UK Government

RAF002/2425: Domestic Energy Affordability Support

Impact and Economic Evaluation
Annex B: Modelling

November 2025

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Introduction to the modelling annex

This annex includes further detail on the methods applied (as well as detailed findings where appropriate) for the modelling conducted to assess the impacts of the domestic energy affordability schemes. This includes the demand, price and income elasticity modelling of energy and non-energy consumption and energy burden; secondary analysis of sources on non-energy expenditure and energy debt; modelling of physical and mental health using the University College London (UCL) Health Impact of Domestic Energy Efficiency Measures (HIDEEM) model. The cost benefit analysis methods and full tables are included in the main Technical Report (Annex A).

Annex 1. Demand, price and income elasticity modelling using EPG Audit and NEED domestic meter level energy usage data

To assess the impacts of the domestic energy affordability support schemes on energy demand, household spend on energy and non-energy goods, and energy burden, the evaluation estimated how the energy affordability schemes affected energy and non-energy consumption during the intervention period. This was achieved by estimating price and income elasticities of demand using econometric demand models[1]. Elasticity is the percentage change in quantity given a percentage change in price (or income). This approach allowed the evaluation to estimate parameters and predictions of counterfactual "Do Nothing" scenarios (what would have happened to consumer demand if the energy affordability support schemes had not been in place).

The analysis used two approaches and several datasets to model consumer' demand, due to the strengths and limitations of the datasets available. The first approach utilised data with wider coverage of energy meters in Great Britain, but limited other variables about household composition and non-energy spending. The second approach used UK-Nationally Representative data, with a smaller sample of households but a wider range of variables, enabling more advanced statistical modelling in the second approach.

The first approach used a combination of data collected during the audit of EPG and the National Energy Efficiency Data-Framework (NEED) dataset, which were linked using energy meter numbers as unique identifiers, and estimated demand, as well as price and income elasticities. The administrative audit data contained both customer meter data, energy prices, and actual consumption. Combining this with NEED provided customer-specific data on house-unit characteristics such as housing type, annual consumption and floor area.[2] The Combined audit and NEED data was a panel dataset as it follows the same meter numbers in households over time. The models developed to estimate the elasticities using this dataset include well-recognised panel data models, such as Fixed Effects (FE), Between group Effects (BE), and Random Effects (RE). In addition, Ordinary Least Squares (OLS) was also modelled as a comparison (see Annex B7.2 for model specification).

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[1] Eales, James S., and Laurian J. Unnevehr. "The inverse almost ideal demand system." European Economic Review 38.1 (1994): 101-115.

[2] Note that EPG final reconciliation (the correcting and approval stage of EPG payments) was completed after the evaluation modelling, which produced a more complete dataset of finalised settlement volumes and supplier customer portfolios (held internally by DESNZ). As a result, the audit dataset will not be fully representative of the evidence on which the scheme was reconciled and closed. However, this more complete dataset was not available at the time that the evaluation analysis was conducted and the audit data was the best available to use in its place. Therefore, the final expenditure of EPG was not based on the audit data and so conclusions drawn from it might not align with the published spend figures from final reconciliation.

The second approach used the Living Costs and Food Survey (LCFS) and used structural demand models such as Linear Expenditure System (LES) and Quadratic Almost Ideal Demand System (QUAIDS), which estimated a system of consumer demand functions for all expenditure categories/commodity types. The functions in these models used expenditure and expenditure shares of commodity types as endogenous variables and take prices and income/total expenditure as the exogenous variables. The resulting parameter estimates could be used to calculate elasticities, and predict expenditures, quantities and budget shares. The demand systems estimate own price elasticities, cross price elasticities, the percentage change in quantity consumed of non-energy goods given a percentage change in energy price, as well as income elasticities.

Given the universal nature of the schemes it was not possible to construct a counterfactual comparison group using standard evaluation approaches such as Difference in Difference, however both the modelling approaches enabled a comparison of the actual (with the energy affordability schemes) consumption levels versus the predicted-counterfactual Do Nothing scenarios (without the energy affordability schemes) by using model estimates to predict the change in household consumption levels given the policy-implied changes in price and income. In other words, the analysis modelled energy demand directly and computed associated parameters to calculate price and income elasticities and then predicted the values under the counterfactual of no energy affordability schemes compared to the actual (with energy affordability schemes) values. This allowed the analysis to estimate the programme impacts and exclude random error. The baseline scenario (actual) versus the counterfactual scenario (with no energy affordability schemes) were modelled in terms of the price change (EPG/EPG NI) and the income benefit (EBSS/EBSS AFP).

1.1. The Combined audit and NEED Dataset

The Combined audit and NEED dataset was a matched panel micro-dataset made up of individual households, recorded over time. It consisted of two sources; Audit data and NEED data. The main identifier used throughout the analysis is the household’s energy meter ID (meter point administration number (MPAN) for electricity and meter point reference number (MPRN) for gas), which was used to model unobserved household-specific heterogeneity that is time-invariant.

The audit data was collected by energy suppliers and collated by independent auditors on behalf of DESNZ. It was collected during the audit of the EPG scheme, which explored whether households received the correct rate of support, and that suppliers had been compensated correctly. It covered a period of approximately 18 months from 2021 to 2023 and included information on the household’s energy consumption (based on meter readings throughout the intervention period), its energy supplier, its energy meter number/s, its reference EPC (Energy Performance Certificate), and its relevant tariffs (specific to electricity heated households). Each observation was a household’s record over a specific billing period, and the length or duration of these varied by household.

Audit data was available for the majority of UK energy suppliers however one of the largest suppliers, and some small suppliers, were not included in the evaluation analysis. There was uniform and consistent data for six gas suppliers and nine electricity suppliers, which were suitable for analysis. Despite the absence of data for some suppliers, the Audit data was still a useful source of insights and valid to be used in the analysis, however it did bring some potential limitations. The large supplier had a higher-than-average proportion of customers on time-of-use tariffs compared to other suppliers and therefore the higher average usage that comes with the drivers of those tariffs (e.g. electric vehicles or heat pumps etc.), The absence of certain suppliers may have led to some over- or underrepresentation of specific household types. In particular, households on time-of-use tariffs may be underrepresented. However, checks on the representativeness of the data used suggested that the dataset was still representative of household types in terms of main socio-demographic categories. See Section 1.2 for a full discussion of representativeness.

The NEED dataset refers to the National Energy Efficiency Data-Framework, which matches gas and electricity consumption data in Great Britain to domestic properties.[3] Data from 2017 to 2022 was available to this evaluation, and all information provided was annualised. The NEED data contained estimated annual electricity and gas consumption, EPC ratings, modelled household characteristics such as income, and post-codes. In addition, the NEED data is lagged (i.e., NEED data is typically released a year and a half after the end of the consumption year, which means that data on the winter following the intervention (2023/24) was not available for this analysis. Overall, NEED contained approximately 23 million Unique Property Reference Numbers (UPRNs).

Most households in the UK have both a gas and an electricity connection. Gas is typically used for central heating and hot water, electricity is typically used for lights, appliances and cooking. In some cases, electricity is the main source of central heating (for example using storage heaters and electric boilers). Despite detailed data on the household's consumption of energy, it was not known what a given household's main source of heating was. In homes without gas consumptions, this was clear; central heating must be electric. In other households, this was less clear. To estimate this, the analysis considered a ratio between gas consumption (kWh) and electricity consumption (kWh). If a household's gas consumption was less than 2.5% of its electricity consumption, then gas was not the main heating fuel, and it was likely only used for cooking or occasionally hot water. Therefore, it was assumed that in these households the primary heating source must be electric.[4]

Prior to merging, to avoid excessive computational time, a random sample from the Audit data was selected, ensuring that this random sample preserved the relative size of each supplier. The NEED data was then joined to the selected Audit data on household MPRN/MPAN numbers, which was present in both Audit and NEED datasets.[5] Two main sample datasets

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[3] Northern Ireland is not included in the NEED dataset, which means that it is not possible to analyse Northern Ireland households in the combined audit and NEED dataset.

[4] It was decided that the identification criteria for electricity heating in households must have a small ratio of gas to electricity, specifically between 0 and 0.025. In other words, gas consumptions must be below 2.5% of total electricity consumption. Sensitivity checks were performed to see if estimates were sensitive to small changes in criteria.

[5] Some MPRN/MPAN numbers in the Audit dataset were not contained in the NEED dataset.

from the Audit data were generated in this way; one for households heated by gas and one for households heated by electricity.

These final datasets were the Combined audit and NEED dataset for gas and electricity heated homes, a micro-level dataset containing household information on income, house type, EPC rating and separately - actual consumption, billing and price details. The main measures of interest for the evaluation were price and quantity of energy consumed. However, other household specific measures like EPC rating, household floor area, type of household unit and others were important to explain variation in quantity of energy consumed. Detailed sensitivity analysis was undertaken on the representative sample of the GB population using income and energy use measures (reported further below).

The preferred model for the Combined audit and NEED dataset was a Random Effects model for both gas heated homes and electricity heated homes. The income data available was provided by the NEED data, which contains modelled household income that is time-invariant within the year and lagged. Thus, Fixed Effects models by household or meter number performed poorly as income was in nearly perfectly collinear with the meter-specific dummy variable, given the Audit data only contained circa 18 months of observations. Other variables were also time-invariant within the Audit period by house-unit, such as unit type (semi-detached, detached, terraced, etc.), and EPC rating. Thus, many important explanatory variables were not able to contribute to variance explained, given the household-specific fixed effect.

