusting for floor area, the median D-rated home in the SERL Observatory sample used 17% more gas per day/m^2 and 1% more electricity imports per day than the median C-rated home in 2022. This difference between metrics reflects that D-rated homes are on average larger than C-rated homes. See Few *et al.* (2023) for analysis of the difference between EPC-modelled and metered energy use in the SERL Observatory sample, which shows that there is a significantly smaller change in metered energy use than the modelled change in energy use between EPC bands.

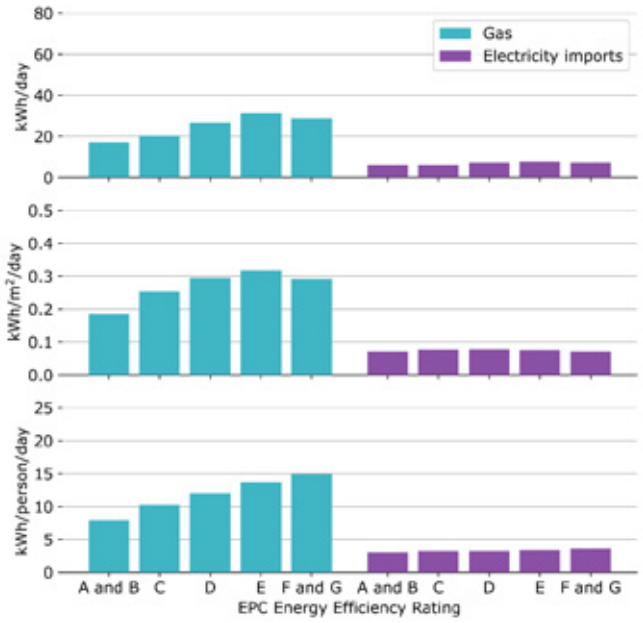


Figure 43 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 by EPC energy efficiency rating. These homes have gas central heating and do not have PV.

Quantity	Minimum	EPC rating with min. value	Maximum	EPC rating with max. value
Electricity	6.1 kWh/day	C	7.8 kWh/day	E
Electricity	0.07 kWh/m^2/day	F & G	0.08 kWh/m^2/day	D
Electricity	3.1 kWh/person/day	A & B	3.6 kWh/person/day	F & G
Gas	17.2 kWh/day	A & B	31.3 kWh/day	E
Gas	0.18 kWh/m^2/day	A & B	0.32 kWh/m^2/day	E
Gas	7.9 kWh/person/day	A & B	14.9 kWh/person/day	F & G

Table 42 Summary statistics for Figure 43

5.1.4 Annual energy use by floor area

Both electricity and gas use increased significantly with floor area in our sample in 2022, see Figure 44 (2023 statistics are shown in Figure 11). Note that floor area is only available for homes with an EPC record (approximately 60% of the sample). Gas use for homes over 200 m² was more than quadruple that for homes less than 50 m², while electricity imports more than tripled between the same groups. Electricity and gas use per occupant also increased significantly with floor area. There was a decrease in electricity and gas use per m² with floor area band showing that the relationship is not linear, although for gas it is very similar for all bands with floor area up to 150 m². Homes over 200 m² used 15% less gas per day/m² and 41% less electricity imports per day/m² than homes less than 50 m². Floor area is closely correlated with number of occupants, IMD quintile and building type.

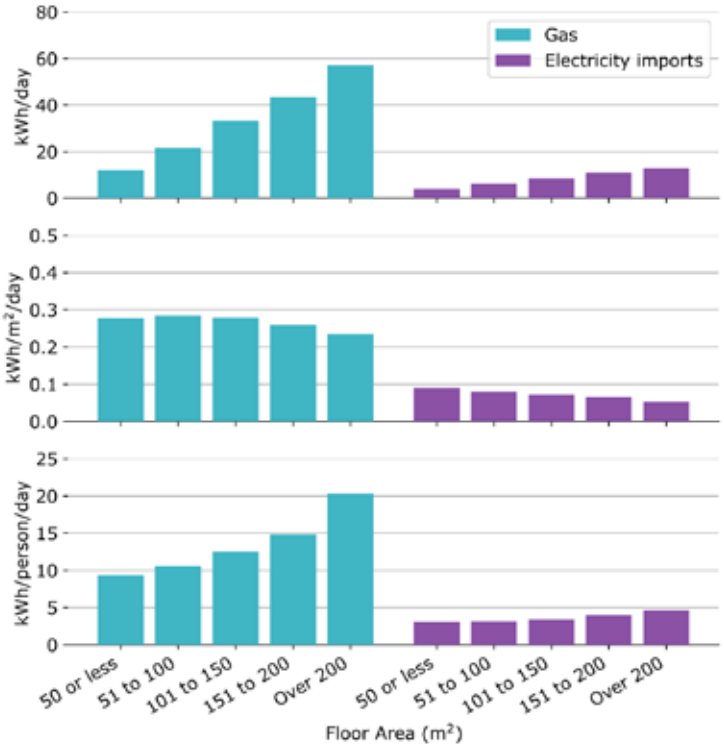


Figure 44 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 by floor area band. These homes have gas central heating and do not have PV.

Table 43 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 44 above.

Quantity	Minimum	Floor area with min. value	Maximum	Floor area with max. value
Electricity	3.9 kWh/day	50 m² or less	12.8 kWh/day	Over 200 m²
Electricity	0.05 kWh/m²/day	Over 200 m²	0.09 kWh/m²/day	50 m² or less
Electricity	3.1 kWh/person/day	50 m² or less	4.64 kWh/person/day	Over 200 m²
Gas	11.9 kWh/day	50 m² or less	57.2 kWh/day	Over 200 m²
Gas	0.24 kWh/m²/day	Over 200 m²	0.28 kWh/m²/day	51 m² to 100 m²
Gas	9.4 kWh/person/day	50 m² or less	20.3 kWh/person/day	Over 200 m²

Table 43 Summary statistics for Figure 44

5.1.5
Annual energy use by building type

Gas and electricity showed a similar pattern with different building types per homes and per occupant, see Figure 45 (note that the equivalent figure for 2023 is Figure 12). The median gas use in detached homes was 48% greater than that in terraced homes, and 35% greater for electricity. However, different building types are strongly related to floor area and the proportional differences reduce significantly when comparing normalised energy use. For example, for example detached homes used 4% more gas per m^2 than terraced homes and used the same electricity per m^2. Purpose-built flats showed the lowest use per m^2 and semi-detached houses had the greatest gas use per m^2.

Table 44 below presents minimum and maximum energy consumption values for the building types presented in Figure 45 above.

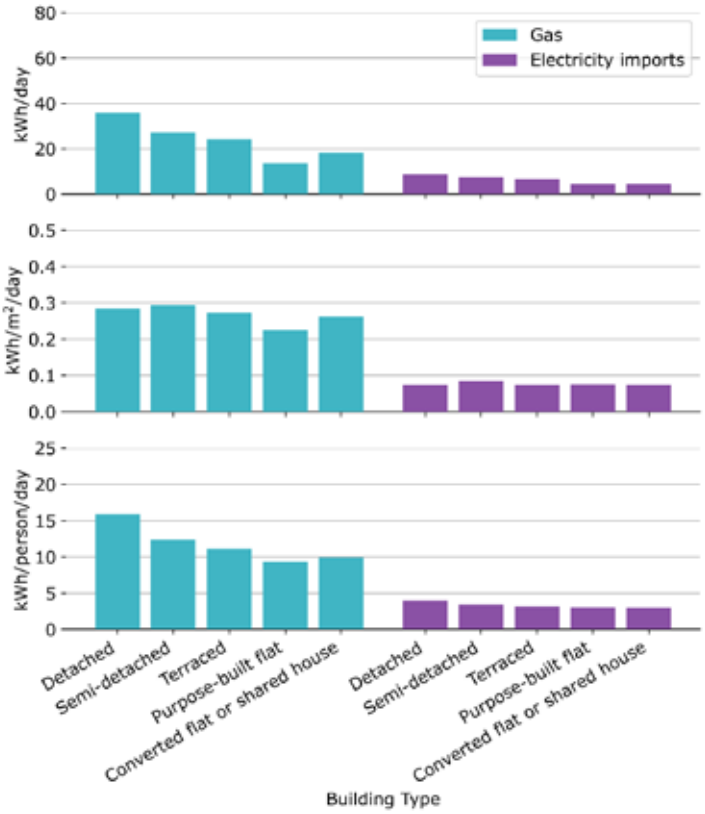


Figure 45 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 by building type[13]. These homes have gas central heating and do not have PV.

Quantity	Minimum	Building type with min. value	Maximum	Building type with max. value
Electricity	4.4 kWh/day	Purpose-built flat	8.8 kWh/day	Detached
Electricity	0.07 kWh/m^2/day	Converted flat or shared house, detached, terraced	0.08 kWh/m^2/day	Semi-detached
Electricity	3.0 kWh/person/day	Converted flat or shared house	4.0 kWh/person/day	Detached
Gas	13.5 kWh/day	Purpose-built flat	35.9 kWh/day	Detached
Gas	0.22 kWh/m^2/day	Purpose-built flat	0.29 kWh/m^2/day	Semi-detached
Gas	9.3 kWh/person/day	Purpose-built flat	15.9 kWh/person/day	Detached

Table 44 Summary statistics for Figure 45

13 Categories in this figure are based on participant responses to the following question: "B1. What type of accommodation do you live in? Tick one answer only". Some small categories have been merged for SDC reasons.

5.1.6 Annual electricity use by central heating system

As expected, homes with any type of electric central heating (electric radiators, electric storage radiators or other electric) used more electricity than homes without in 2022, see Figure 46 (note that the equivalent figure for 2023 is Figure 13). However, the proportional difference is much greater for electricity use per m^2, this likely reflects the higher prevalence of electric heating in flats, particularly electric radiators and electric storage heaters, which will have relatively small floor areas. Homes with gas boilers, gas boiler plus other and oil, solid fuel or biomass all have very similar electricity use for all metrics, this is expected since these homes do not use any form of electric heating as their main heating source. Note also that the gas boiler group is by far the largest group with over 7,000 households contributing to the kWh/day statistic (reflecting the prevalence of this type of heating), the rest are all less than 500 households and other electric and district or community groups are less than 100.

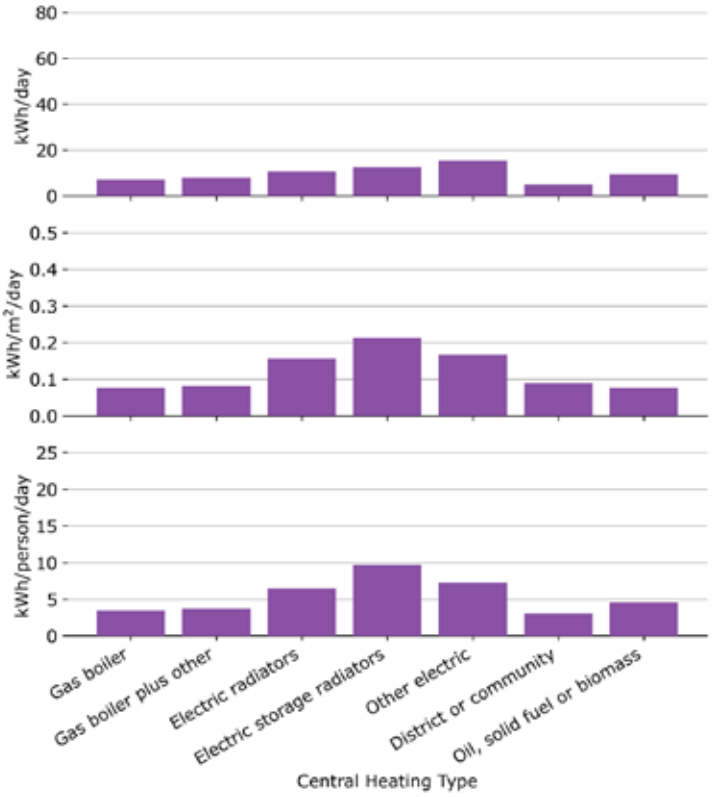


Figure 46 Median consumption of electricity imports for homes in the SERL Observatory in 2022 by central heating system These homes do not have PV [14].

Table 45 below presents minimum and maximum energy consumption values for the central heating systems presented in Figure 46 above.

Quantity	Minimum	Central heating type with min. value	Maximum	Central heating type with max. value
Electricity	4.9 kWh/day	District or community	15.4 kWh/day	Other electric
Electricity	0.08 kWh/m^2/day	Gas boiler, & Oil, solid fuel or biomass	0.21 kWh/m^2/day	Electric storage radiators
Electricity	3.1 kWh/person/day	District or community	9.7 kWh/person/day	Electric storage radiators

Table 45 Summary statistics for Figure 46

14 Categories in this figure are based on participant responses to the following question: "A3. What type of central heating does your accommodation have? By central heating we mean a central system that generates heat for multiple rooms. Tick all that apply whether or not you use it'. Most participants chose only one type of heating, but those that chose multiple forms have been grouped in this figure either as 'gas boiler plus other' or 'other mix', some small categories have also been grouped for this figure.

5.1.7 Annual energy use by year of building construction

In general, older properties use more gas than modern ones according to all metrics in our analysis in 2022, see Figure 47 (note that the equivalent figure for 2023 is Figure 14). The oldest homes, built before 1900, use 32% more gas and 4% less electricity than the newest homes, built since 2003. After normalising for floor area, the oldest homes use 30% more gas per m^2 and 4% less electricity per m^2 than the newest homes. Homes built before 1950 have very similar gas use per m^2, while homes built after this have lower gas use per m^2. Building Regulations were introduced in 1965 and have been progressively tightened since then. The trends are different for gas use per occupant, which may be associated with differences in typical property sizes, types and occupancy. The most modern homes, built since 2003 show the lowest gas use according to all metrics in this analysis, suggesting higher efficiency in this group. Electricity use shows relatively little variation and no clear pattern with construction age band according to all metrics in our analysis.