1.2. Representativeness of samples taken from the full audit and NEED Datasets

This section outlines how it was ensured that the GB Combined audit and NEED samples used in the analysis were representative of the GB population using income and energy use measures. Although each sample had a high number of observations (150,000+ for gas and 250,000+ for electricity), if certain groups were underrepresented in the sample dataset, this would distort the findings. The electricity sample required oversampling to capture the complexity of tariff types among electricity heating homes, compared to the relatively simple tariff structure of gas heating homes.

Each sample was compared to the main NEED dataset[6] using income and energy consumption. Figure 1.1 shows that income statistics from the gas sample and the wider gas data had similar distributions. The gas sample and the full NEED dataset had similar means of £49,600 and £50,700, respectively; they also had similar medians; £39,300 and £40,200 respectively.[7]

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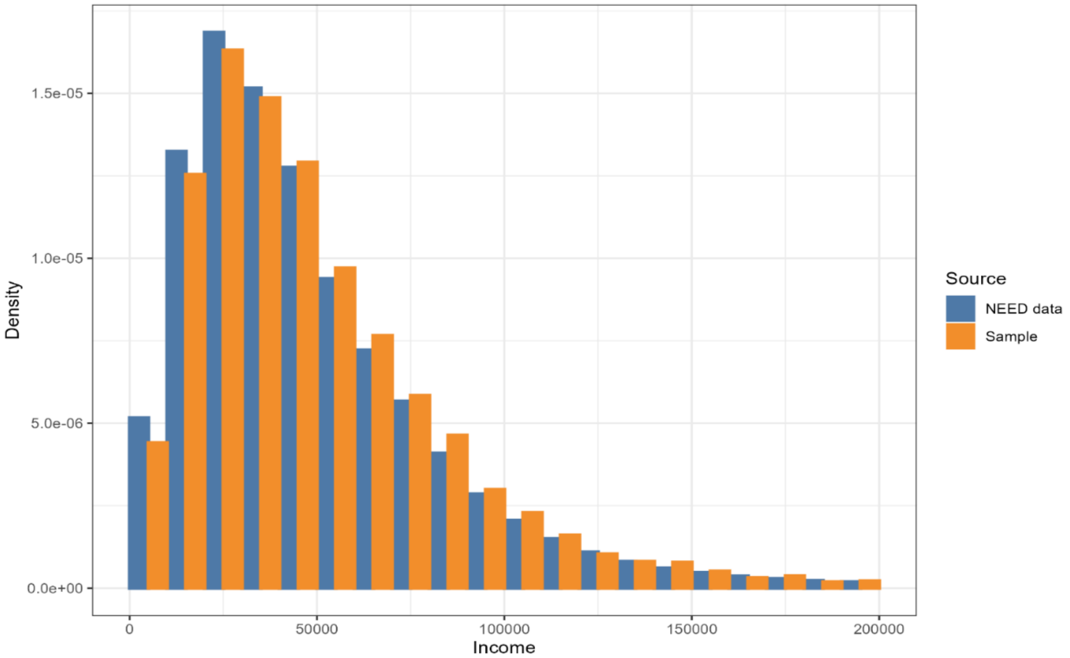
[6] Note that throughout this refers to the main NEED dataset provided to this project, not published NEED data.

[7] Values of above £200,000 were truncated in the plot.

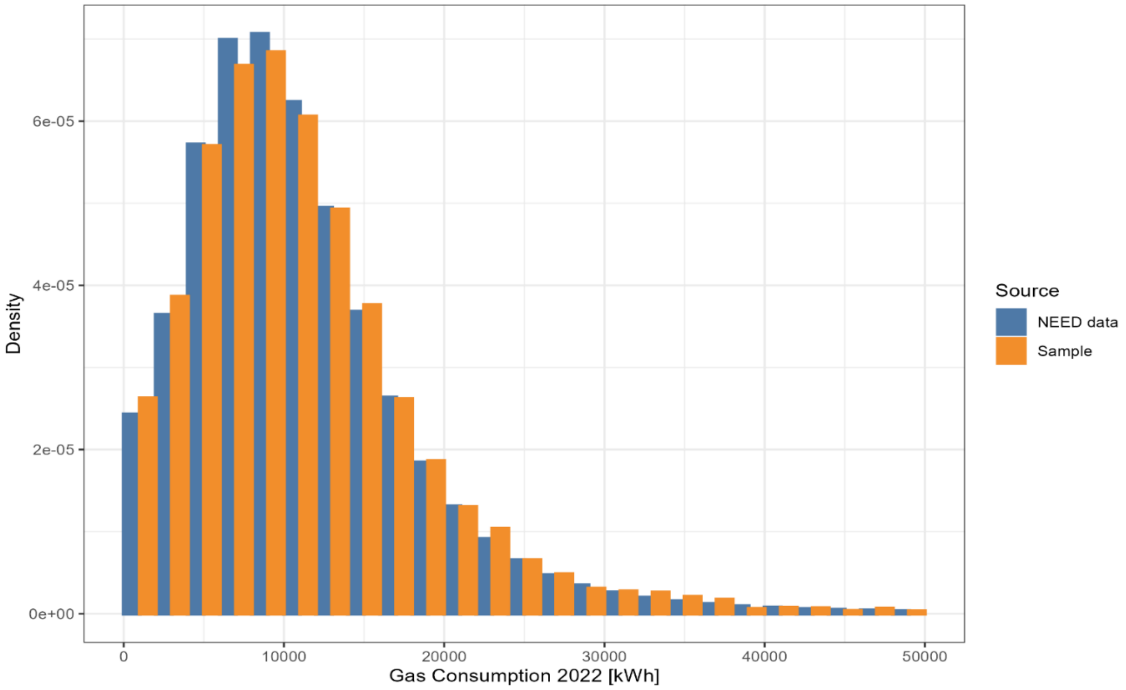
Figure 1.1 Income for Gas Sample and Full Gas NEED Data



Source: NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351.

Figure 1.2 shows that the distributions of gas consumption in 2022 for the sample and the wider gas dataset were also similar. The gas sample had a mean and median usage of approximately 11,100 kWh and 9,600 kWh, which was similar to, although lower than, the full NEED dataset's mean and median usage of 11,700 kWh and 9,800 kWh, respectively.[8]

Figure 1.2 Consumption of Gas: Gas Sample (2022) and Full Gas NEED Data



Source: NEED GB. Random sample of Gas meters = 158,143, model sample = 70,351.

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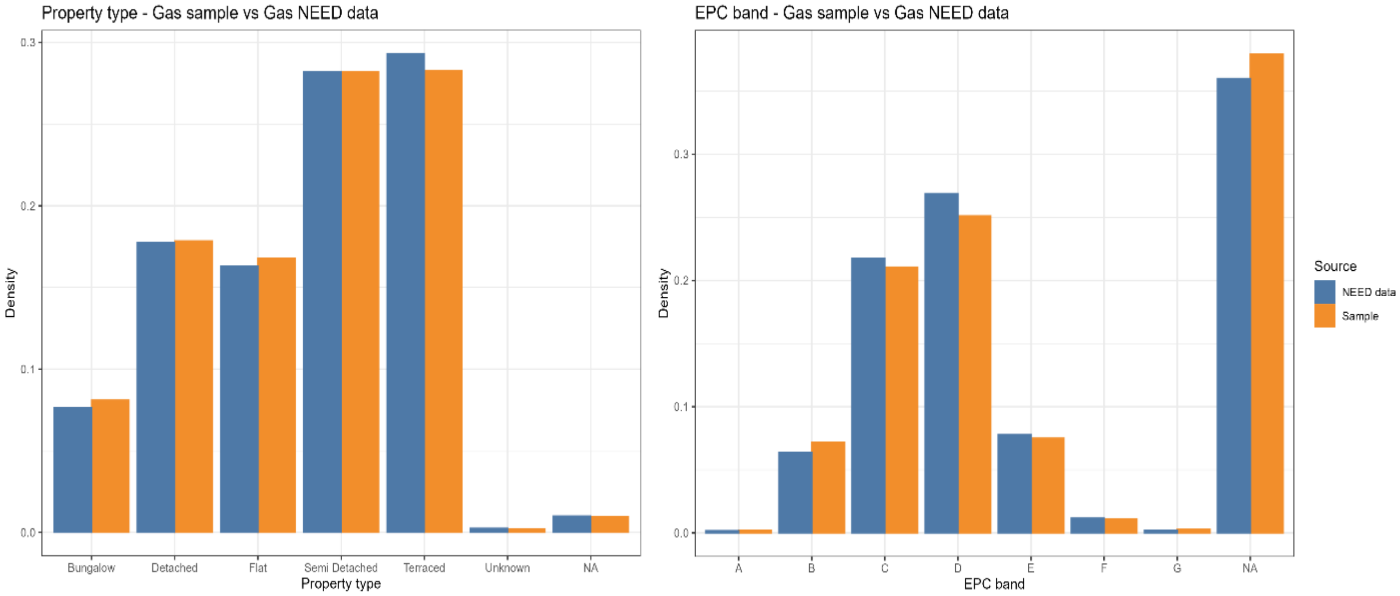
[8] Values above 50,000 kWh are truncated in the plot.

Figure 1.3 considers the distribution of other key variables like property type and EPC rating categories. In each plot, it is noted that the distribution of the gas sample was similar to the distribution of gas households in the NEED data.

Figure 1.3 Property Type and EPC Band for Gas Sample and Full Gas NEED Data

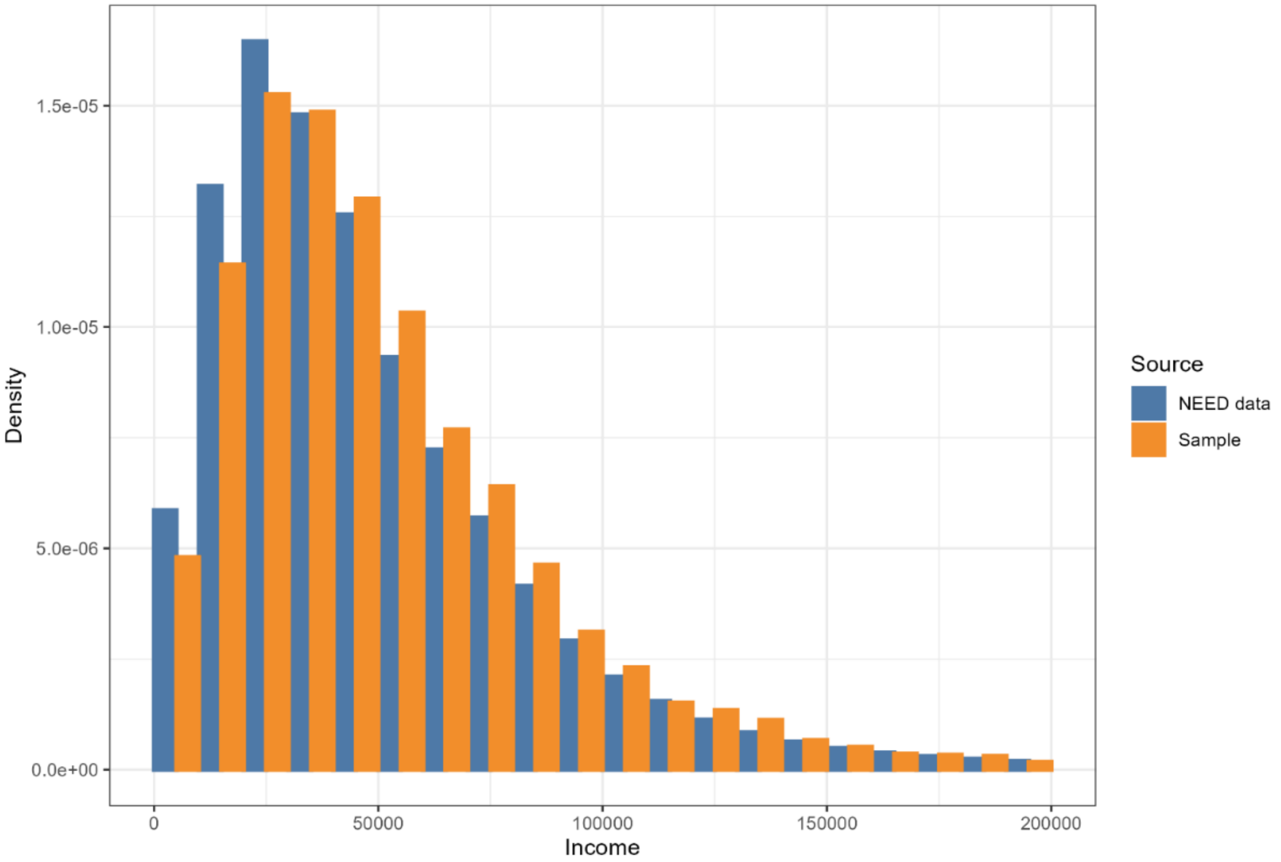


Source: Audit GB. Random sample of Gas meters = 158,143, model sample = 70,351.

Considering the electricity sample, it is noticeable that the distribution of important measures was largely similar to that of the full NEED dataset, although there were minor differences.

Income statistics from the electricity sample were slightly higher than the full NEED dataset, with averages of £53,500 and £50,800, respectively. The same trend appeared for the median income, with measures of £43,300 and £40,300 respectively, as illustrated in Figure 1.4 (values above £200,000 are truncated in the plot below).

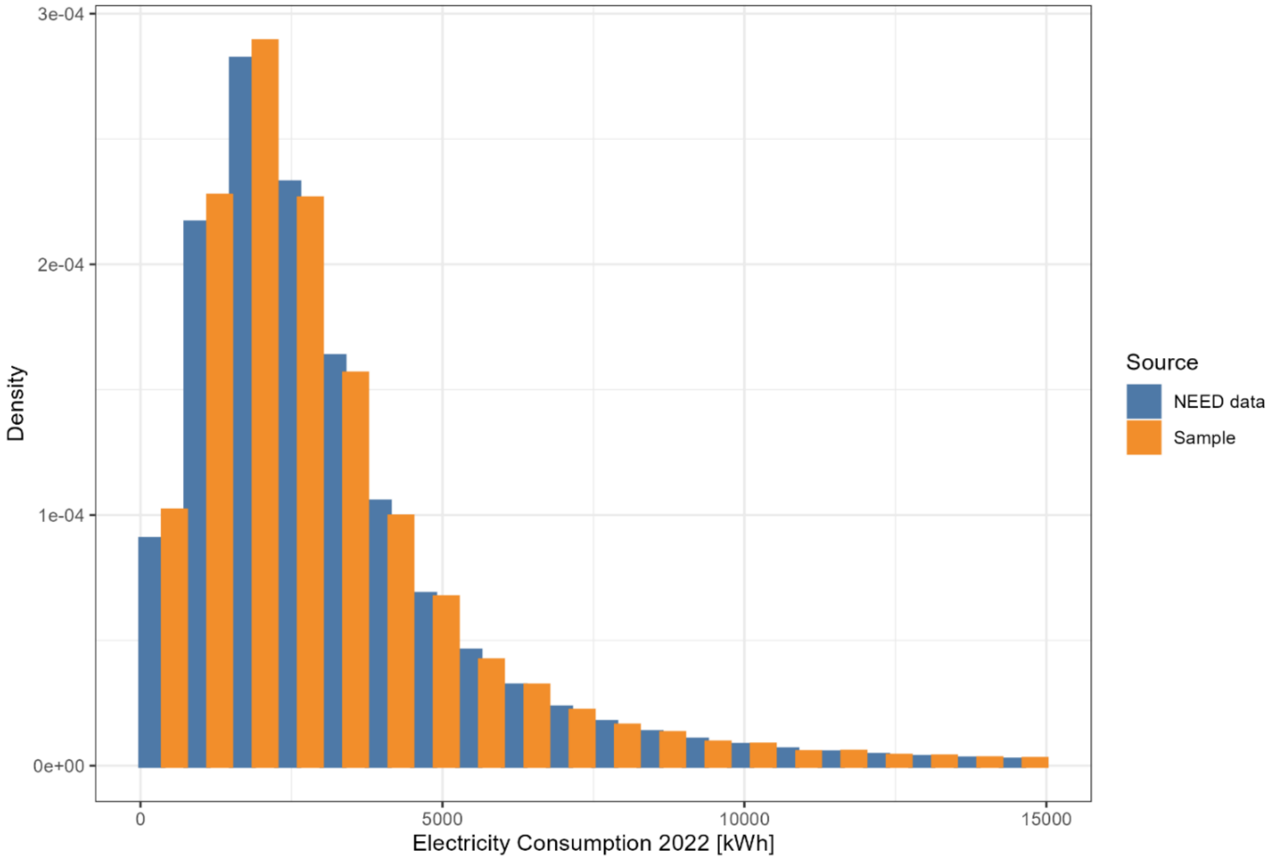
Figure 1.4 Income for Electricity Sample and Full Electricity NEED Data



Source: NEED GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

Likewise, the electricity sample had a mean and median usage of approximately 3,100 kWh and 2,400 kWh, which was similar to, albeit lower than, the full NEED dataset's mean and median usage of 3,400 kWh and 2,500 kWh, as illustrated in Figure 1.5 (values above 15,000 kWh are truncated in the plot below).

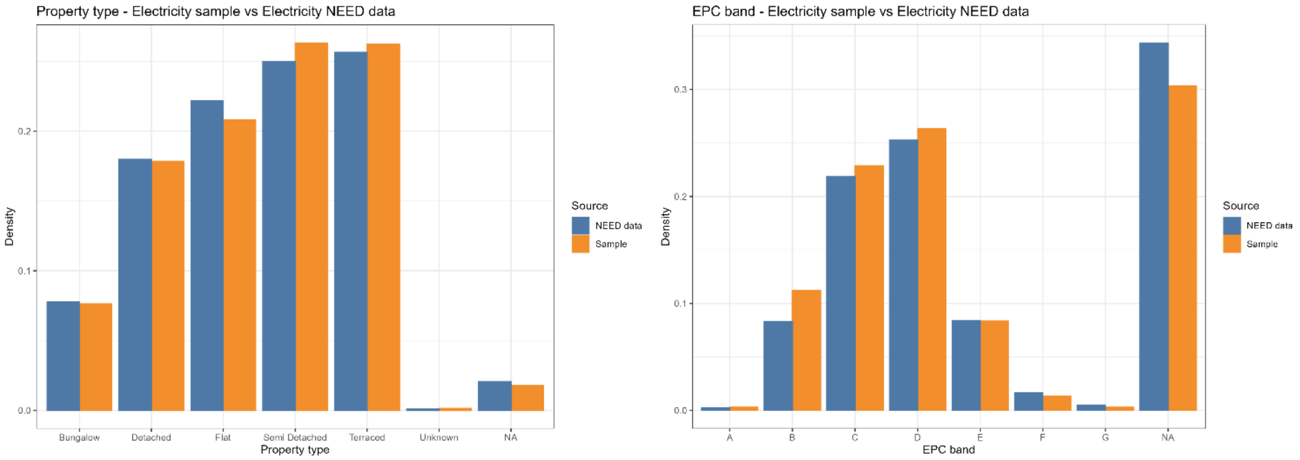
Figure 1.5 Electricity Consumption for Electricity Sample and Full Electricity NEED Data



Source: NEED GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

When examining the distribution of other measures, such as property type and EPC ratings, the electricity sample data (in orange) matched the NEED data (in blue) closely, as seen in Figure 1.6 below.