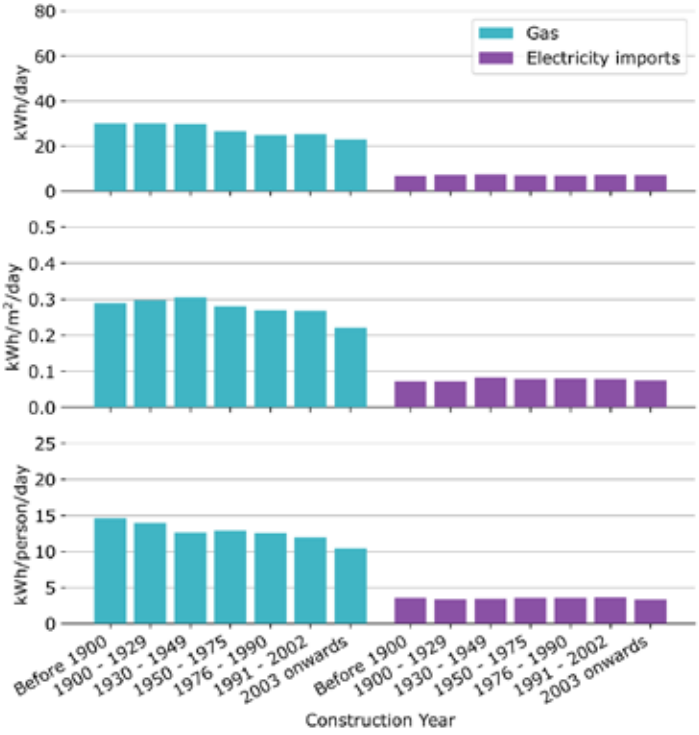


Figure 47 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 by construction year bands[15]. These homes have gas central heating and do not have PV.

Table 46 below presents minimum and maximum energy consumption values for the construction year bands presented in Figure 47 above.

Quantity	Minimum	Construction year with min. value	Maximum	Construction year with max. value
Electricity	6.8 kWh/day	Before 1900	7.5 kWh/day	1930 - 1949
Electricity	0.07 kWh/m^2/day	Before 1900	0.08 kWh/m^2/day	1930 – 1949
Electricity	3.3 kWh/person/day	2003 onwards	3.6 kWh/person/day	1991 – 2002
Gas	22.9 kWh/day	2003 onwards	30.2 kWh/day	Before 1900
Gas	0.22 kWh/m^2/day	2003 onwards	0.30 kWh/m^2/day	1930 - 1949
Gas	10.4 kWh/person/day	2003 onwards	14.6 kWh/person/day	Before 1900

Table 46 Summary statistics for Figure 47

15 Categories in this figure are based on participant responses to the following question: "B9. Approximately when do you think your accommodation was built? Tick one answer only."

5.1.8 Annual energy use by number of occupants

Both gas and electricity use increase with number of occupants in 2022, see Figure 48 (note that the equivalent figure for 2023 is Figure 15). For both gas and electricity, an increase of 1 in the number of occupants shows the greatest increase in energy use when the occupant number increases from 1 to 2, with median gas use increasing by 8.0 kWh/day, and electricity use by 2.9 kWh/day. Floor area is also strongly correlated with number of occupants, however, the gas use per m^2 continues to increase with increasing occupant numbers, even though gas use is largely driven by space heating in the UK. This may be because each additional occupant also requires hot water, which is largely provided by gas in the UK. Electricity use per m^2 increases with increasing occupant numbers, and gas and electricity use per occupant decrease with increasing occupant numbers showing that each additional occupant does not increase energy use by the same amount as the one before.

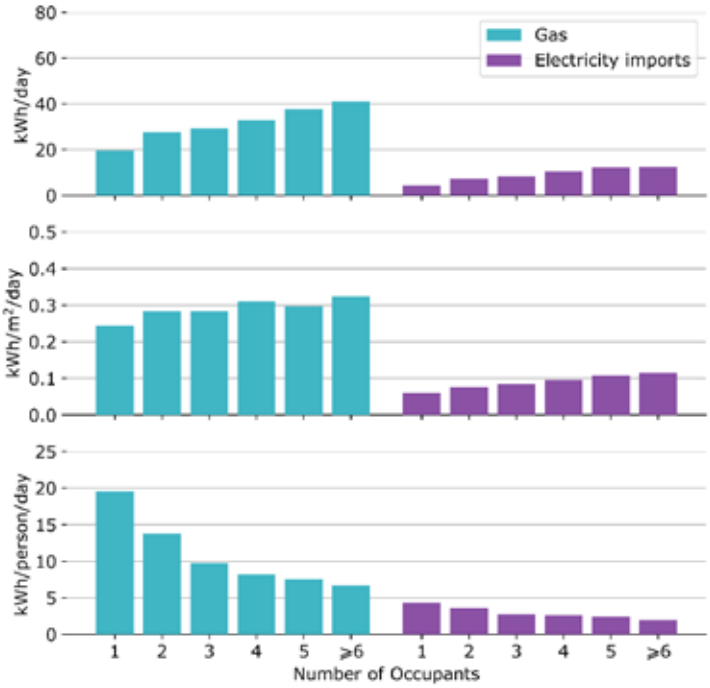


Figure 48 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 by number of occupants[16]. These homes have gas central heating and do not have PV.

Table 47 below presents minimum and maximum energy consumption values by number of occupants as presented in Figure 48 above.

Quantity	Minimum	Number of occupants with min. value	Maximum	Number of occupants with max. value
Electricity	4.4 kWh/day	1	12.4 kWh/day	≥6
Electricity	0.06 kWh/m²/day	1	0.11 kWh/m²/day	≥6
Electricity	2.0 kWh/person/day	≥6	4.4 kWh/person/day	1
Gas	19.6 kWh/day	1	41.1 kWh/day	≥6
Gas	0.24 kWh/m²/day	1	0.32 kWh/m²/day	≥6
Gas	6.7 kWh/person/day	≥6	19.6 kWh/person/day	1

Table 47 Summary statistics for Figure 48

16 Categories in this figure are based on participant responses to the following question: "C1. How many people currently live in your household, including you? Please include all those who are there regularly, even if not every day, including children who live away from home during term time." Large numbers have been grouped into one category for SDC reasons.

5.1.9
Annual energy use by tenure

Homes that are owned outright or with a mortgage and rent-free homes use the most gas by all metrics in this analysis and have the greatest electricity use per household and per person in 2022, see Figure 49 (note that the equivalent figure for 2023 is Figure 16). Gas use per m^2 is similar for all groups except homes that are part-owned part-rented which show lower use per m^2. Part-own part-rent is a relatively new form of tenure and so these homes are possibly more modern and efficient buildings.

Homes that are private or social rent have the lowest electricity use per household and per occupant, but have similar electricity use per m^2 to part-own part-rent homes. Tenure is also likely to be associated with affluence and this is likely to affect the trends for these types of homes.

Note that the rent-free and part-own part-rent groups are both small, with 40 and 50 households in each category respectively for the electricity imports per day statistic. The statistics for these groups are therefore less reliable than the other categories which all have over 400 households.

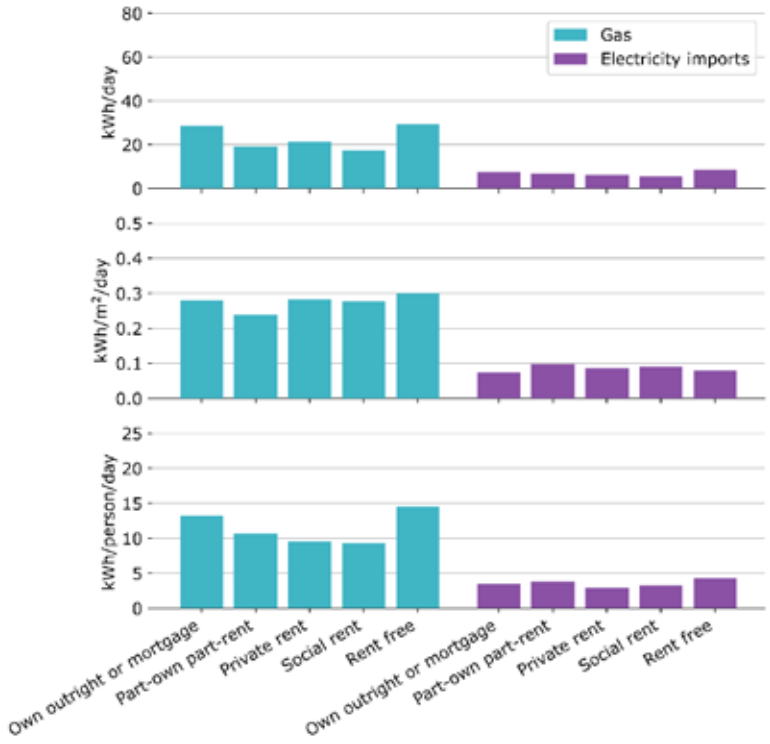


Figure 49 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 by tenure[17]. These homes have gas central heating and do not have PV.

Table 48 below presents minimum and maximum energy consumption values by tenure as presented in Figure 49 above.

Quantity	Minimum	Tenure with min. value	Maximum	Tenure with max. value
Electricity	5.3 kWh/day	Social rent	8.4 kWh/day	Rent free
Electricity	0.07 kWh/m^2/day	Own outright or mortgage	0.10 kWh/m^2/day	Part-own part-rent
Electricity	2.9 kWh/person/day	Private rent	4.3 kWh/person/day	Rent free
Gas	17.3 kWh/day	Social rent	29.2 kWh/day	Rent free
Gas	0.24 kWh/m^2/day	Part-own part-rent	0.30 kWh/m^2/day	Rent free
Gas	9.3 kWh/person/day	Social rent	14.5 kWh/person/day	Rent free

Table 48 Summary statistics for Figure 49

17 Categories in this figure are based on participant responses to the following question: "B4. Do you (or your household) own or rent this accommodation? Tick one answer only". Some small categories have been merged for SDC reasons.

5.1.10 Annual electricity use by electric vehicle ownership

The median home with an EV used double the electricity imports and 14% more gas than the median home without in 2022, see Figure 50 (note that the equivalent figure for 2023 is Figure 17). The gas use per m^2 and per occupant are slightly higher for homes with EVs, this may because households with an EV are likely to be more affluent than households without. As expected, homes with electric vehicles show significantly higher electricity use per m^2 and per occupant, reflecting the additional electricity load associated with the EV.

Note that this analysis is based on the household's response to a question about EVs when they signed up to be part of the SERL Observatory, between August 2019 and February 2021, so some households who initially answered that they did not have an EV may have subsequently acquired one. As part of our follow-up survey in 2022, we asked again if households had an EV as well as asking how many; future analysis will investigate this updated information.

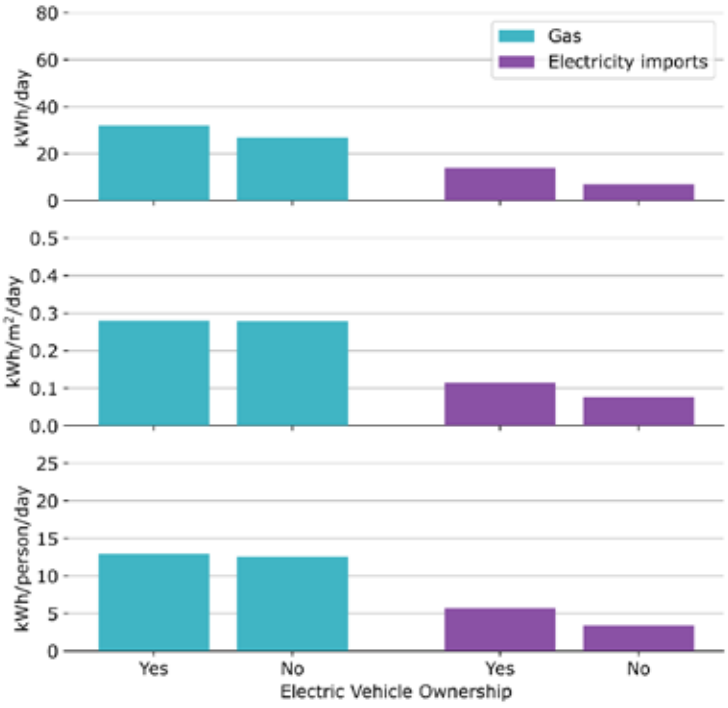


Figure 50 Median consumption of gas and electricity imports for homes in the SERL Observatory in 2022 by electric vehicle ownership[18]. These homes have gas central heating and do not have PV.

Table 49 below presents minimum and maximum energy consumption values by EV ownership status as presented in Figure 50 above.

Quantity	Minimum	EV ownership status with min. value	Maximum	EV ownership status with max. value
Electricity	7.0 kWh/day	No	13.9 kWh/day	Yes
Electricity	0.08 kWh/m^2/day	No	0.12 kWh/m^2/day	Yes
Electricity	3.4 kWh/person/day	No	5.7 kWh/person/day	Yes
Gas	26.8 kWh/day	No	32.1 kWh/day	Yes
Gas	0.28 kWh/m^2/day	No	0.28 kWh/m^2/day	Yes
Gas	12.6 kWh/person/day	No	13.0 kWh/person/day	Yes

Table 49 Summary statistics for Figure 50

18 Categories in this figure are based on participant responses to the following question: "C5. Does your household have a plug-in electric vehicle? This does not include hybrid cars which are not plugged-in to charge. Tick one answer only".

5.2
Monthly energy use in 2022

5.2.1
Monthly energy use by EPC energy efficiency rating

Gas consumption by month varied by EPC energy efficiency rating, see Figure 51 (note that the equivalent figure for 2023 is Figure 18). December 2022 was the coldest month of the year (averaging 4.3 °C), and median gas consumption in F & G-rated homes was almost twice that of A & B-rated homes. Note that figures normalised by floor area and by occupant are available in the aggregated statistics dataset which accompanies this report. The difference in median gas consumption between EPC ratings reduces considerably over the summer months when average temperatures are above 15 °C (June, July and August), although bands C to F & G continue to use more gas than B-rated homes, possibly because of lower boiler efficiency for hot water. Unexpectedly, A & B-rated homes use the most gas in August, however, the gas use per m^2 and per occupant (available in the aggregated statistics) lower than most bands in August.

Table 50 below presents minimum and maximum gas consumption values for the EPC bands presented in Figure 51 above.

Finally, it should be noted that F & G-rated homes are often heated by fuels other than gas, so the sample presented in this analysis is unusual compared to typical F & G homes. Note that the sample size for A & B and F & G rated homes is much smaller than for the other bands, 150 and 90 homes respectively, compared to over 500 for all other bands. The results for these bands are therefore less reliable than the middle bands.

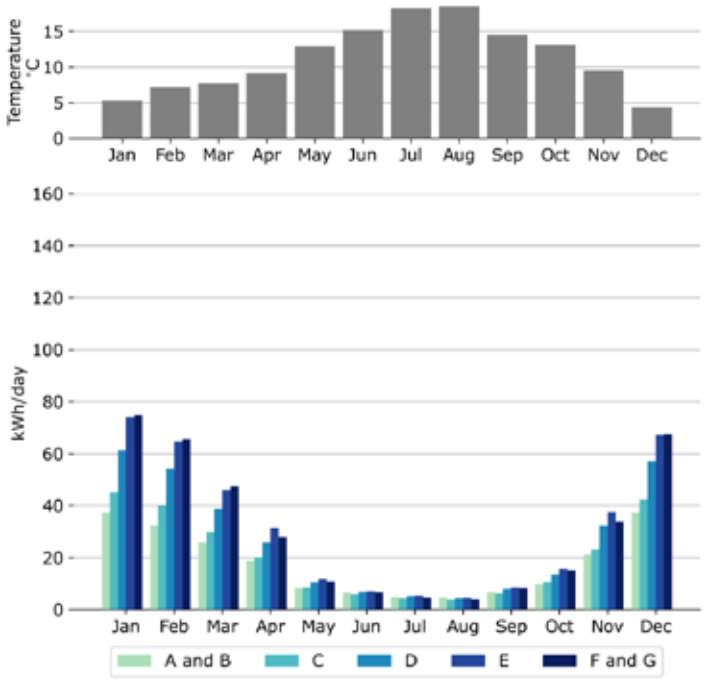


Figure 51 Median consumption of gas and electricity import for homes in the SERL Observatory by month and EPC energy efficiency rating in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value	EPC band
Gas	4.6 kWh/day	August	18.5 °C	37.3 kWh/day	January	5.3 °C	A & B
Gas	3.9 kWh/day	August	18.4 °C	45.0 kWh/day	January	5.2 °C	C
Gas	4.4 kWh/day	August	18.5 °C	61.2 kWh/day	January	5.2 °C	D
Gas	4.5 kWh/day	August	18.7 °C	74.0 kWh/day	January	5.2 °C	E
Gas	4.0 kWh/day	August	18.5 °C	74.8 kWh/day	January	5.3 °C	F & G

Table 50 Summary statistics for Figure 51

Electricity demand also varied by month and EPC rating, see Figure 52 (note that the equivalent figure for 2022 is Figure 19), although by less than the variation in gas consumption, with homes that have lower energy efficiency bands using more import electricity. Note that in general, A & B-rated homes have solar PV, whereas the sample presented in these figures do not have PV and so are unusual compared to typical A & B homes. Additionally, the sample size for A & B and F & G rated homes is much smaller than for the other bands, 220 and 120 homes respectively, compared to over 600 for all other bands. The results for these bands are therefore less reliable than the middle bands.

Table 51 below presents minimum and maximum electricity consumption values for the EPC bands presented in Figure 52 above.

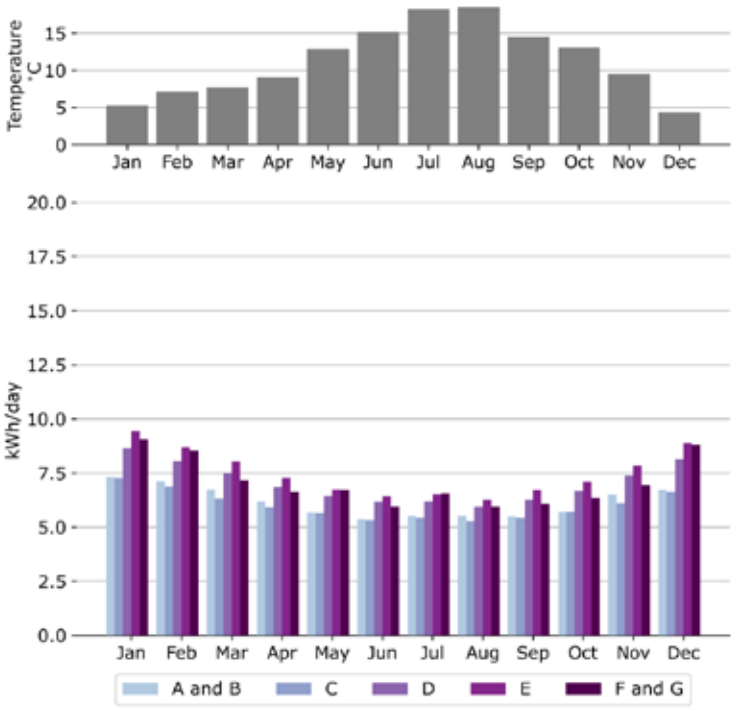


Figure 52 Median consumption of electricity imports for homes in the SERL Observatory by month and by EPC energy efficiency rating in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value	EPC band
Electricity	5.4 kWh/day	June	15.2 °C	7.3 kWh/day	January	5.3 °C	A & B
Electricity	5.3 kWh/day	August	18.3 °C	7.3 kWh/day	January	5.3 °C	C
Electricity	5.9 kWh/day	August	18.5 °C	8.6 kWh/day	January	5.2 °C	D
Electricity	6.3 kWh/day	August	18.6 °C	9.4 kWh/day	January	5.2 °C	E
Electricity	6.0 kWh/day	August	15.1 °C	9.1 kWh/day	January	5.3 °C	F & G

Table 51 Summary statistics for Figure 52

5.2.2
Monthly energy use by floor area

Gas use by month also varied by floor area, see Figure 53 (note that the equivalent figure for 2023 is Figure 20). December 2022 was the coldest month of the year (averaging 4.4 °C), and median gas consumption in homes over 200 m² was almost five times larger than in homes of 50 m² or less. Smaller homes continue to use less gas over the summer months, and in the warmest month of the year (August, 18.5 °C), the smallest homes use about a quarter of the gas that the largest use. Summer gas use is likely to be largely related to water heating (with some residual space heating) and it is likely that larger homes have more occupants and therefore have greater hot water demand than smaller homes (note that energy statistics normalised by m² and occupant number are available in the statistical dataset that accompanies this report).

Table 52 below presents minimum and maximum gas consumption values for the floor area bands presented in Figure 53 above.

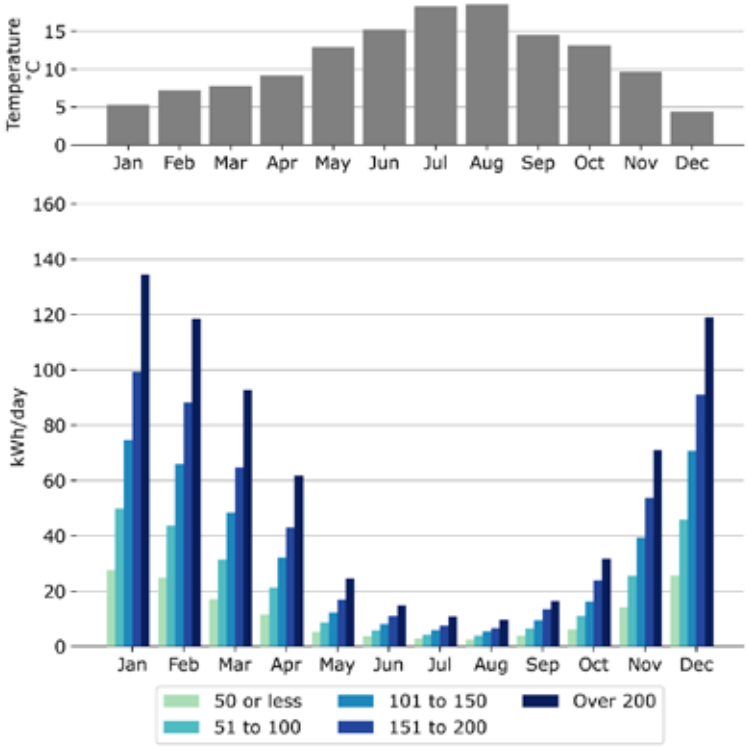


Figure 53 Median gas consumption per day for homes in the SERL Observatory sample by month and floor area in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value	Floor area band
Gas	2.4 kWh/day	August	18.6 °C	27.6 kWh/day	January	5.3 °C	50 m² or less
Gas	3.8 kWh/day	August	18.5 °C	49.8 kWh/day	January	5.2 °C	51 m² to 100 m²
Gas	5.4 kWh/day	August	18.6 °C	74.6 kWh/day	January	5.3 °C	101 m² to 150 m²
Gas	6.5 kWh/day	August	18.5 °C	99.4 kWh/day	January	5.3 °C	151 m² to 200 m²
Gas	9.5 kWh/day	August	18.6 °C	134.6 kWh/day	January	5.3 °C	Over 200 m²

Table 52 Summary statistics for Figure 53

Electricity demand also varied by month and floor area in 2022, although by less than the variation in gas consumption, with smaller homes consuming less electricity in all months, see Figure 54 (note that the equivalent figure for 2023 is Figure 21). In December 2022 the median electricity use in homes smaller than 50 m² was less than a third of that in homes larger than 200 m². This was similar in the warmest month, August 2022, where the smallest homes again had a median consumption almost a third of the largest homes.

Table 53 presents minimum and maximum energy consumption values for the floor area bands presented in Figure 54.

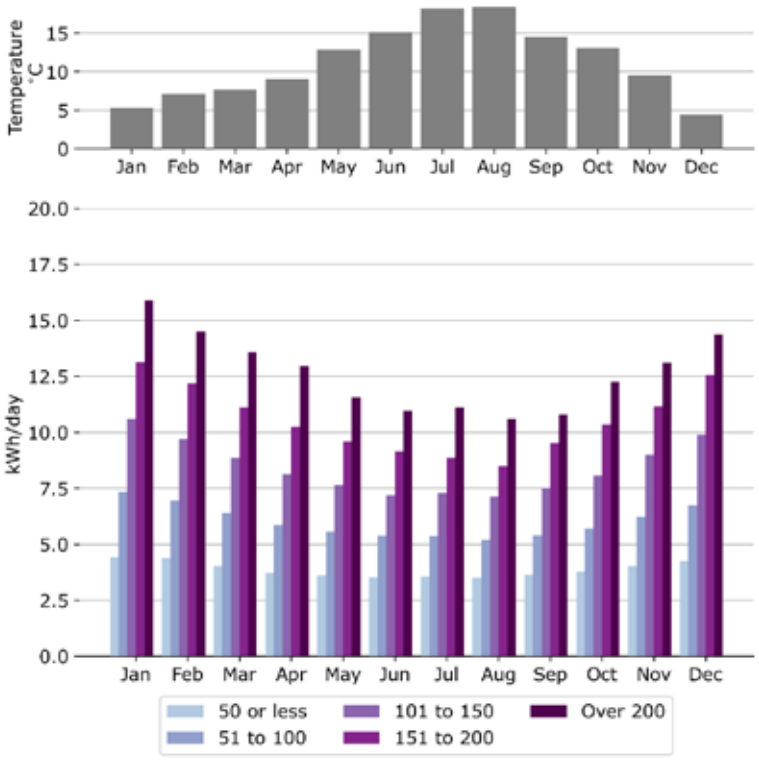


Figure 54 Median consumption of electricity imports per day for homes in the SERL Observatory sample by month and floor area in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value	Floor area band
Electricity	3.5 kWh/day	August	18.5 °C	4.4 kWh/day	January	5.3 °C	50 m² or less
Electricity	5.2 kWh/day	August	18.4 °C	7.3 kWh/day	January	5.2 °C	51 m² to 100 m²
Electricity	7.1 kWh/day	August	18.5 °C	10.6 kWh/day	January	5.3 °C	101 m² to 150 m²
Electricity	8.5 kWh/day	August	18.4 °C	13.1 kWh/day	January	5.3 °C	151 m² to 200 m²
Electricity	10.6 kWh/day	August	18.5 °C	15.9 kWh/day	January	5.3 °C	Over 200 m²

Table 53 Summary statistics for Figure 54

5.2.3 Monthly electricity imports and exports for homes with PV

Figure 55 shows the monthly median electricity imports and exports for homes in the SERL Observatory which have solar PV. Note that imported electricity is the amount of electricity taken from the grid, and export is the amount exported back to the grid. The means the amount of self-generated electricity used by the household is not known. The figure shows a very clear pattern in which electricity exports are strongly correlated with mean solar irradiance (as expected).

Note that due to activities associated with migrating our data infrastructure very few export electricity readings were collected in October 2022 and so these results are not shown in the figure.

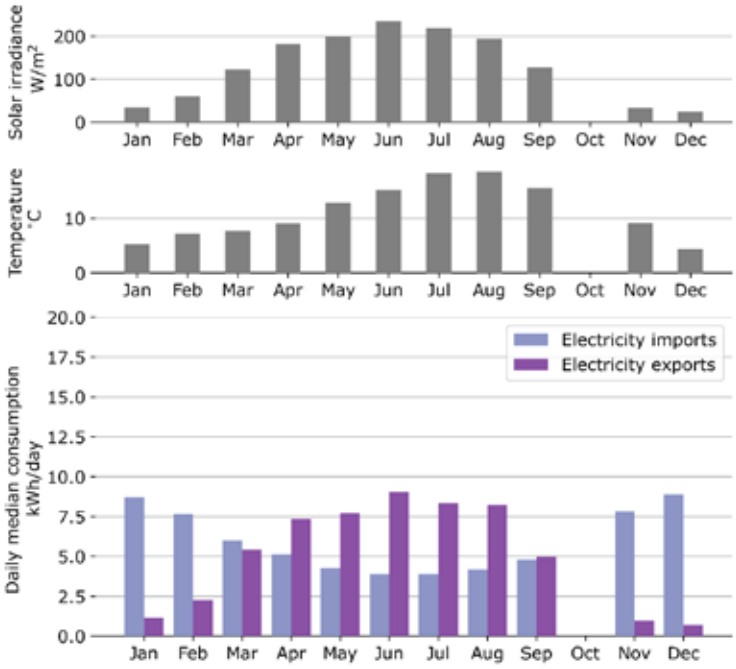


Figure 55 Median electricity imports and exports per day for homes in the SERL Observatory sample by month in 2022. These homes have gas central heating and PV.