Figure 1.6 Property Type and EPC Band for Electricity Sample and Full Electricity NEED Data



Source: NEED GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

While the NEED dataset contained circa 23 million UPRNs, each sample contained circa 25,000 UPRNs. Since the generated gas and electricity samples were random, as expected, they represented the overall population well, since the distribution of all key variables matched regardless of source.

1.3. Estimation

The analysis used Random Effects (RE) Linear Models throughout. Additional models (Ordinary Least Squares, Fixed Effects, and Between Effects) and sensitivity checks (income squared terms, income-price interactions, and other checks) are presented in Annex B7, which also contains post estimation results (residual plots and other checks) available for QA purposes.

The energy demand models presented here were a significant improvement on the analysis presented in the Interim Evaluation, where aggregate quarterly data was used. This data had few observations and limited variation. Audit NEED used household level consumption and characteristics which were associated with heating and energy use.

Models were estimated for gas heated homes and electricity heated households separately, although most households in GB are heated using gas (approximately 85%[9]). In addition, the electricity elasticity estimates posed issues that arose from the inability to explicitly identify electricity used for heating in households. In addition, the level of electricity consumed per day was capped at a reasonable level to remove extreme outliers. This is described in more detail below.

The main models used panel data estimation techniques. Panel models are very similar to standard Ordinary Least Squares (OLS); however, they allow for parameters which model household-specific unobserved effects. A typical functional form of a model, such as OLS, is;

$$ln\, q = \alpha + \beta\, ln\, p + \gamma\, ln\, I + \boldsymbol{BX} + \varepsilon$$

Where q is the quantity consumed, p is the price, I is the income, ε is the error term, and $\mathbf{X}$ represents other explanatory variables of interest. α, β, γ, $\mathbf{B}$ are parameters to be estimated. By assumption, the error term is iid normal with an expected value of zero[10]. The quantity and price are in natural logs, so the price elasticity is given by:

$$E = \frac{\%\Delta q}{\%\Delta p} = \frac{\Delta q/q}{\Delta p/p} = \frac{\partial\, ln\, q}{\partial\, ln\, p} = \beta$$

Where Δ denotes change, when looking at panel data, the general estimation equation for panel models is;

$$ln\, q_i = \alpha_i + \beta\, ln\, p_i + \gamma\, ln\, I_i + \boldsymbol{BX} + \varepsilon_i$$

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[9] DESNZ, 2024. Hydrogen Heating Overview

[10] Independently Identically Distributed (iid) is a standard assumption. It in general is not needed for OLS or similar models to be best or unbiased but is needed for easy interpretation of the statistical significance tests, such as that the coefficient parameter estimates are t-distributed.

The parameters in the panel data model were the same as for the general model, but with the subscript i, which is specific for each household (note: there were as many alpha parameters as there are households). While there were several panel data methods applicable, including Random Effects (RE), Fixed Effects (FE), and Between Group Effects (BE), the analysis focused on the RE model. Specifically, the α_i is the intercept parameter, which represents the mean value of q_i should all other parameters be equal to zero. Should α_i be a fixed parameter, it is an additive to the intercept with expected value α_i, then the model is the FE model. If α_i is a random parameter with a variance parameter for each household, it is an additive to the error term with expected value of zero, then the model is RE. If averaged over households and the model is estimated on the group averages, the model is the BE model.

The RE model is a weighted-average of the BE and FE models. Model selection was based on fit, residuals inspection and judgement regarding the expected signs and significance of key parameters. Details of the estimates from the OLS, the FE, and BE models are provided below.

Using the Combined audit and NEED dataset, the analysis tested whether price and income elasticities were constant or should include non-linear terms. Therefore, the approach used included a squared $ln\, p_i$ variable and the significance of the related parameter, δ, was tested.

$$ln\, q_i = \alpha_i + \beta\, ln\, p_i + \delta(ln\, p_i)^2 + \gamma\, ln\, I_i + \boldsymbol{BX} + \varepsilon_i$$

If the second term on price, gamma, is significant, the elasticity estimate varies with price, making the own price elasticity;

$$E = \frac{\%\Delta q}{\%\Delta p} = \frac{\partial lnq}{\partial lnp} = \beta + 2\, ln\, p_i$$

Using this method, then the counterfactual prediction for consumption is conditional on each household price.

The analysis of the Combined audit and NEED data did not use demand systems estimation since the required data was not present. Demand system models which were estimated with the LCFS data described below, would have been challenging to perform with the Combined audit and NEED dataset, since the income variable in the NEED data was time-invariant within the year. In addition, there was no consistent data on prices and quantities expenditure on non-energy goods, which prevented estimation of cross-price elasticities or implementation of the demand system models. However, by carrying out two approaches with two different datasets (Combined audit and NEED and LCFS), the analysis was able to compare the results for households with gas and electricity heating on the main parameters, e.g., own price and income elasticities, for which the two approaches gave reasonably similar results.

Table 1.1 compares the R-Squared figure for each type of model by gas and electricity datasets. The table suggests that RE models fit the data best and have the highest R-squared value; meaning these models explain the largest portion of the variance in energy demanded. While OLS provides the same R-squared, it is not a panel model and likely violates several assumptions (like independence between observations). This estimate is listed for comparative purposes only. The broadly invariant results by OLS vs RE nonetheless indicate that choice of model is not a significant driver of different modelling results.

Table 1.1 R-Squared Comparison for Model Selection

	OLS	Random Effects	Fixed Effects	Between Group Effects
Gas	0.49	0.49	0.16	0.48
Electricity	0.28	0.28	0.02	0.18

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351. Random sample of Electricity meters = 236,500, model sample = 19,544.

1.4. Model and Results: Gas

This section presents the final model for gas heated homes and discusses its results. There were approximately 158,000 observations in the gas sample dataset. The panel regression models used in this analysis for the gas sample dataset (namely RE) is shown below;

$$lnGas = lnPrice + lnPrice^2 + lnIncome + EPC + lnFloorArea + UsageSource + GasCompany + MonthMid + YearMid + AdultOccupants + Region + MeterStatus + Tenure + PropType + lnGas21$$

Where:

lnGas = the log of quantity of gas consumed per unit of time.
lnPrice = the log of unit price of gas.
lnIncome = the log of household income.
EPC band = the energy performance certificate.
lnFloorArea = the log of floor area.
UsageSource = the source of the usage level (estimated, actual etc.,).
GasCompany = the name of gas company.
MonthMid = the mid-point of consumption period (month).
YearMid = the mid-point of consumption period (year).
AdultOccupants = the number of adults in the household.
Region = the region.
MeterStatus = the status of meter (live, closed etc.,).
Tenure = the type of tenure.
PropType = the property type.
lnGas21 = annual gas consumption 2021.

Only the unit price and charges for energy were included as price in the models. As set out in Table 1.2 below, there was complete data for approximately 70,350 observations, with most of the data lying between Q4 2022 and Q1 2023 (the intervention period).

Table 1.2 Distribution of Observations by Year and Quarter in Gas Model Sample

	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
2021	0	3	10	10	23
2022	12	453	1,768	29,666	31,899
2023	26,939	10,838	652	0	38,429
Total	**26,951**	**11,294**	**2,430**	**29,676**	**70,351**

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351.

On average, during the intervention period homes that heat with gas used approximately 48 kWh per day in the overall sample and 46 kWh per day in the model sample. As shown in Table 1.3, the overall sample contained negative values for quantity of units consumed.[11] The source of negative values in the audit data is unclear (it could be due to human error or due to accounting practices at any given supplier), and consequently the analysis is limited to households with positive values for gas consumed to avoid these.

Table 1.3 Average Levels of Gas Consumption in Model Sample and Overall Sample

	No. of Observations	Mean	Standard Deviation	Minimum	Maximum
Model Sample					
Units Consumed	70,351	1,356	1,807	0	95,262
Units Consumed per Day	70,351	46	128	0	17,777
Overall Sample					
Units Consumed	158,143	1,176	2,040	-61,120	95,262
Units Consumed per Day	136,631	48	131	0	20,081

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351.

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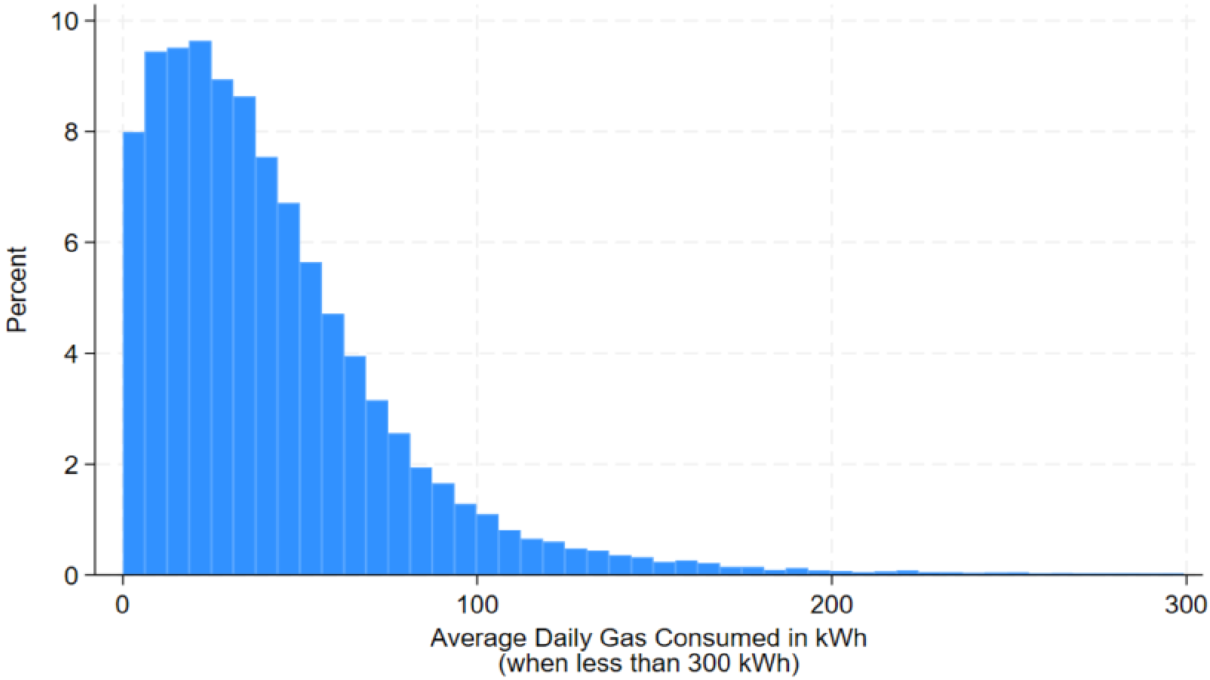
[11] While units consumed had negative values in the overall sample, units consumed per day did not due to the method of creation for this variable; it was created as a log initially and then the exponential was derived, removing any negative values of gas consumed in the overall sample dataset.