Table 54 below presents minimum and maximum energy consumption values for the electricity imports and exports presented in Figure 55 above.

Quantity	Minimum	Month with min. value	Temp. for min. value	Maximum	Month with max. value	Temp. for max. value
Electricity imports	3.9 kWh/day	July	18.2 °C	8.9 kWh/day	December	4.3 °C
Electricity exports	0.7 kWh/day	December	4.3 °C	9.0 kWh/day	June	15.1 °C

Table 54 Summary statistics for Figure 55

5.3
Diurnal energy use in 2022

5.3.1
Full sample

Gas consumption over the course of the day (Figure 56) shows two main peaks, in the morning and evening, with little overnight consumption and moderate levels during the day between the peaks[19] (note that the equivalent figure for 2023 is Figure 23). The median morning peak occurs at 07:30 whilst the, slightly higher, afternoon peak occurs at 18:30. Daytime usage falls to below half the morning peak; a very slight peak centred on 12:30 can be observed, possibly associated with lunchtime cooking and washing-up. Overnight usage falls close to zero, suggesting that at least half the sample does not use its central heating overnight.

For the 25th percentile, the morning peak occurs slightly later at 08:00, and is only around 45% of the median peak, while its afternoon peak is just over 60% of the median. The 75th percentile meanwhile shows a larger morning rather than evening peak – the morning peak is 90% higher than the median, while the afternoon peak is just over 50% larger than the median. Overnight usage is also low, although at its lowest the 75th percentile usage is 3.5 times larger than the lowest median usage.

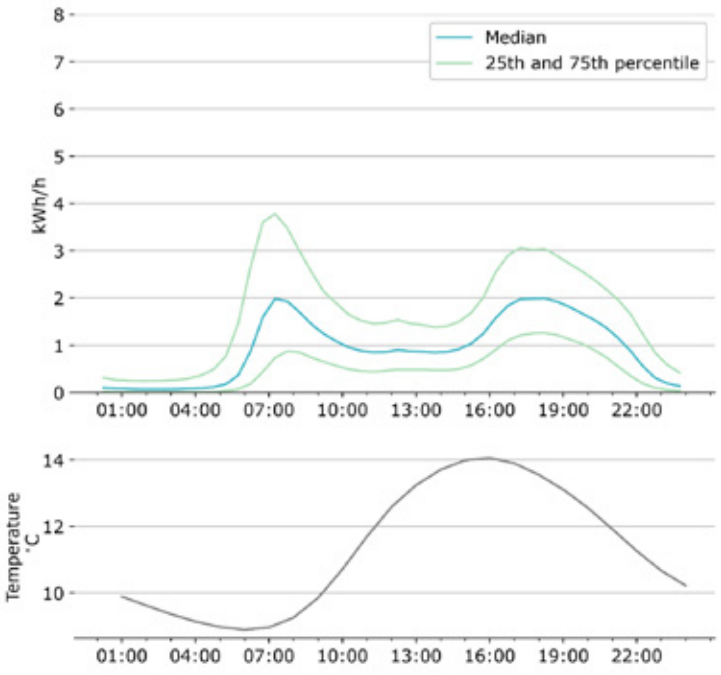


Figure 56 Quartiles of gas consumption for SERL Observatory participants in 2022. These homes have gas central heating and do not have PV.

Table 55 below presents minimum and maximum energy consumption values for the quartiles presented in Figure 56 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Quartile
Gas	0.07 kWh/h	03:00	1.99 kWh/h	18:30	Median
Gas	0.01 kWh/h	03:00	1.26 kWh/h	18:30	25th
Gas	0.25 kWh/h	02:00	3.78 kWh/h	07:30	75th

Table 55 Summary statistics for Figure 56

19 The median and quartiles presented here are drawn independently for each half hour from the distribution of the mean energy use per household for that period. For statistical disclosure control, the median and quartile values shown are the mean of the 10 values closest to the median or quartile, although note that each half hour is not necessarily comprised of the same 10 dwellings.

Electricity use across the day shows a different profile to gas (Figure 57), generally flatter, with a rise in the morning from the overnight lows then a levelling off until an evening increase that peaks at 18:30 (note that the equivalent figure for 2023 is Figure 24). Demand then gradually declines into the early hours of the next day, reaching the minimum at 04:30. A slight peak near the middle of the day, at around 13:00, can again be discerned.

The 25th and 75th percentiles show very similar profiles to the median, simply scaled lower or higher. The 25th centile peak demand is about two thirds that of the median, while the 75th centile peak demand is 1.5 times that of the median.

Table 56 below presents minimum and maximum energy consumption values for the quartiles presented in Figure 57 above.

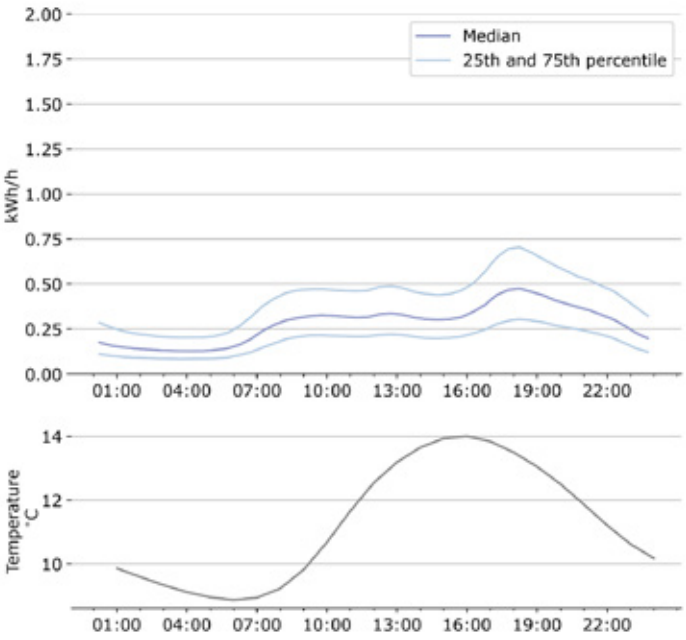


Figure 57 Quartiles of electricity imports for SERL Observatory participants in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Quartile
Electricity	0.13 kWh/h	04:30	0.48 kWh/h	18:30	Median
Electricity	0.08 kWh/h	04:00	0.30 kWh/h	18:30	25th
Electricity	0.20 kWh/h	04:00	0.70 kWh/h	18:30	75th

Table 56 Summary statistics for Figure 57

5.3.2
Diurnal energy use by temperature band

In Figure 58, half-hourly gas consumption is plotted by daily mean external temperature band (note that the equivalent figure for 2023 is Figure 25). This shows the strong relationship between external temperature and gas use across the day for these gas centrally-heated homes. Morning and evening peaks are evident across all the temperature bands, even the 20 °C to 25 °C band mostly associated with the summer period. This suggests that hot water use in the mornings and evenings may in part drive these peaks. Gas use between the peaks is a smaller proportion of peak usage at lower temperatures. A small spike in use is also evident around midday, potentially for cooking and washing up.

The morning peak in gas demand is 12 times higher in the coldest temperature band shown (-5 °C to 0 °C) than in the warmest band (20 °C to 25 °C), while the evening peak is over 13 times higher.

Night-time use is relatively low at all temperatures, although the lowest mean usage in the -5 °C to 0 °C temperature band is still nearly 90% higher than peak usage in the 20 °C to 25 °C band. This suggests that there is a significant increase in the proportion of homes using night-time space heating as temperatures get colder.

Table 57 below presents minimum and maximum energy consumption values for the quartiles presented in Figure 58 above.

The fact that the gas profiles for 15 °C to 20 °C and 20 °C to 25 °C bands are similar suggests that this is mostly not space heating but hot water and cooking gas use. This is consistent with the use of a 15.5 °C degree-day base temperature for UK homes, i.e. space heating will normally come on when the outside temperature drops below 15.5 °C.

It is interesting to compare the median peak gas demand during the coldest period (-5 °C to 0 °C) of 5.9 kW to the capacity of gas boilers, which tends to range from 12-35 kW depending on the number of rooms, heat loss and, for combi-boilers, the number of bathrooms. This means that even during cold spells, many boilers will have to significantly modulate their output and/or cycle on and off, which can impact their efficiency (Bennett *et al.*, 2019)

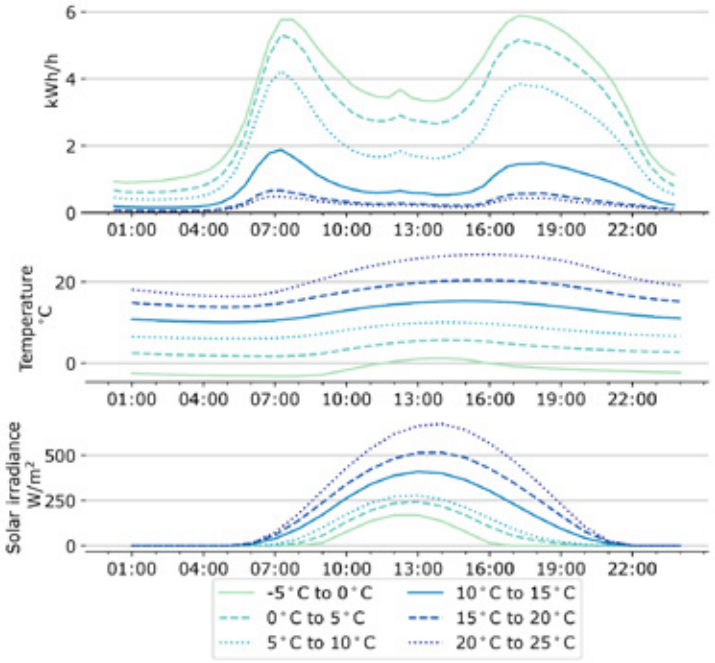


Figure 58 Mean gas consumption by temperature band in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Temperature band
Gas	0.90 kWh/h	01:00	5.89 kWh/h	17:30	-5 °C to 0 °C
Gas	0.61 kWh/h	02:00	5.31 kWh/h	07:30	0 °C to 5 °C
Gas	0.39 kWh/h	02:00	4.23 kWh/h	07:30	5 °C to 10 °C
Gas	0.15 kWh/h	02:30	1.88 kWh/h	07:30	10 °C to 15 °C
Gas	0.06 kWh/h	03:00	0.66 kWh/h	07:30	15 °C to 20 °C
Gas	0.04 kWh/h	03:00	0.48 kWh/h	07:30	20 °C to 25 °C

Table 57 Summary statistics for Figure 58

The net electricity profile (Figure 59) for all the temperature bands show similar overall shapes, beginning to rise from an overnight low at around 05:00 or 05:30 then staying relatively flat until rising again to an evening peak at 18:00 or 18:30 (note that the equivalent figure for 2023 is Figure 26). Demand then declines slowly through the evening and night until the overnight low. Across all bands, a slight rise in usage in the early afternoon is observed, perhaps due to cooking for lunch.

Differences in demand are proportionally higher during the day than overnight, with peak demand over 60% higher in the -5 °C to 0 °C temperature band than in the 20 °C to 25 °C band.

The variation that is observed between temperature bands could be the result of various factors, including increased use of supplementary electric heating, lighting, and energy-using appliances for indoor activities in the colder winter months.

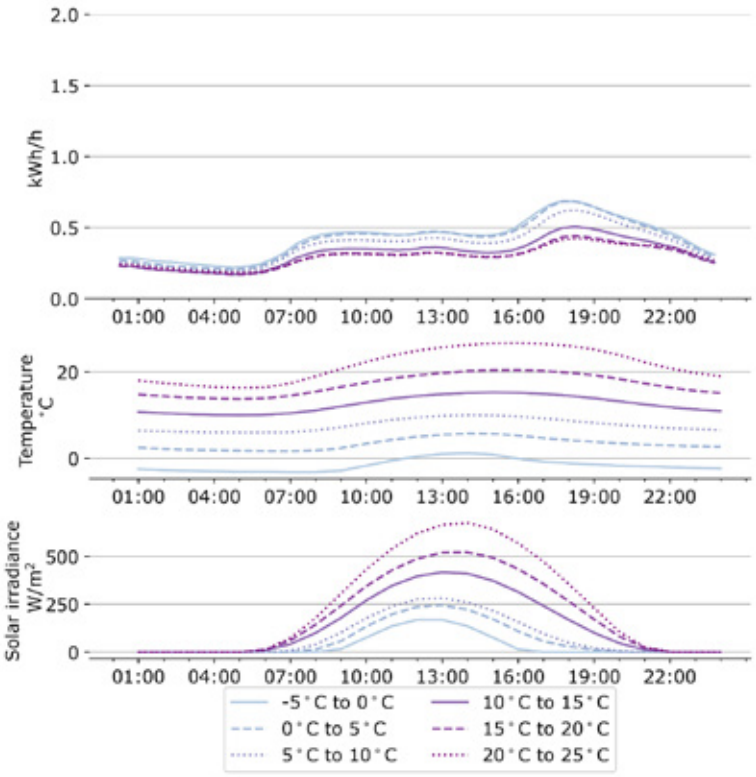


Figure 59 Mean electricity imports by temperature band in 2022. These homes have gas central heating and do not have PV.

Table 58 below presents minimum and maximum energy consumption values for the temperature bands presented in Figure 59 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Temperature band
Electricity	0.22 kWh/h	05:00	0.69 kWh/h	18:00	-5 °C to 0 °C
Electricity	0.20 kWh/h	05:00	0.68 kWh/h	18:30	0 °C to 5 °C
Electricity	0.19 kWh/h	05:00	0.62 kWh/h	18:30	5 °C to 10 °C
Electricity	0.17 kWh/h	05:00	0.51 kWh/h	18:30	10 °C to 15 °C
Electricity	0.17 kWh/h	05:00	0.44 kWh/h	18:30	15 °C to 20 °C
Electricity	0.18 kWh/h	05:30	0.42 kWh/h	18:30	20 °C to 25 °C

Table 58 Summary statistics for Figure 59

5.3.3
Diurnal energy use by deprivation quintile

In Figure 60, mean gas consumption is presented for households segmented by the Index of Multiple Deprivation (IMD) quintile of the areas in which they are located (note that the equivalent figure for 2023 is Figure 27). The figure shows that over the whole day mean gas consumption increases with IMD quintile (i.e. with reducing deprivation). Peak usage, particularly in the morning, varies most, whilst usage during the daytime and overnight varies less; overnight usage varies little with IMD. In IMD quintile 1 (most deprived areas), the evening peak is higher than the morning; for quintiles 2 to 5, the morning peak is higher. Peak demand in IMD quintile 5 (in the morning) is twice the peak demand in IMD quintile 1 (in the evening). A smaller midday spike becomes more prominent as IMD increases.

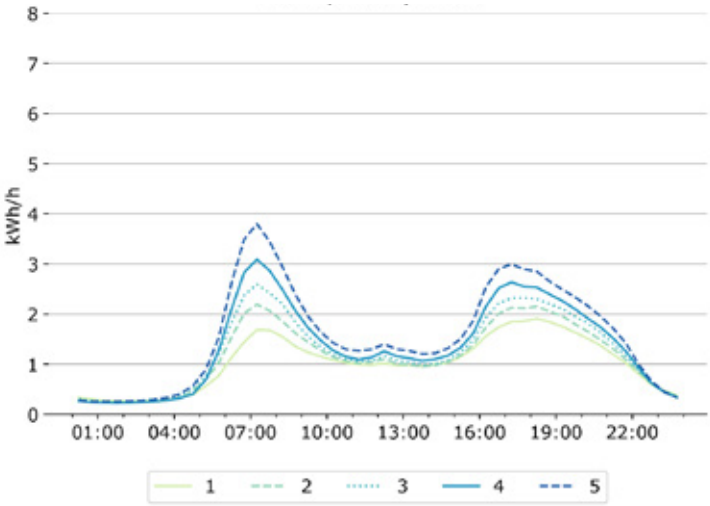


Figure 60 Mean gas consumption by IMD quintile in 2022. These homes have gas central heating and do not have PV.

Table 59 below presents minimum and maximum energy consumption values for the IMD quintiles presented in Figure 60 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	IMD quintile
Gas	0.27 kWh/h	02:30	1.91 kWh/h	18:30	1
Gas	0.24 kWh/h	02:30	2.19 kWh/h	07:30	2
Gas	0.26 kWh/h	02:00	2.60 kWh/h	07:30	3
Gas	0.23 kWh/h	02:00	3.09 kWh/h	07:30	4
Gas	0.26 kWh/h	01:30	3.80 kWh/h	07:30	5

Table 59 Summary statistics for Figure 60

Figure 61 shows electricity consumption by IMD quintile (note that the equivalent figure for 2023 is Figure 28). The typical electricity profile for the full sample is broadly present across all IMD bands, with the morning peak being relatively small, of a similar order to the daytime usage up until the late afternoon, when it begins to rise to an evening peak at 18:30. Across the day, mean electricity usage is generally higher as the IMD quintile increases. A slight morning peak is visible in IMD quintiles 3-5 that is absent in quintiles 1 and 2.

IMD quintile 5, the least deprived, has a distinctly higher overnight demand that the other bands, with a small peak at 01:00. This is a pattern consistent with EV charging profiles (see section 5.3.10), and its presence in IMD quintile 5 may be due to EV ownership being higher among higher income households.

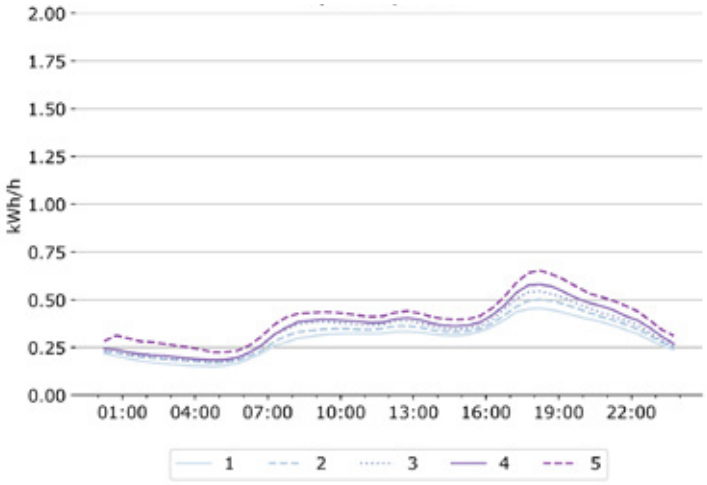


Figure 61 Mean electricity imports by IMD quintile in 2022. These homes have gas central heating and do not have PV.

Table 60 below presents minimum and maximum energy consumption values for the IMD quintiles presented in Figure 61 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	IMD quintile
Electricity	0.15 kWh/h	05:00	0.45 kWh/h	18:30	1
Electricity	0.17 kWh/h	05:00	0.50 kWh/h	18:30	2
Electricity	0.18 kWh/h	05:00	0.54 kWh/h	18:30	3
Electricity	0.18 kWh/h	05:00	0.58 kWh/h	18:30	4
Electricity	0.22 kWh/h	05:00	0.65 kWh/h	18:30	5

Table 60 Summary statistics for Figure 61

5.3.4
Diurnal energy use by EPC band

Figure 62 presents mean gas usage by EPC energy efficiency rating (note that the equivalent figure for 2023 is Figure 29). The general picture is of household gas usage being lower across the day for homes with higher EPC ratings, however there are significant nuances. The morning peak in gas demand among the most energy efficient homes (bands A & B) is substantially higher than it is for band C, and thereafter bands A, B and C have broadly similar demand profiles. The demand profile normalised by floor area shows a clearer difference with homes in bands A & B showing lower consumption per m^2 throughout the day.

The difference in household demand between bands C, D and E is more substantial, and present throughout the daytime, but minimal overnight. The difference between these bands is also clear in the profile normalised by floor area. Bands F & G have similar demand to band E, except that F & G's morning peak is slightly later. This difference remains in the profile normalised by floor area, but the evening peak for F & G homes is notably lower than that for E-rated homes.

As noted previously, care should be taken in interpreting these differences as there are important contributing factors to consider: the sample includes only homes with gas central heating, however most F & G rated homes are not gas heated,and those that are gas heated are more likely to have inefficient gas systems such as old system boilers rather than combi boilers.

This could explain the lower night-time gas use in F & G-rated homes (there is no combi boiler keep-warm function) and later start to their morning rise in demand, as hot water use in the morning in these homes would come from the store rather than immediately using gas to heat the water as would happen with a combi boiler. Sample sizes are also small for both the A & B and F & G groups.

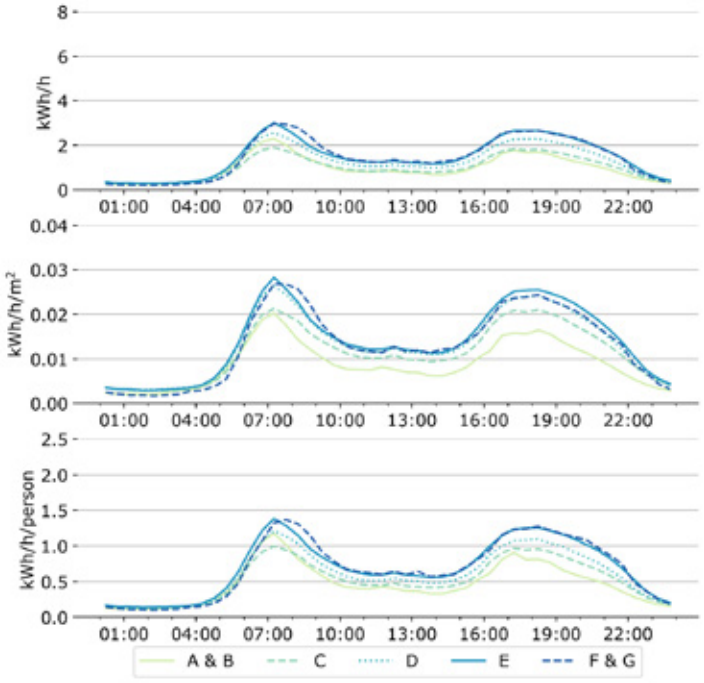


Figure 62 Mean gas consumption by EPC energy efficiency rating in 2022. These homes have gas central heating and do not have PV.

Table 61 below presents minimum and maximum energy consumption values for the EPC bands presented in Figure 62 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	EPC band
Gas	0.24 kWh/h	01:30	2.30 kWh/h	07:30	A & B
Gas	0.24 kWh/h	02:00	1.89 kWh/h	07:30	C
Gas	0.27 kWh/h	02:00	2.56 kWh/h	07:30	D
Gas	0.29 kWh/h	02:00	3.00 kWh/h	07:30	E
Gas	0.20 kWh/h	02:30	2.98 kWh/h	07:30	F & G
Gas	0.002 kWh/h/m^2	01:30	0.020 kWh/h/m^2	07:30	A & B
Gas	0.003 kWh/h/m^2	02:00	0.021 kWh/h/m^2	07:30	C
Gas	0.003 kWh/h/m^2	02:00	0.026 kWh/h/m^2	07:30	D
Gas	0.003 kWh/h/m^2	02:00	0.028 kWh/h/m^2	07:30	E
Gas	0.002 kWh/h/m^2	02:30	0.027 kWh/h/m^2	07:30	F & G
Gas	0.11 kWh/h/person	01:30	1.17 kWh/h/person	07:30	A & B
Gas	0.12 kWh/h/person	02:00	0.99 kWh/h/person	07:30	C
Gas	0.13 kWh/h/person	02:00	1.21 kWh/h/person	07:30	D
Gas	0.14 kWh/h/person	02:00	1.38 kWh/h/person	07:30	E
Gas	0.10 kWh/h/person	02:30	1.37 kWh/h/person	08:00	F & G

Table 61 Summary statistics for Figure 62

Figure 63 presents electricity use by EPC rating (note that the equivalent figure for 2023 is Figure 30). Electricity use is higher with lower EPC bands across the whole day between bands C and E. Bands F & G have overall similar demand to band E, except for slightly higher overnight demand from around 01:00 through into the morning rise in demand. This could be due to a small proportion of them using economy seven electric heating as a secondary heating source, which could be one of the factors contributing to a low EPC rating for homes with gas central heating. The profile normalised by floor area shows that bands F & G have slightly higher electricity use per m^2 throughout most of the day and particularly overnight. The other bands show very similar energy use per m^2 to each other at all times.

A & B-rated properties have similar demand to C-rated homes across the daytime, and slightly higher overnight. Normalised by floor area, A & B-rated homes have slightly lower use per m^2 than other bands through the daytime and evening, and similar overnight. However, most A & B-rated homes achieve their rating by having rooftop solar panels, and homes with PV are excluded from this figure, so the profile is unlikely to be typical of A & B-rated homes.

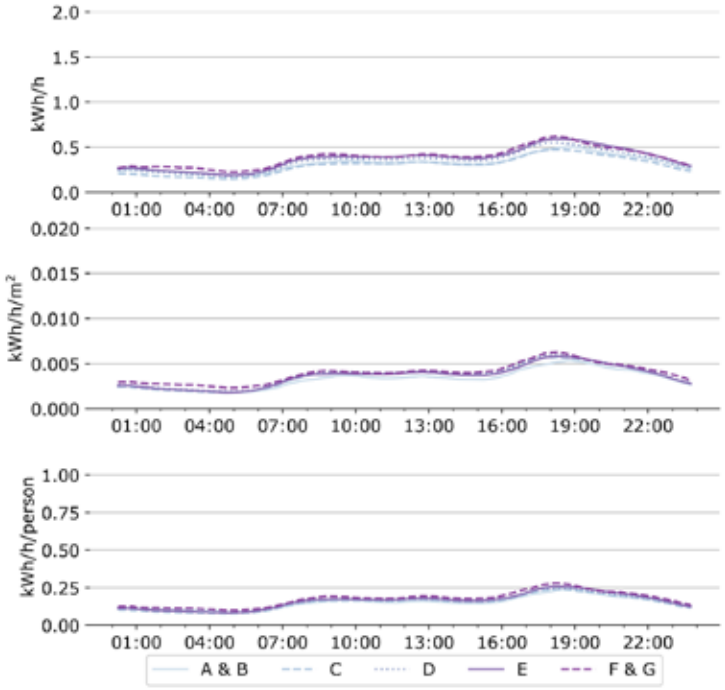


Figure 63 Mean electricity imports by EPC energy efficiency rating in 2022. These homes have gas central heating and do not have PV.

Table 62 below presents minimum and maximum energy consumption values for the IMD quintiles presented in Figure 63 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	EPC band
Electricity	0.19 kWh/h	05:00	0.51 kWh/h	19:00	A & B
Electricity	0.15 kWh/h	05:00	0.48 kWh/h	18:30	C
Electricity	0.18 kWh/h	05:00	0.55 kWh/h	18:30	D
Electricity	0.19 kWh/h	05:00	0.59 kWh/h	18:30	E
Electricity	0.22 kWh/h	05:00	0.62 kWh/h	18:30	F & G
Electricity	0.002 kWh/h/m^2	05:00	0.005 kWh/h/m^2	19:00	A & B
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	C
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	D
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	E
Electricity	0.002 kWh/h/m^2	05:00	0.006 kWh/h/m^2	18:30	F & G
Electricity	0.09 kWh/h/person	05:00	0.24 kWh/h/person	19:00	A & B
Electricity	0.08 kWh/h/person	05:00	0.24 kWh/h/person	18:30	C
Electricity	0.08 kWh/h/person	05:00	0.25 kWh/h/person	18:30	D
Electricity	0.08 kWh/h/person	05:00	0.26 kWh/h/person	18:30	E
Electricity	0.10 kWh/h/person	05:00	0.28 kWh/h/person	18:30	F & G

Table 62 Summary statistics for Figure 63

5.3.3 Diurnal energy use by floor area band

Mean gas consumption throughout the course of the day varies substantially by floor area (Figure 64), with the greatest variation occurring during the morning and evening peak periods (note that the equivalent figure for 2023 is Figure 31). A midday peak also generally becomes more prominent as floor area increases. The morning peak is 6.1 times higher in homes over 200 m² than in homes of 50 m² or less, and the evening peak 5.3 times higher. The morning peak time is at 07:30 for all the floor area bands. The evening peak occurs an hour earlier in the larger homes (17:30 vs 18:30).