The figure below (1.7) graphs the average consumption of gas per day by kWh (under 300 kWh). Most households used less than 100 kWh per day, though a small portion used more than this amount. As mentioned in the table above, the average household used 48 kWh of gas per day during the intervention period.

Figure 1.7 Daily Gas Consumption in Model Sample



Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided for GB. Random sample of Gas meters = 158,143, model sample = 70,351.

The regression output for the RE model, as well as the regression output from the OLS model, the FE Model, and the BE Model is available in Annex B7. Of importance for this analysis was the estimated own price elasticity from the RE model for gas heated homes shown in Table 1.4 below. The elasticity is a function of the price which varies by household/tariff, and so the average over the sample is presented. Own-price elasticity was between -1 and 0, as expected, and income elasticity was between 0 and 1, as expected; both were statistically significant.

A one per cent increase in price was associated with a 0.46% reduction in gas consumption. This is intuitive with underlying economic theory, since an increase in price is expected to lower demand. A one per cent increase in income was associated with a 0.07% increase in gas consumption. This is also intuitive, since an increase in income likely increases demand.

Table 1.4 Own Price and Income Elasticity for Gas

	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
Price	51,949	-0.46	0.06	-8.32	0.00	-0.57	-0.35
Income	51,949	0.07	0.01	9.50	0.00	0.05	0.08

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample for GB. Random sample of Gas meters = 158,143, model sample = 70,351.

However, own price elasticity in the model was non-linear, and so this effect varied with the price of gas. The elasticities at different price points are shown in Table 1.5 below, which highlights the own price elasticity from the RE model at different prices of gas within the distribution, namely the 25th percentile unit price of gas, the median unit price of gas, and the 75th percentile unit price of gas.[12]

Table 1.5 Own Price Elasticity for Gas at Different Prices of Gas (per kWh)

	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
9.8p	51,949	-0.47	0.06	-8.29	0.00	-0.59	-0.36
9.9p	51,949	-0.48	0.06	-8.27	0.00	-0.60	-0.37
10.5p	51,949	-0.53	0.06	-8.19	0.00	-0.66	-0.40

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351.

At lower prices of gas, the impact of a one per cent increase in the price of gas on the consumption of gas had a smaller impact than at higher prices of gas. Therefore, the higher the price of gas was, the larger the impact of the 1% price increase will have had on consumption.

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[12] Unit is per kWh.

1.5. Model and Results: Electricity

This section presents the final model for electricity heated homes and discusses its results. There were approximately 236,500 observations in the electricity sample dataset. The model used to estimate electricity consumption (using RE) is shown below;

$$lnElec = lnPrice + lnPrice^2 + TariffType + RegType + lnIncome + EPC + lnFloorArea + lnFloorArea^2 + UsageSource + Company + MonthMid + YearMid + AdultOccupants + Region + MeterStatus + Tenure + PropType + lnElec21$$

Where:

lnElec = the log of quantity of electricity consumed per unit of time.
lnPrice = the log of unit price of electricity.
TariffType = the tariff type (fixed, standard, etc.,).
RegType = the rate type (day, night, single rate, unit rate, etc.,).
lnIncome = the log of household income.
EPC band= the energy performance certificate.
lnFloorArea = the log of floor area.
UsageSource = the source of the usage level (estimated, actual etc.,).
Company = the name of electricity company.
MonthMid = the mid-point of consumption period (month).
YearMid = the mid-point of consumption period (year).
AdultOccupants = the number of adults in the household.
Region = the region.
MeterStatus = the status of meter (live, closed etc.,).
Tenure = the type of tenure.
PropType = the property type.
lnElec21 = annual electricity consumption 2021.

For electricity, the model was restricted to run on households that had between 0.0 and 0.25 for their ratio between the consumption of gas and electricity. This was to exclude households who heat with gas. Some homes may have had gas but heated their home with electricity nonetheless, such as those with a heat pump. The daily quantity of electricity was also restricted in the model to only include those that used over 1 kWh per day but under 55 kWh per day[13], as some households used either a very small amount (less than 1kWh per day) or a very large amount (over 500,000 kWh). Large figures as such were likely billing errors or bills being pooled together. Additionally, it could be due to the additional uncertainty around the exact use of electricity in a household, as some households might have used electricity day-to-day, but not for heating. In the sample dataset, the average daily consumption of electricity was 23 kWh. However, the median daily consumption of electricity was 7 kWh.[14] The large difference between the mean and median suggests there may have been outliers in the data. Including these outliers in the analysis could have distorted results.

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13 Sensitivities on this were carried out and doubling to 110kWh per day did not have large effects on the results.

[14] This figure reflects the average observation in the electricity dataset, which is a single customer registry within a customer time period. Within each customer time period, there can be multiple customer registries. These are aggregated to get a total post-estimation.

It was necessary to restrict the sample to homes using between 1 kWh and 55 kWh per day, since the analysis was interested in homes which use electricity (over 1 kWh per day) but not excessively (below 55 kWh). There was complete data for 19,500 observations, with most lying between Q4 2022 and Q1 2023.

Table 1.6 Distribution of Observations by Year and Quarter in Electricity Model Sample

	Quarter 1	Quarter 2	Quarter 3	Quarter 4	Total
2022	1	92	404	5,997	6,494
2023	8,627	4,291	132	0	13,050
Total	8,628	4,383	536	5,997	19,544

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

Analysis also examined the units consumed per day. While there were negative values of units consumed in the overall sample, the observations in the regression model sample did not contain negative values for units consumed, as the log of units was used as the dependent variable in the regression (converting these to missing). In addition, as the model sample was restricted to households that used between 1 kWh of electricity per day and 55 kWh of electricity per day, the summary statistics for the model sample were significantly lower than that for the overall sample, which included outliers as discussed above. On average, households that heated with electricity in the model regression consumed 10 kWh of electricity per day.

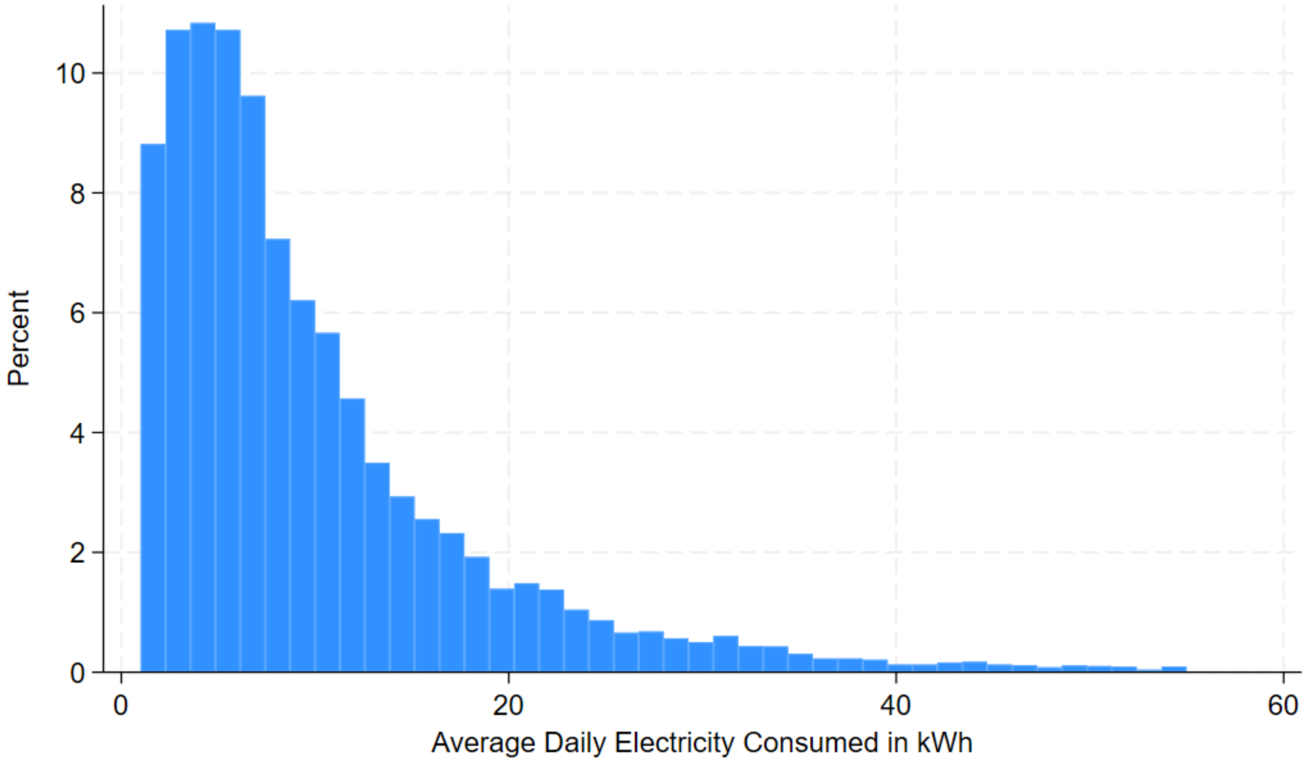
Table 1.7 Average Levels of Electricity Consumption in Model Sample and Overall Sample

	No. of Observations	Mean	Standard Deviation	Minimum	Maximum
Model Sample					
Units Consumed	19,544	285	347	1	4,210
Units Consumed per Day	19,544	10	9	1	55.9
Overall Sample					
Units Consumed	236,500	315	26,274	-99,062	8,898,616
Units Consumed per Day	214,989	23	2,648	0	549,346

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample for GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

When considering the distribution of electricity consumption, most homes used less than 20 kWh of electricity. However, a small portion of the dataset used more than this (see Figure 1.8 below).