The lunchtime peak is most prominent in bigger homes and almost absent in homes of 50 m² or less, which are likely to be small flats, more likely with single occupants who are out during the day, leaving the home unoccupied.

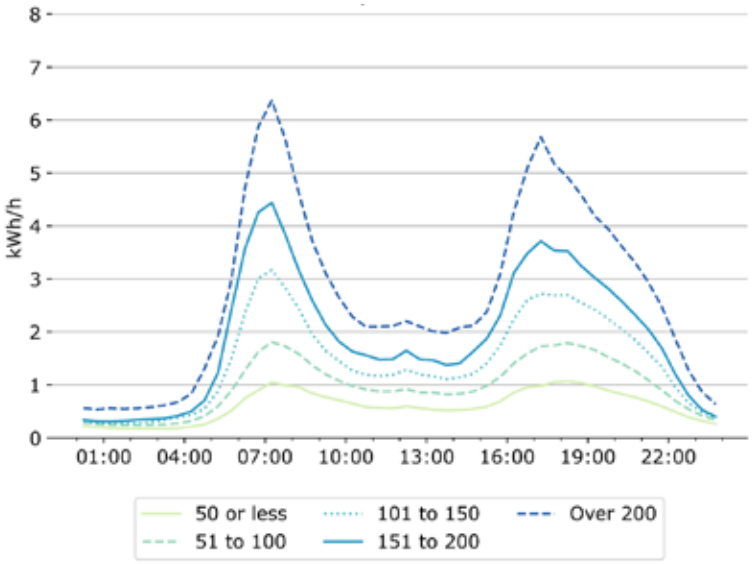


Figure 64 Mean gas consumption by floor area in 2022. These homes have gas central heating and do not have PV.

Table 63 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 64 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Floor area band
Gas	0.18 kWh/h	02:00	1.07 kWh/h	18:30	50 m² or less
Gas	0.24 kWh/h	02:30	1.81 kWh/h	07:30	51 m² to 100 m²
Gas	0.27 kWh/h	02:00	3.17 kWh/h	07:30	101 m² to 150 m²
Gas	0.31 kWh/h	01:30	4.44 kWh/h	07:30	151 m² to 200 m²
Gas	0.54 kWh/h	01:00	6.37 kWh/h	07:30	Over 200 m²
Gas	0.04 kWh/h	03:00	0.48 kWh/h	07:30	20 °C to 25 °C

Table 63 Summary statistics for Figure 64

Electricity use also varies substantially by floor area (Figure 65) (note that the equivalent figure for 2023 is Figure 32). Although the increase is generally more consistent throughout the day than is the case for gas demand, there are some nuances. In particular, overnight demand from larger homes shows a substantial peak from 01:00, unlike in smaller homes. Slight lunchtime peaks also become more apparent in larger homes. One possible reason for the large early morning peaks in larger homes may be higher levels of EV charging, with EV ownership and larger homes both more common among more affluent and bigger households. Larger homes are also more likely to be houses rather than flats, with space for EV charging. Off-peak rate electric storage heaters may also be more commonly used as secondary heating in larger homes, and so also contribute to the early morning peaks.

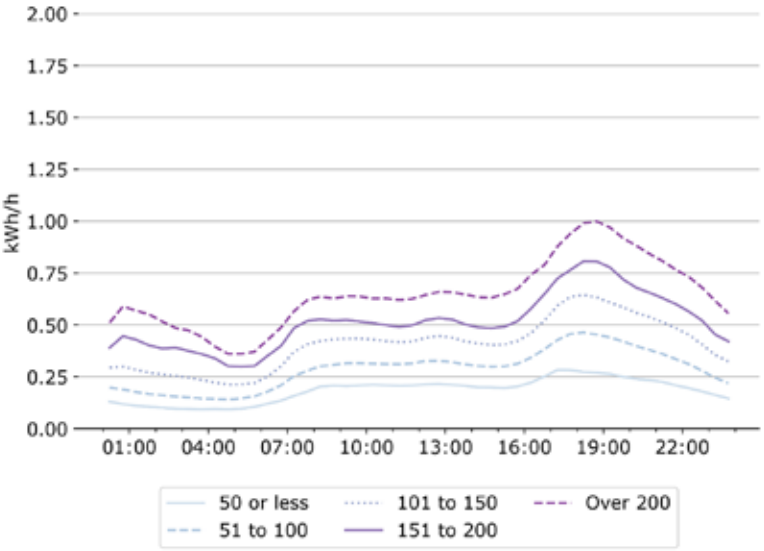


Figure 65 Mean electricity imports by floor area in 2022. These homes have gas central heating and do not have PV.

Table 64 below presents minimum and maximum energy consumption values for the floor area bands presented in Figure 65 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Floor area band
Electricity	0.09 kWh/h	05:00	0.28 kWh/h	17:30	50 m^2 or less
Electricity	0.14 kWh/h	05:00	0.46 kWh/h	18:30	51 m^2 to 100 m^2
Electricity	0.21 kWh/h	05:00	0.64 kWh/h	18:30	101 m^2 to 150 m^2
Electricity	0.30 kWh/h	05:30	0.81 kWh/h	18:30	151 m^2 to 200 m^2
Electricity	0.36 kWh/h	05:00	1.00 kWh/h	19:00	Over 200 m^2

Table 64 Summary statistics for Figure 65

5.3.6
Diurnal energy use by building type

Mean gas usage varies substantially throughout the daytime between the main building types present in Figure 66, particularly during the morning and evening peaks (note that the equivalent figure for 2023 is Figure 33). Purpose-built flats have substantially lower usage than other building types throughout the day, whilst detached homes have by far the highest usage, especially during the morning peak, with the evening peak in particular occurring earlier. Detached houses also have the most pronounced midday peak, whilst th peak is almost absent in flats. Correlations between building type, floor area, occupancy levels, energy efficiency and other factors means a range of these factors will contribute to the observed patterns in demand.

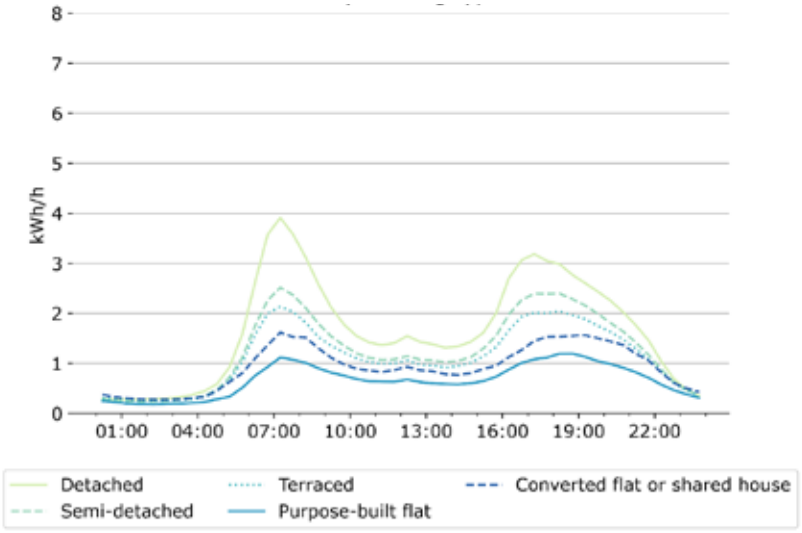


Figure 66 Mean gas consumption by building type in 2022. These homes have gas central heating and do not have PV.

Table 65 below presents minimum and maximum energy consumption values for the building types presented in Figure 66 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Building type
Gas	0.28 kWh/h	01:00	3.91 kWh/h	07:30	Detached
Gas	0.24 kWh/h	02:00	2.52 kWh/h	07:30	Semi-detached
Gas	0.25 kWh/h	02:30	2.13 kWh/h	07:30	Terraced
Gas	0.18 kWh/h	02:30	1.20 kWh/h	19:00	Purpose-built flat
Gas	0.28 kWh/h	02:30	1.62 kWh/h	07:30	Converted flat or shared house

Table 65 Summary statistics for Figure 66

Electricity demand varies more consistently over the day with building type than does gas demand (Figure 67), although there is most variation in the evening peak (note that the equivalent figure for 2023 is Figure 34). The order of building type with demand is the same as for gas, with purpose-built flats having the lowest mean demand and detached houses the highest. A spike in demand from 01:00 is observable for detached houses. This again may be due to higher EV charging in this group, with detached houses being more likely to be owned by more affluent households, and more likely to have space for EV chargepoints.

Table 66 below presents minimum and maximum energy consumption values for the building types presented in Figure 67 above.

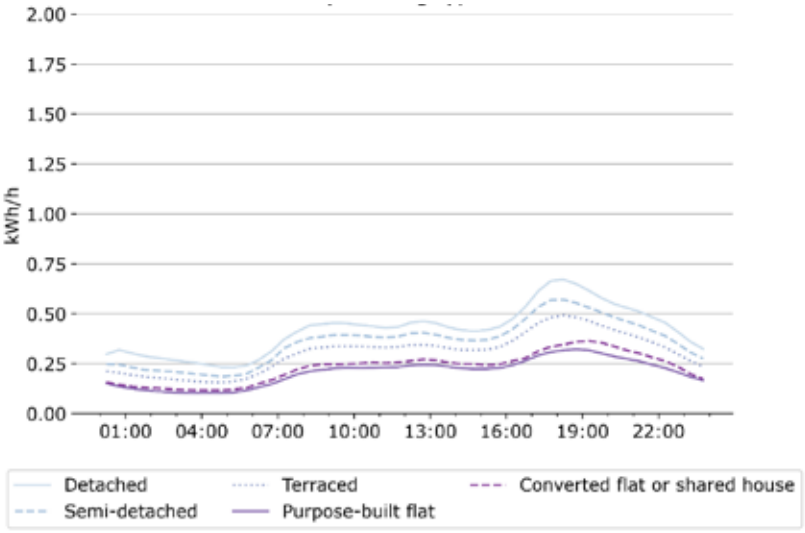


Figure 67 Mean electricity imports by building type in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Building type
Electricity	0.23 kWh/h	05:30	0.67 kWh/h	18:30	Detached
Electricity	0.18 kWh/h	05:00	0.57 kWh/h	18:30	Semi-detached
Electricity	0.16 kWh/h	05:00	0.49 kWh/h	18:30	Terraced
Electricity	0.10 kWh/h	05:00	0.32 kWh/h	19:00	Purpose-built flat
Electricity	0.12 kWh/h	05:00	0.36 kWh/h	19:30	Converted flat or shared house

Table 66 Summary statistics for Figure 67

5.3.7
Diurnal electricity use by heating system

The type of heating system has a substantial impact on homes' electricity demand profiles, as seen in Figure 68, which includes homes with all types of heating system (note that the equivalent figure for 2023 is Figure 35).

Four of the categories are for central heating systems that do not use electricity as the fuel source: gas boilers, gas boilers plus other, district or community heating, and oil, solid fuel or biomass heating. These all show similar shapes of profile through most of the day, with the main difference being in the level of demand. This is likely down to differences in the characteristics of these groups, such as average floor area and number of occupants. The oil, solid fuel and biomass group also has an overnight peak in demand that is consistent with EV ownership as seen in other sections of the report, or may be due to use of supplementary electric storage heaters in some of the homes.

Among homes with electric central heating systems, demand profiles vary substantially by technology, consistent with what would be expected for each type. Homes with electric storage radiators show a large overnight peak in demand: this is the time of day when the storage radiators normally use electricity to build up their heat store for use during the daytime, taking advantage of off-peak electricity rates. While the off-peak period varies by supplier and region, it is normally between 10pm and 8am. Homes with electric radiators show a similar profile to homes with non-electric heating, particularly the oil, solid fuel or biomass group. This is likely to be due to differences in average floor area and number of occupants, although a higher morning peak might be expected. Homes with 'other' electric heating have by far the highest electricity use across the daytime, in particular having high morning and evening peaks, as well as higher overnight use than all groups except for those with electric storage heaters. The other electric group is likely to include homes with heat pumps, but may include additional forms of electric heating. High day and night usage in the other electric group is consistent with the presence of heat pumps, and homes with heat pumps are less likely to be flats than those with electric radiators or electric storage radiators, which could account for the overall high electricity use in this group. The afternoon rise begins earlier in the other electric group than in the rest of the groups shown. Due to the range of electric heating options available in the survey, it is also possible that response errors may account for some of the differences between groups observed.

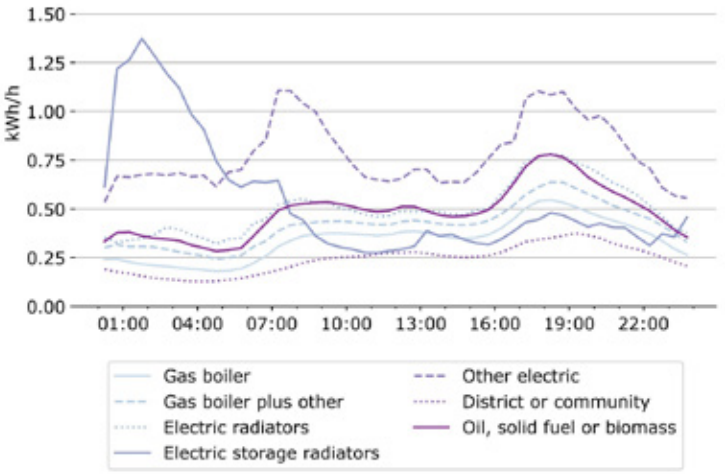


Figure 68 Mean electricity imports consumption by central heating system in 2022. These homes do not have PV.