Figure 1.8 Daily Electricity Consumption in Model Sample



Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample for GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

Across the sample dataset, electricity could be broken down by tariff type and rate type. In Table 1.8, the percentages for tariff type and rate type are depicted for the overall sample. Standard tariffs were the largest category in the sample, with the majority having a single rate (as opposed to day and night rates).

Table 1.8 Tariff Type and Rate Type for Electricity (Percentages)

	Fixed Rate Tariff	Multi-Rate Fixed Tariff	Multi-Rate Standard Tariff	Standard Tariff	Total
24-Hour Rate	-	-	-	<0.1%	<0.1%
Day Rate	0.9%	0.2%	3.2%	18.6%	22.8%
Night Rate	0.6%	0.2%	2.8%	13.9%	17.4%
Single Rate	2.0%	0.2%	0.8%	56.0%	58.9%
Standard Rate	-	-	-	<0.1%	<0.1%
Period 1 Unit Rate	-	0.1%	0.1%	-	0.2%
Period 2 Unit Rate	-	<0.1%	0.1%	-	0.1%
Period 3 Unit Rate	-	<0.1%	-	-	<0.1%
Single Rate Unit Rate	0.1%	-	-	0.3%	0.4%
Unit Rate	<0.1%	-	-	0.2%	0.2%
Total	3.6%	0.6%	6.9%	88.9%	100%

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

In the sample dataset, there were a variety of issues associated with tariffs. The time-of-day variation that was presented in the Audit data was to have different ‘registers’, but then the actual billing periods were, for example, over a week or month, meaning it wasn’t always clear what periods and what rates were referring to for multi-rate tariffs. This was subsequently looked at further by estimating separate models for standard and fixed rate tariffs discussed in the next section. All regression outputs for electricity for OLS, RE Model, FE Model, and BE Model are available in Annex B7.

Of importance for this analysis are the estimated own price elasticities from the RE model for electricity, shown in Table 1.9 below. This was estimated by a margins command in Stata after the RE regression had run and was based on the model sample. Own-price elasticity was between -1 and 0, as expected, and income elasticity was between 0 and 1, as expected.

Table 1.9 Own Price and Income Elasticity for Electricity

	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
Price	13,250	-0.18	0.06	-3.19	0.00	-0.30	-0.07
Income	13,250	0.09	0.02	4.75	0.00	0.05	0.12

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Electricity meters = 236,500, model sample = 19,544.

A 1% increase in the price of electricity resulted in a 0.2% decrease in the consumption of electricity. In addition, a 1% increase in income led to a 0.1% increase in the consumption electricity.

However, it is also important to consider tariff type for electricity. Table 1.10 below shows the differing price elasticities based on tariff type. Standard tariffs were the largest category, were statistically significant and had the expected sign for a price elasticity estimate of this kind (a 1% increase in price led to a 0.45% fall in demand). Fixed tariffs made up a much smaller share of the sample, and while these types of households had the expected sign for the price elasticity, it was not statistically significant at the 10% level. Furthermore, the multi-rate tariffs had the wrong sign but were statistically significant.

Table 1.10 Own Price Elasticities for Electricity by tariff type

	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
Fixed	13,250	-0.09	0.08	-1.13	0.26	-0.26	0.07
Multi-Rate Fixed	13,250	0.44	0.08	5.72	0.00	0.29	0.59
Multi-Rate Standard	13,250	0.26	0.02	13.31	0.00	0.22	0.29
Standard	13,250	-0.45	0.09	-4.75	0.00	-0.63	-0.26

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB.

Given the proportion of households on fixed tariffs in GB, additional sampling was developed on a larger sample of 7,547 fixed tariff households to enable more detailed subgroup analysis. This allowed for exploration of whether the income effects were more prevalent among fixed or standard tariffs. There are a variety of issues here, including the fact that there are very few multi-rate tariffs in the sample and that it is very difficult to interpret the meaning of some of the tariff key characteristics. In addition, billing data is not available that is time specific.

Overall, it is not expected that multi-rate tariff users are less elastic than standard type tariff users. Like gas, own price elasticity was non-linear and so it varied with the price of electricity. Own price elasticity across different prices within the distribution is shown in the table below. Namely the varying prices of unit price for electricity include the 25th percentile unit price of electricity, the median unit price of electricity, and the 75th percentile unit price of electricity.[15]

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[15] Unit is per kWh.

Table 1.11 Own Price Elasticity for Electricity at Different Prices of Electricity (per kWh)

	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
31p	13,250	-0.11	0.05	-2.18	0.03	-0.21	-0.01
33p	13,250	-0.17	0.06	-3.09	0.00	-0.28	-0.06
35p	13,250	-0.26	0.06	-4.14	0.00	-0.39	-0.14

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB.

At lower prices of electricity, the impact of a one per cent increase in the price of electricity on the consumption of electricity had a smaller impact that at higher prices of electricity. This highlights household’s sensitivity to price increases in electricity at different price levels. In addition to varying across price and tariff type separately, own price elasticity for electricity varied across both price and tariff type, as set out above.

1.6. Sub-group analysis of energy consumption

The electricity demand modelling on the Combined audit and NEED dataset above showed that the energy affordability schemes had a different scale of effect on energy consumption depending on the type of electricity tariff households were on (note that gas tariffs do not vary across the gas sample). Due to the low proportion of households on fixed tariffs in GB, it is necessary to build upon the previous section, using the same methodology, with an analysis on subgroups. This was completed using a larger sample of 7,547 fixed rate and 11,003 standard rate tariff households, where the model was restricted to exclude households who heat with gas. What follows is an exploration of whether the income effects were more prevalent among fixed or standard tariffs. It considers these effects by income decile (Table 1.12) before exploring results by EPC rating and tenancy. The energy affordability schemes may also have been expected to have had different impacts on energy consumption behaviour depending on the energy efficiency of the home. In both gas and electricity heated households, there is a linear relationship between higher levels of actual energy usage and lower levels of efficiency (with EPC ratings of F-G being the least efficient homes). In other words, homes which are less energy efficient require more energy to be consumed to heat their homes and so may be more affected by increasing energy prices. It could be expected that the energy affordability schemes were more necessary for lower efficiency households, whose energy bills were larger, and whose response to energy price rises should have been less elastic (because they need to use a large amount of energy to keep their homes to a comfortable level regardless of the price).

However, this was not reflected in the findings. As can be seen in Table 1.12, the modelled counterfactual scenario predicted a more pronounced reduction in energy consumption without the energy affordability scheme, with those living in more energy efficient homes reducing their electricity consumption by nearly a third in response to higher prices, while those in less efficient houses reduced it by only around a fifth. In the case of gas heated homes, the modelled counterfactual showed that in the absence of the scheme, all gas heated households would have used around a quarter less energy than what was observed in the actual Combined audit and NEED data, regardless of their energy efficiency. In other words, without the energy affordability schemes, more energy efficient, electricity heated houses would have reduced their energy consumption more than those in less efficient homes, while for gas heated households there was no difference in the effect between more and less efficient houses.

Table 1.12 Energy demand modelling predicted quantity electricity consumed (total effect) for electricity households on standard and fixed tariffs in GB (Audit and NEED Q4 2022- Q1 2023)

Income Decile	Actual: Intervention	Counterfactual No Intervention	Difference (actual – counterfactual)	Actual: Intervention	Counterfactual No Intervention	Difference (actual – counterfactual)
1	42.06	30.74	26.90%	28.73	26.69	7.10%
2	50.34	37.11	26.30%	42.27	39.01	7.70%
3	58.67	43.05	26.60%	47.09	44.28	6%
4	58.30	43.06	26.10%	53.76	50.36	6.30%
5	54.81	40.49	26.10%	58.11	54.87	5.60%
6	64.81	46.87	27.70%	63.87	58.97	7.70%
7	62.64	45.49	27.40%	68.21	65.31	4.30%
8	64.35	46.85	27.20%	75.38	70.46	6.50%
9	66.03	47.88	27.50%	82.17	77.55	5.60%
10	77.27	55.26	28.50%	109.62	102.36	6.60%
Total	**61.00**	**44.36**	**27.30%**	**64.53**	**60.43**	**6.30%**

Source: Combined audit and NEED: Sample size: Fixed booster 7,547 households; standard 11,003 households. Note, fixed and standard both include blend of single and multi-rate tariffs.

Intuitively it may have been expected that the effect of price increases under the counterfactual would have been more pronounced among less energy-efficient homes, due to the higher baseline consumption (as observed in the actual data) meaning that price increases would have resulted in larger absolute increases in energy bills. In theory, in less energy efficient homes there is a greater potential for savings, with more room for improvement in energy efficiency that could lead to significant reductions in consumption; and greater financial pressure motivating more aggressive energy-saving measures or energy use restriction.

However, it is important to note that there could be barriers to implementing changes. Less efficient homes often belong to lower-income households who might struggle to afford the up-front short-term costs of efficiency upgrades. Furthermore, in rental properties, tenants bear the cost of higher energy prices, but landlords might not be motivated to invest in efficiency improvements. In the next set of tables, the differential effects of the energy affordability schemes on homeowners and tenants are explored, to cast further light on the differential effects observed among less and more efficient properties.

Table 1.13 Energy demand modelling predicted quantity energy consumed by Energy Efficiency Certificate (EPC) rating (total effect EBSS and EPG) for electricity and gas households in GB (Q4 2022- Q1 2023)

	Gas heating households			Electricity heating households		
EPC Rating	Actual: Intervention	Counterfactual No Intervention	Difference (actual – counterfactual)	Actual: Intervention	Counterfactual No Intervention	Difference (actual – counterfactual)
A/B	196.59	148.57	24.40%	71.53	50.97	28.70%
C	222.68	166.69	25.10%	91.94	76.41	16.90%
D	280.41	210.87	24.80%	115.51	100.49	13%
E	310.47	232.44	25.10%	128.42	114.94	10.50%
F/G	376.77	280.15	25.60%	151.95	140.27	7.70%
Total	257.55	193.33	24.90%	99.07	82.68	16.55%

Source: Combined audit and NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351. Random sample of Electricity meters = 236,500, model sample = 19,544.

There is some evidence that the energy affordability schemes had a greater effect on electricity heated, owner occupied properties, which the modelling suggests would have reduced their energy consumption to a greater degree (27%) without the energy affordability schemes compared to private and social tenants (24% and 23% respectively). This could be explained by the greater ability of homeowners to respond to higher energy prices by investing in energy efficiency measures, which bring down their energy consumption, as well as by the correlation between home ownership and higher incomes, and a greater elasticity between income and energy compared to lower income groups (see Table 1.15). However, among gas heating households this relationship was not observed, with all tenancy types reducing their energy consumption by between 24%-26% under the counterfactual scenario.

Table 1.14 Energy demand modelling predicted quantity energy consumed by tenancy type (total effect EBSS + EPGEBSS AND EPG) for electricity and gas households in GB (Audit and NEED Q4 2022- Q1 2023)

	Gas heating households			**Electricity heating households**		
Tenancy type	**Actual: Intervention**	**Counterfactual No Intervention**	**Difference (actual – counterfactual)**	**Actual: Intervention**	**Counterfactual No Intervention**	**Difference (actual – counterfactual)**
Owner occupied	280.52	212.09	24.40%	98.42	79.36	19.40%
Private rented	250.61	185.37	26%	105.54	92.46	12.40%
Council/ Housing Association	190.04	140.34	26.20%	89.73	76.06	15.20%
Total	257.55	193.33	24.90%	99.07	82.68	16.55%

Source: Combined audit and NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351. Random sample of Electricity meters = 236,500, model sample = 19,544.

Table 1.15 shows that without the energy affordability schemes, it is predicted that at all income levels, gas heating households would have consumed around a quarter less energy than they actually did with the schemes. Whereas it is predicted that in electricity heating households, the lowest income households would have reduced their energy consumption by 21% under the counterfactual, compared to the highest income households, who would have reduced their energy consumption to a greater degree, by up to 30%.

Table 1.15 Modelled household energy consumption by household income deciles for mains gas and electricity households in GB (administrative data Q4 2022- Q1 2023)

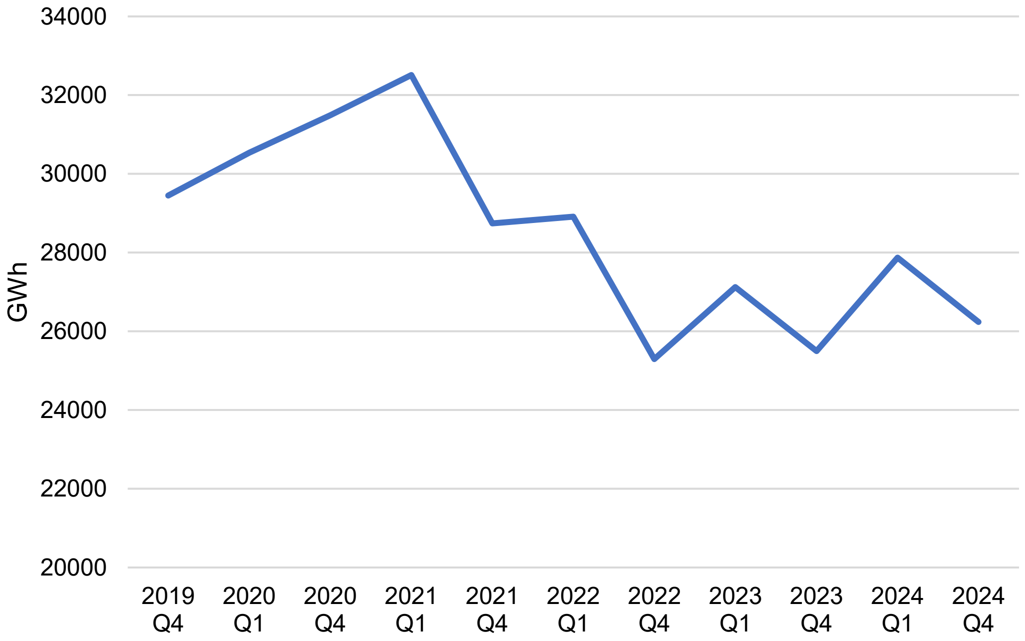
	Gas heating homes			Electricity heating homes		
Income Decile	Actual: Intervention kWh per week	Counterfactual No Intervention kWh per week	Difference (actual – counterfactual)	Actual: Intervention kWh per week	Counterfactual No Intervention kWh per week	Difference (actual – counterfactual)
1	162.77	120.48	26.00%	43.12	34.05	21.00%
2	197.64	147.56	25.30%	50.05	40.24	19.60%
3	220.88	164.58	25.50%	54.57	42.71	21.70%
4	224.30	167.62	25.30%	56.79	43.69	23.10%
5	246.62	184.53	25.20%	54.42	42.73	21.50%
6	251.77	189.99	24.50%	60.92	45.40	25.50%
7	265.84	200.93	24.40%	58.94	43.44	26.30%
8	281.46	212.76	24.40%	62.34	44.65	28.40%
9	310.62	234.17	24.60%	63.85	44.95	29.60%
10	406.68	305.22	24.90%	73.98	51.10	30.90%

Source: Combined audit and NEED: Note Electricity and gas consumption based on actual meter data provided from random sample for GB. Random sample of Gas meters = 158,143, model sample = 70,351. Random sample of Electricity meters = 236,500, model sample = 19,544.

1.7. Winter energy trends 2019 to 2024

Of relevance to the assessment of the impacts of the energy affordability schemes on consumption and underheating, Figure 1.9 below extracts gas and electricity consumption from National Statistics publication Energy Trends produced by DESNZ.[16] for the UK in quarters 4 and 1 from 2019 to 2024, but was not adjusted for seasonal variations (i.e., accounting for warmer winters). The figure shows that domestic winter energy consumption dropped during Q4 2021 and then remained low in subsequent winters. This would suggest that trends in domestic energy consumption were already reducing prior to the energy price shock of 2022/23, due to the increase in prices before then, as well as due to ongoing improvements in households' energy efficiency.[17] However, for both gas and electricity Q4 of 2022 was the lowest consumption point on record, with a small increase in consumption in the winter of 23-24.

Figure 1.9 Domestic winter energy consumption in UK (gas and electricity): DESNZ data (GWh)



Source: National Statistics publication Energy Trends produced by DESNZ for the UK in quarters 4 and 1 from 2019 to 2024.[18]

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[16] Energy Trends UK, January to March 2025

[17] Energy consumption trends in the UK, as reported by DESNZ in Energy Trends, are influenced by a combination of factors including energy efficiency improvements, weather patterns, economic activity, and energy prices.

[18] Data extracted from Table 5.2 supply and consumption of electricity, quarterly data (GWh), and Table 4.1 Natural gas supply and consumption, quarterly data (GWh): Energy UK gas

Annex 2. Energy and non-energy household consumption analysis of the Living Costs and Food Survey

Several items needed for the evaluation could not be estimated using the Combined audit and NEED data. Since only households with a gas and/or electricity connection received EPG, it would not be possible to model the impact of the schemes on households relying on an alternative heating fuel. Additionally, NEED does not contain data on NI and neither the audit data nor NEED contains information on the consumption of non-energy goods. Thus, the prediction of the impact of the schemes on consumption of non-energy items, consumption of energy including heating oil, and the estimation of impacts on Energy Burden/Fuel Poverty (see section A1.3) had to use an alternative dataset and method.

This analysis used the Living Costs and Food Survey (LCFS) for years 2019-2023, specifically, the household datasets with derived variables. It paid special attention to Q4 2022 and Q1 2023, the period of the energy affordability schemes intervention. The sample was expanded for oil household estimation, and tests of whether parameter estimates were sensitive to the time-period selection showed insensitivity.