Table 67 below presents minimum and maximum energy consumption values for the central heating types presented in Figure 68 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Central heating type
Electricity	0.18 kWh/h	05:00	0.55 kWh/h	18:30	Gas boiler
Electricity	0.24 kWh/h	05:00	0.64 kWh/h	18:30	Gas boiler plus other
Electricity	0.32 kWh/h	05:00	0.78 kWh/h	18:30	Electric radiators
Electricity	0.27 kWh/h	11:30	1.37 kWh/h	02:00	Electric storage radiators
Electricity	0.53 kWh/h	00:30	1.11 kWh/h	07:30	Other electric
Electricity	0.13 kWh/h	04:30	0.38 kWh/h	19:30	District or community
Electricity	0.28 kWh/h	05:00	0.78 kWh/h	18:30	Oil, solid fuel or biomass
Electricity	0.38 kWh/h	00:00	0.73 kWh/h	18:30	Other or other mix
Electricity	0.25 kWh/h	05:00	0.55 kWh/h	18:30	None

Table 67 Summary statistics for Figure 68

5.3.8 Diurnal energy use by number of occupants

Although gas consumption across the day correlates with number of occupants (Figure 69), above two occupants the increases with each additional person are relatively small or only at certain times of day (note that the equivalent figure for 2023 is Figure 36). The difference in peaks is greatest between 1 and 2 occupants. Homes with 2 and 3 occupants have very similar profiles throughout the day. Homes with 4, 5 and 6 or more occupants have similar morning peaks (higher than for 2 occupants), and demand that diverges to differing degrees across the rest of the day, although it generally increases with higher occupant numbers. The morning and evening peaks for 6 or more occupants are both around 1.9 times higher than for one occupant. The morning peak occurs half an hour earlier for homes with 6 or more occupants (at 07:00 vs 07:30). The evening peak is at 18:30 for 6 or more occupants, and at 18:00 for 1 occupant.

The observed patterns are likely due to a range of interacting factors that influence gas demand differently across the day, including the tendency of larger households to live in larger homes that require more space heating to reach a given indoor temperature, an increasing likelihood of homes being occupied during the day as the number of occupants increases, and variation in how much of the home is heated at different times.

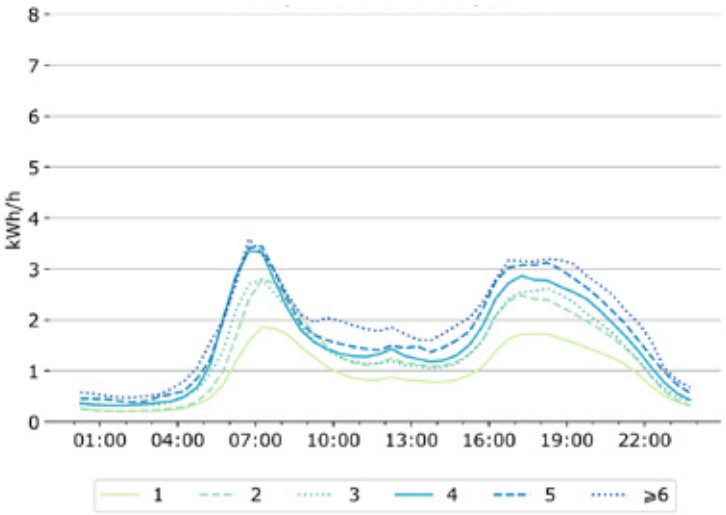


Figure 69 Mean gas consumption by number of occupants in 2022. These homes have gas central heating and do not have PV.

Table 68 below presents minimum and maximum energy consumption values for the occupant bands presented in Figure 69 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Number of occupants
Gas	0.22 kWh/h	02:30	1.86 kWh/h	07:30	1
Gas	0.21 kWh/h	02:00	2.80 kWh/h	07:30	2
Gas	0.32 kWh/h	02:00	2.80 kWh/h	07:30	3
Gas	0.32 kWh/h	02:00	3.36 kWh/h	07:00	4
Gas	0.38 kWh/h	02:30	3.44 kWh/h	07:30	5
Gas	0.48 kWh/h	02:30	3.59 kWh/h	07:00	≥6

Table 68 Summary statistics for Figure 69

In contrast to gas usage, electricity usage differs more substantially with the number of occupants (Figure 70) and, broadly, more consistently across the day (note that the equivalent figure for 2023 is Figure 37). Evening peak electricity usage in homes with six or more occupants is three times higher than in homes with one occupant, but occurs at the same time, as do the minimum values for these groups.

This pattern could be accounted for by the types of activities which use electricity. Unlike gas usage, where space heating is largely shared by the occupants, more electricity-using activities are per-person, e.g. heating water for laundry, hot drinks and (in some cases) washing; personal electronic devices; lighting of more rooms; etc.

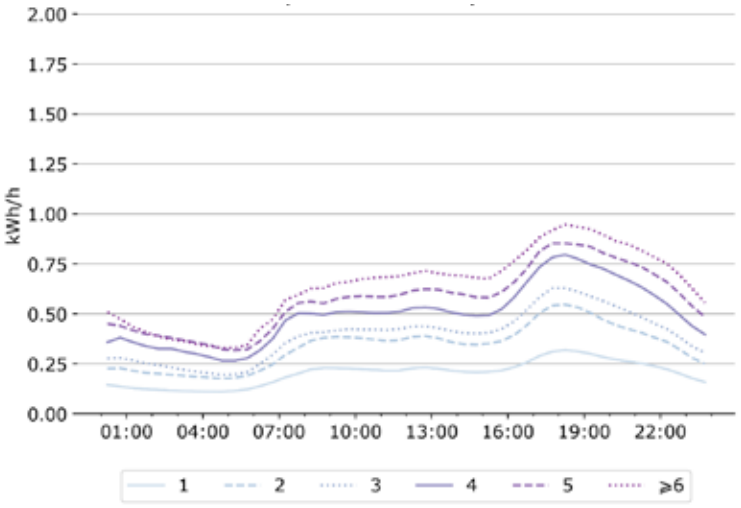


Figure 70 Mean electricity imports by number of occupants in 2022. These homes have gas central heating and do not have PV.

Table 69 below presents minimum and maximum energy consumption values for the occupant bands presented in Figure 70 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Number of occupants
Electricity	0.11 kWh/h	05:00	0.32 kWh/h	18:30	1
Electricity	0.18 kWh/h	05:00	0.55 kWh/h	18:30	2
Electricity	0.20 kWh/h	05:00	0.63 kWh/h	18:30	3
Electricity	0.27 kWh/h	05:30	0.80 kWh/h	18:30	4
Electricity	0.32 kWh/h	05:30	0.85 kWh/h	18:00	5
Electricity	0.33 kWh/h	05:00	0.95 kWh/h	18:30	≥6

Table 69 Summary statistics for Figure 70

5.3.9
Diurnal energy use by day of the week

Both gas and electricity usage show small variations between weekdays and weekends, with the differences being similar for both fuel types (Figure 71 and Figure 72) (note that the equivalent figures for 2023 are Figure 38 and Figure 39). Compared to weekdays, weekend morning peaks in usage occur slightly later and progress into slightly higher daytime usage, before converging to very similar evening peaks and overnight usage patterns. In the case of electricity, the morning peak at weekends continues on as a gradual rise in demand through the morning, merging with the slight midday peak. This is likely an effect of typical Monday to Friday working patterns, with more households getting up later and staying home during the day at weekends, hence using more energy.

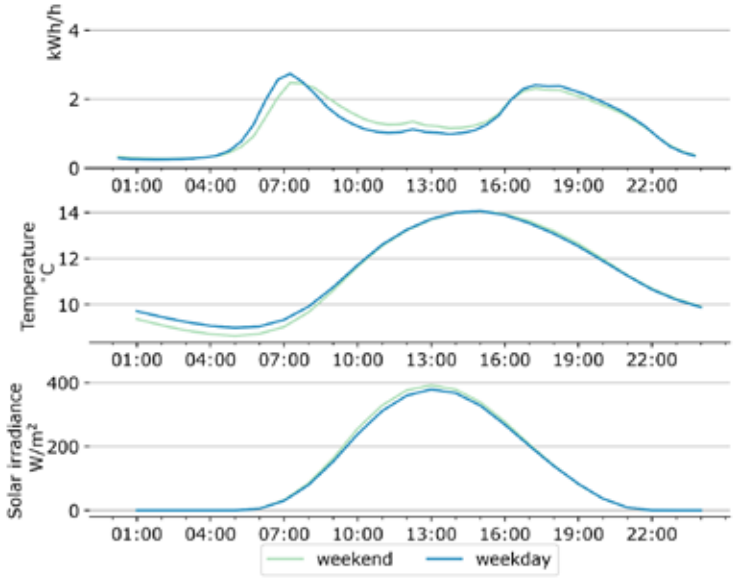


Figure 71 Mean gas consumption by weekend and weekday in 2022. These homes have gas central heating and do not have PV.

Table 70 below presents minimum and maximum energy consumption values by weekend and weekday as presented in Figure 71 above.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Period
Gas	0.27 kWh/h	02:30	2.48 kWh/h	07:30	Weekend
Gas	0.25 kWh/h	02:00	2.74 kWh/h	07:30	Weekday

Table 70 Summary statistics for Figure 71

Table 71 below presents minimum and maximum energy consumption values by weekend and weekday as presented in Figure 72 above.

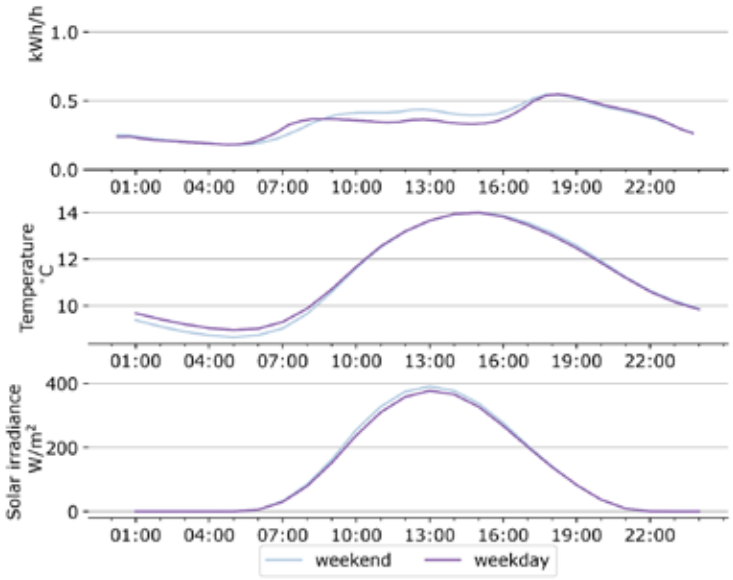


Figure 72 Mean electricity imports by weekend and weekday in 2022. These homes have gas central heating and do not have PV.

Table 71 Summary statistics for Figure 72

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	Period
Electricity	0.18 kWh/h	05:00	0.54 kWh/h	18:30	Weekend
Electricity	0.18 kWh/h	05:00	0.55 kWh/h	18:30	Weekday

5.3.10 Diurnal electricity use by EV ownership

Throughout the day, households with electric vehicles have a higher mean electricity use than those without (Figure 73) (note that the equivalent figure for 2023 is Figure 40). Here, households who own EVs are identified based on their responses to the SERL recruitment survey. For most of the day the mean profile is similar in shape, although the evening peak for EV owners is slightly later and proportionally higher than other daytime differences, and includes a slight secondary peak after the first, at 21:00. The main difference between the two groups is overnight from approximately midnight until around 06:00, when the EV group shows a peak in usage that reaches levels substantially higher than at any other time of the day. This is most likely due to automated charging periods for the electric vehicles.

In addition to EV charging during the day, the higher electricity usage among the EV group at other times of the day could be due to differences in other characteristics between the two groups: EV owning households in the sample are on average more affluent, live in homes with larger floor areas, and have higher numbers of occupants.

Table 72 below presents minimum and maximum energy consumption values by EV ownership status as presented in Figure 73 above.

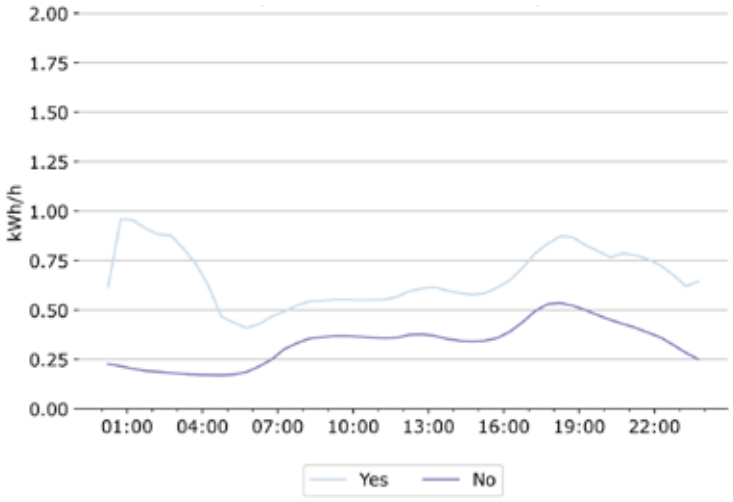
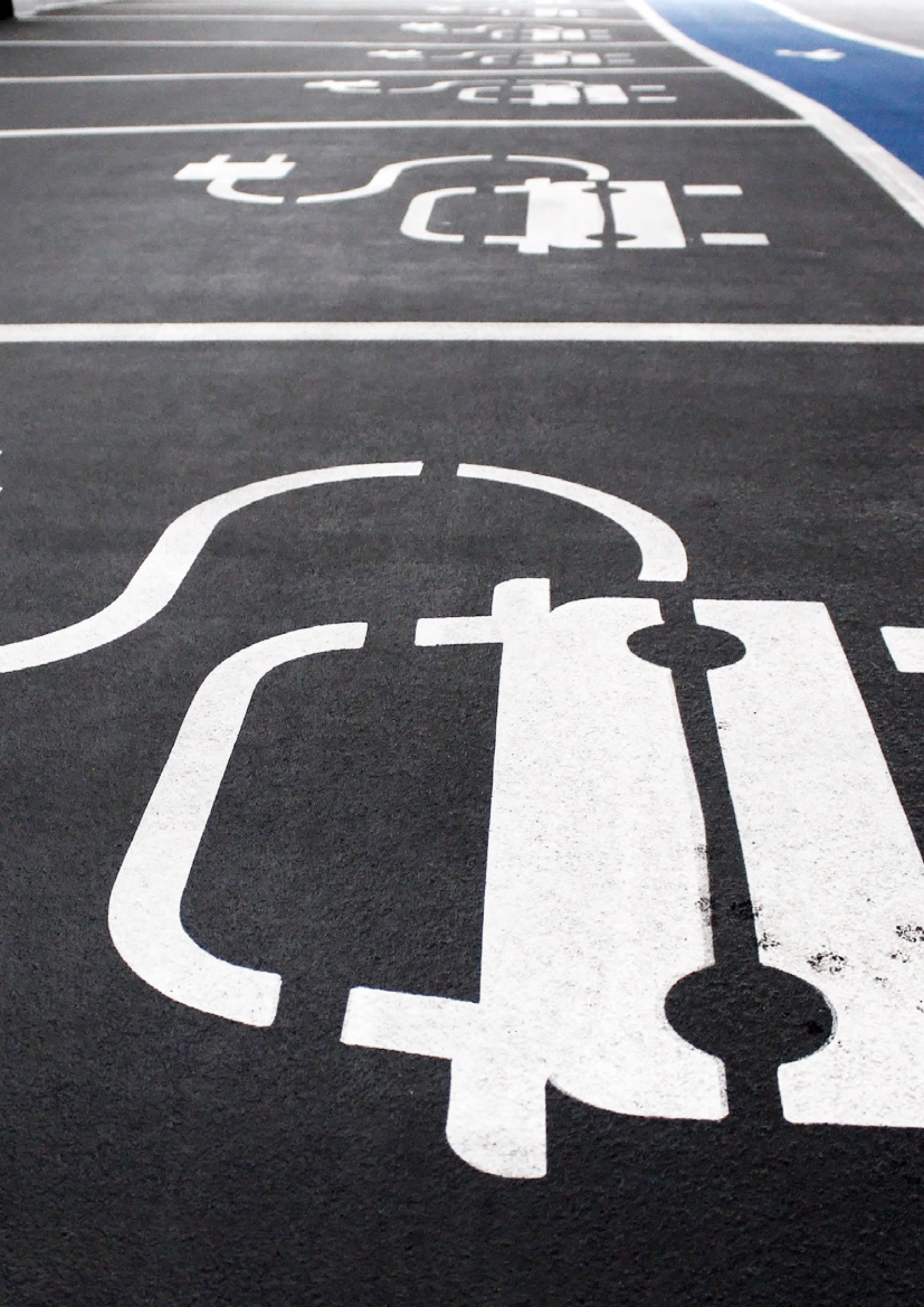


Figure 73 Mean electricity imports by electric vehicle ownership in 2022. These homes have gas central heating and do not have PV.

Quantity	Minimum	Time of min. value	Maximum	Time of max. value	EV ownership
Electricity	0.41 kWh/h	06:00	0.96 kWh/h	01:00	Yes
Electricity	0.17 kWh/h	05:00	0.53 kWh/h	18:30	No

Table 72 Summary statistics for Figure 73



6 Future work

The need for research related to domestic energy use has never been greater as we undergo a net zero and energy security transition as well as a period of rapidly rising energy and living costs. The SERL Observatory is helping to track how this transition is occurring over time, providing data complementary to other national data sources such as NEED and EFUS. This has enabled analysis of the impact on domestic energy use of Covid-19 and the rising energy costs in winter 2022/2023 (McKenna *et al.*, 2024b, 2024a; Zapata-Webborn *et al.*, 2023, 2024).

The main advantages of SERL are its relatively quick data provisioning, wide range of relevant contextual variables, and high resolution (half-hourly) energy data for both gas and electricity. This enables the diurnal energy profile (comprising 48 half-hourly readings) to be compared between homes with EVs, different heating systems and EPC ratings, which are all areas of significant research and policy focus, as well as comparisons between many other factors.

SERL data collection is ongoing and we will provide an update to the analyses presented here at regular intervals. We also aim to provide a subset of the analysis provided in this report at more frequent intervals. Future reports are likely to include more breakdowns by season and weather conditions to give more information regarding the variation in energy use through the year, and may provide statistics related to tariffs.

This report has demonstrated that many factors are correlated with domestic energy use but does not attempt to understand how these interact with each other. We have undertaken analyses of such interactions in McKenna *et al.* (2022), and future work will continue to explore this.

Government policies aim to increase the EPC ratings of dwellings and increase the uptake of heat pumps, solar panels (PVs) and electric vehicles (EVs). SERL data provides an insight into the associated energy use in homes. For example, Few *et al.* (2023) explored the difference between EPC modelled and metered energy use (primary energy use intensity) for homes in the SERL Observatory, finding metered energy use on average much lower than modelled energy use, with the gap increasing from no significant difference for A & B rated homes to 276 kWh/m^2/yr (48%) for F & G homes. Future work will further investigate EPCs, as well as the key domestic technologies associated with reducing the carbon emissions from homes.

Alongside these priority areas of research, we will be further developing a backbone of analysis techniques to understand the underlying patterns of domestic energy use in GB. This will be via a range of approaches including developing models for understanding and analysing different aspects of the data e.g., statistical models for explaining and predicting variation in energy use over different time periods, cluster analysis for identifying common diurnal profiles of energy consumption (Pullinger *et al.*, 2024) and specific models to assess the thermal performance of dwellings.

Alongside continued SERL data collection we will be developing data collection via the Energy Demand Observatory and Laboratory (EDOL) project. EDOL aims to recruit a subset of 2,000 participants from the SERL Observatory and monitor their indoor temperature and other relevant data streams. Alongside this 'EDOL Observatory', 'EDOL Laboratories' will explore recruit participants and collect data-streams for researching topics in fine detail. For example, EDOL may recruit participants for a heat pump laboratory project in which further data streams would include heat pump submetering, hot water monitoring and participant surveys.

This and future similar reports will summarise high-level aggregated statistics for the SERL Observatory. However much of the value and benefit of SERL will be derived from the many individual research projects undertaken by the wider research community. These projects utilise the full longitudinal, high-resolution, controlled SERL Observatory dataset and more information about the research can be found on the Projects page of the SERL website.

Applications for further research projects wishing to utilise SERL data are strongly encouraged from across the research community. The SERL Observatory dataset is available to accredited researchers via a secure lab environment. See below for information on accessing the full SERL Observatory dataset.

7
Data access and further information

The SERL Observatory data is available to UK accredited researchers via the UK Data Service. See the SERL website for instructions on how to apply for access to use SERL data for your research. The SERL Observatory Sixth Edition of data will be made available in early spring 2024 and will provide data from August 2018 until the end of 2023. We aim to release new editions with updated data every three to six months.

The statistics presented in this report can be found at:

https://serl.ac.uk/key-documents/reports/.

Far more statistics are available via the full aggregated statistics dataset which can be accessed via UKDS Study Number 8963. This dataset includes: statistics for 2020 – 2023; energy use per household; per m^2 and per occupant for annual, monthly and half-hourly averages; statistics for the same contextual breakdowns as presented in this report, as well as for homes with electric heating, and with and without PV.

We have endeavoured to ensure that the information presented here is as free from errors as possible, however any corrections will be published here.

We welcome feedback and comments, both about this report and about the Observatory data; please contact info@serl.ac.uk.

The SERL Observatory includes European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 data. Neither the European Commission nor the European Centre for Medium-Range Weather Forecasts is responsible for any use that may be made of the Copernicus information or data it contains.

8 Acknowledgements

We would like to thank:

The 13,000+ SERL Observatory participants for giving permission for the use of their data for scientific research in the public interest.

EPSRC of UKRI for providing initial funding for SERL (grant reference: EP/P032761/1), and additional funding via EDOL (grant reference: EP/X00967X/1)

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The SERL Independent Advisory Board, SERL Research Programme Board, and SERL Data Governance Board, who have guided the development of SERL and our research.

This project was approved by UCL Research Ethics, and access to SERL Observatory data for the purposes of this project was approved by the SERL Data Governance Board. All researchers accessing SERL Observatory data are Accredited Researchers.

This report is the result of the authors' own research and analysis. The views and opinions expressed herein do not necessarily reflect those of the funders, or any other organisation, or any of their employees or affiliates. Neither the funders nor any of their affiliates endorse or is responsible for the accuracy or reliability of any information, data, opinions, advice, or statements made in this report.

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10 Appendix: Methods

All the outputs in this report are based on statistical analysis of the 6th Edition of the SERL Observatory dataset, UKDS Study Number 8666, which will be available in spring 2024.

The statistical release that accompanies this report consists of aggregated summaries of the (imported, exported and net) electricity and gas consumption data with aggregated linked contextual data, optionally grouped by three levels of contextual data. Contextual data groupings are either categorical variables (e.g. region, EPC rating) or banded continuous variables (e.g. ranges of daily external temperature, ranges of floor areas).

The summaries are provided at the following levels of aggregation:

1. Annual: annual aggregate statistics of daily electricity or gas consumption, external temperature, heating degree days, and solar irradiance

2. Monthly: monthly averages of daily electricity or gas consumption, external temperature, heating degree days, and solar irradiance

3. Diurnal: annual averages of half-hourly electricity or gas consumption, hourly external temperature, and hourly solar irradiance

The first level categorical variable which is used for grouping is:

- Central heating type: gas, electric, or all homes.
  - The central heating type for each home is based on the responses in the SERL sign-up survey[20].

The second level categorical variable which is used for grouping is:

- Presence of photovoltaic (PV) generation: yes, no, or all homes
  - Presence of PV is inferred for each year separately. Homes which export electricity for at least one half hour a year are classed as having PV present for that year.

The third level of variables which are used for grouping are:

- Temperature data is grouped by mean external temperature bands: 5°C to 0°C, 0°C to 5°C, 5°C to 10°C, 10°C to 15°C, 15°C to 20°C, 20°C to 25°C
- Region
- Index of Multiple Deprivation (IMD) quintile: 1 to 5
- Energy Performance Certificate rating: A & B, C, D, E, F & G
- Floor area of building (in 50 m^2 bands)
- Heating system e.g. gas boiler, electric radiators, etc.
- Year of construction of building (in bands)
- Building type
- Number of occupants
- Number of bedrooms
- Tenure
- Electric vehicle ownership

The process for producing statistics is as follows.

1. Household-level aggregation

For each household, half-hourly and daily electricity (imports, exports and net) and gas consumption, and hourly external temperature data and solar irradiance are aggregated for each month to produce:

- Average diurnal profiles for each month:
  - Mean half-hourly consumption
  - Mean hourly external temperature
  - Mean hourly solar irradiance
- Average daily statistics for each month:
  - Mean daily consumption
  - Mean daily external temperature
  - Mean solar irradiance
  - Mean heating degree days

For each household, these monthly means are then averaged over each calendar year to produce:

An annual mean half-hourly profile (weighted for the number of days in each month), and

Annual mean daily values (weighted for the number of days in each month) for each year.

Note on missing data: we use a missing data threshold of 50% for the monthly aggregations e.g. at least 50% valid half-hourly reads are required to estimate the average energy use in that half-hour for any given month.

20 Categories are based on participant responses to the following question: "A3. What type of central heating does your accommodation have? By central heating we mean a central system that generates heat for multiple rooms. Tick all that apply whether or not you use it'. Participants who selected gas and no other options are reported as having gas heating, those who selected only electric forms of heating are reported as having electric heating.

And we require all monthly aggregations to produce the annual aggregations (i.e. 0% missing data threshold). This ensures that if data is missing in any particular season then the annual result will not be skewed as a result.

This results in:

- hou**sehold-level annual summaries of daily averages**
- **household-level monthly summaries of daily averages**
- **household-level annual summaries of half-hourly averages**

This step is repeated with household-level data filtered by temperature band (e.g. household-level averages of daily consumption on days with mean temperature between 0-5°C) and for weekdays vs weekends. This results in a further set of household-level summaries *for each temperature band and for weekends/weekdays.*

Note the household-level annual summaries are not included in the statistical dataset released to the public as part of the SERL Statistical Report or Aggregated Dataset but are used to create the outputs included in this report

2. Household-level normalised energy use

The household level energy use is normalised by dividing by:

- Floor area obtained from the EPC certificate where available (approximately 60% of the sample)
- The number of occupants reported on the SERL sign-up survey where available (over 95% of the sample)

3. Grouping-level aggregation

Groupings of households in the three levels of segmentation categories listed above are used for specific outputs. For example, this could be 'all households', in which case segmentation 1, central heating type, would be 'all'; segmentation 2, has PV, would be 'all'; and segmentation variable 3 would be 'none'. As another example, the grouping of interest could be 'gas heated households which do not have PV and which are in Scotland, in this case segmentation variable 1, central heating type, would be 'gas'; segmentation variable 2, has PV, would be 'no'; and segmentation variable 3 would be 'region' and the value would be 'Scotland' .

For each grouping, the relevant households are identified and the following aggregations are calculated:

- Mean of the household-level summaries of:
  - Electricity (imports, exports and net) and gas consumption and normalised consumption
  - External temperature
  - Solar irradiance
  - Heating degree days (for daily summaries only)
- Standard deviation of the household level summaries of:
  - Electricity (imports, exports and net) and gas consumption
- Percentiles (25^{th}, 50^{th}, 75^{th}) of the household-level summaries of:
  - Electricity (imports, exports and net) and gas consumption
  - Note that for statistical disclosure control reasons percentile values report the mean of the 10 observations closest to the true percentile value
- N – the number of household-level summaries used to compute the statistic
  - Note that for statistical disclosure control reasons if N is less than 10 it is reported as 0 and no statistics are provided, if N is greater than 10 then it is rounded to the nearest 10.

This results in

- **Grouping-level annual summaries of daily averages**
- **Grouping-level monthly summaries of daily averages**
- **Grouping-level annual summaries of half-hourly averages**

Note on figures in this report: where statistics are broken down by contextual variables based on the SERL survey we have not presented data for the participants who did not answer the question or who answered, 'don't know'. This data is available in the statistical release that accompanies this document.

For half hourly smart meter data, the energy use associated with the data at timestamp 11:00 occurred between 10:30 and 11:00. For this reason, in the figures of diurnal profiles, we have plotted the data in the middle of the half hour slot over which the energy use occurs (i.e. at 10:45 in the above example).

Finally, for all figures of the same type, we have used the same y-axis limits to aid comparisons between figures.

We will make the code used to produce the statistical dataset and outputs available on the SERL GitHub.

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