This dataset was used for three reasons. First, it was a Nationally Representative, cross-sectional, sample of households in the UK. It recorded approximately 5,000 households per year and 1,250 households per quarter. Second, it represented a complete system of all goods, commodities, and services purchased by consumers on a quarterly basis, recording the expenses of households over a two-week period, and presenting the data as weekly household expenditure. Third, all data necessary for the project, except data on prices, was present in the LCFS. It is the most significant self-reported consumer study undertaken in the UK.

The LCFS recorded important measures of household characteristics: the main energy source for central heating (electricity, mains gas, solid fuel, oil, bottled gas, renewable energy or other), the number of people in the home, the dwelling type and the occupancy type of the household. The LCFS also recorded a full account of the household’s total expenditure, including expenditure on the type of energy used (electricity, oil, or natural gas).

The LCFS organised expenditure using the Classification of Individual Consumption by Purpose (COICOP), a standardized system to categorise and analyse household expenditures. COICOP is widely used in national accounts, consumer price indices (CPI), and household budget surveys to ensure consistency and comparability across countries and over time (See below).

To limit the number of parameters to be estimated, demand systems were considered using four broad categories and one focused category, shown below.

- Food, Beverages and Health (COICOP 1 + 6)

- Alcohol, Recreation, Restaurants, and Misc (COICOP 2 + 9 + 11 + 12)
- Clothing, Furnishings, Transport, Communication and Education (COICOP 3 + 5 + 7 + 8 + 10)
- Housing Without Energy Costs (COICOP 4 – 4.05)
- Electricity, gas, and other fuels (COICOP 4.5.1, COICOP 4.5.2, or COICOP 4.5.3)

The demand systems models focused on the following three sets of variables. First, expenditure shares (the total value of a COICOP Category divided by the home's Total Expenditure)

- Share of expenditure on food and health
- Share of expenditure on alcohol, tobacco, restaurant spending, hotels, recreation and miscellaneous
- Share of expenditure on clothing, furnishings, transport, communication, and education
- Share of expenditure on housing without heat or energy costs
- Share of expenditure on energy

Second, measures tied to the characteristics of the home

- Main Source of Central Heating
- Household size

Third, details on the price of goods and services. Although this data was not available in the LCFS explicitly, the analysis was able to combine ONS "Consumer trends" data without the LCFS sample. "Consumer trends" data allowed inclusion of:

- Chained volume measure, not seasonally adjusted
- Current price, not seasonally adjusted

This further allowed the use of existing ONS data on price indices for each consumption category.

- Price Index for goods tied to food and health
- Price Index for goods tied to alcohol, tobacco, restaurant spending, hotels, recreation and miscellaneous
- Price Index for goods tied to clothing, furnishings, transport, communication, and education
- Price Index for goods tied to housing without heat or energy costs
- Price Index for goods tied to energy (further disaggregated by electricity, oil, and natural gas)

Demand system models were run for oil, gas, and electricity separately.[19] This built on the previous analysis in the Interim Evaluation, which used only an aggregate category of expenditure on gas, electricity and fuel, whereas the LFCS gave access to more detailed expenditure types (oil, electricity, natural gas etc.). The analysis was therefore able to estimate separate models for each main fuel type, greatly improving estimation.

The main models of interest were Demand Systems using the LES or QUAIDS approach. These models have benefits because they allow for quadratic Engel curves, meaning goods can be normal, luxuries, or inferior goods over a range of incomes. The main parameter of interest were the elasticities between income and energy spending, as well as price and energy spending. Price elasticities were estimated to ensure 'all else equal' estimation of income and other impacts. This assumes as is common in the literature additive separability between expenditure and savings, which means that there are no cross price interactions between savings and expenditure.

2.1. Data cleaning

When cleaning LCFS data, negative expenditure values were recoded as missing values. When combining COICOP categories, expenditures and shares were treated as additive. Two counterfactuals were used in the analysis. For the gas and electricity heated homes who received a £400 EBSS payment in addition to EPG, the weekly value of the total £400 (£400/26 weeks) was subtracted from total expenditure/total income, but only for the intervention period (Q4 2022 and Q1 2023). Further, the price of energy was adjusted for the counterfactual by 35% for Q4 in 2022 and 53.75% for Q1 in 2023. The estimated price changes were taken from Ofgem's announcement letters of the price caps for both quarters. For the second, for oil users and other alternative fuels not on the grid, the weekly value of the total EBSS and AFP payment of £600 (£600/26) was subtracted from total expenditure/total income, but only for the intervention period (Q4 2022 or Q1 2023). Again, the price of energy was adjusted for the counterfactual by 35% for Q4 in 2022 and 53.75% for Q1 in 2023. The estimated price changes were taken from Ofgem's announcement letters of the price caps for both quarters. Importantly, this change only applied to the price of gas and electricity.

2.2. LCFS and Demand System Modelling (LES and QUAIDS)

The main models of interest were Demand Systems using the LES or QUAIDS approach. LES demand systems make eight important assumptions.

1. Goods are normal, meaning that demand increases as income increases if price does not change.
2. Prices are the same across households.

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[19] Note there are too few observations in the LCFS to estimate models outside the above three energy sources.

3. Homogeneity of degree zero, meaning that if all prices and incomes change by the same proportion, the quantities demanded by homes will remain the same. If the price of natural gas doubles, and incomes also double, homes can afford the same amount of natural gas as before the change.
4. Expenditures and shares "add up", meaning that the total expenditure on all goods and services equals the consumer's total income.
5. Rational consumer behaviour.
6. Linearity of expenditure, which refers to the functional form of the demand equations where total expenditure on each good is expressed as a linear function of prices and income.
7. Additive utility, meaning that total utility for a home is the sum of utilities obtained from consuming each good. This again assumes that all goods are normal and none are inferior. It also implies that all pairs of goods are substitutes (meaning they serve the same purpose for households as another good) and none are complementary (meaning goods do not add value to another good when consumed together).
8. The Marshallian own-price elasticity, which refers to how the quantity demanded of a good responds to changes in its price, holding other prices and income constant, is between -1 and 1.

These models were beneficial because they have a simple specification and linear Engel curves. LES models take the following form:

$$p_i q_i = p_i * \gamma_i + \beta_i(M - \sum_{j=1} p_i * \gamma_i)$$

Where,

p_i is the price of good i,

q_i is the quantity of good i,

γ_i is the basic need for good i,

β_i is the marginal propensity to spend on good i,

M is the total income, and

$\sum_{j=1} p_i * \gamma_i$ is the total expenditure on basic need.

In this model γ_i and β_i are parameters to be estimated.

QUAIDs demand systems hold many similar assumptions, except for the linearity of expenditure. These are listed below.

Prices are the same across households.

Homogeneity of degree zero, meaning that if all prices and incomes change by the same proportion, the quantities demanded by homes will remain the same. If the price of natural gas doubles, and incomes also double, homes can afford the same amount of natural gas as before the change.

Expenditures and shares "add up", meaning that the total expenditure on all goods and services equals the consumer's total income.

Rational consumer behaviour.

Instead of linearity of expenditure, the assumption in QUAIDs modelling is that the Slutsky matrix is symmetric and negative semi-definite. These assumptions are necessary for the demand system to be theoretically consistent.

These models have benefits because they allow for quadratic Engel curves, meaning goods can be normal, luxuries, or inferior goods over a range of incomes. Engel curves are graphs of how expenditure on a good varies by household income, and these are allowed a quadratic term in the QUAIDS approach. They take the following form:

$$w_i = a_i + \sum_{\mathrm{j=1}} \gamma_{ij} * \ln(p_j) + \beta_i * ln(\frac{M}{P}) + \frac{\lambda_i}{b(p)} * [ln(\frac{M}{P})]^2$$

Where,

w_i Expenditure share of good i,

a_i, γ_{ij}, β_i, and λ_i are parameters to be estimated,

p_j price of good j,

β_i is the marginal propensity to spend on good i,

M is the total income or total expenditure,

P is a price index

$b(p)$ is a price aggregator function

$\frac{\lambda_i}{b(p)} * [ln(\frac{M}{P})]^2$ is a function of the non-linear relationship between income and expenditure share, allowing for more complex Engel curves.

2.3. Comparison of price elasticities between Combined audit and NEED and the LCFS

Comparison of the analysis of the audit and NEED dataset with the LCFS suggested that LCFS does provide reliable estimates of own price elasticity (how much people change their energy buying habits when the price of energy changes) and predicted quantity of energy consumed, which provides external validity to the core LCFS analysis. Demand system models would have been challenging to perform with the audit and NEED dataset, since the income variable in the NEED data was time-invariant within the year. In addition, consistent data on prices and quantities expenditure on non-energy goods was unavailable, which prevented estimating cross-price elasticities or implementing the demand system models. However, by carrying out two approaches with two different datasets (Combined audit and NEED and LCFS), results for households with gas and electricity heating could be compared on the main parameters, e.g., own price and income elasticities, for which the two approaches gave reasonably similar results (see Table 2.1).

Table 2.1 Own Price and Income Elasticity for Gas and Electricity under different datasets and model specifications

Model	**LCFS, LES model**			**LCFS, QUAIDS model**			**Combined audit and NEED, Random Effects**		
Main source of heating	**Elasticity**	**SE**	**P-value**	**Elasticity**	**SE**	**P-value**	**Elasticity**	**SE**	**P-value**
Electricity (Q4 2021 - Q1 2023)	Income	0.42	0.05	0	0.23	0.07	0	0.09	0.02
Electricity (Q4 2021 - Q1 2023)	Price	-0.67	0.12	0	-0.5	0.23	0.03	-0.18	0.06
Gas (Q4 2021 - Q1 2023)	Income	0.39	0.01	0	0.24	0.02	0	0.07	0.01
Gas (Q4 2021 - Q1 2023)	Price	-0.57	0.02	0	-0.44	0.04	0	-0.46	0.06
Oil (Q4 2021 - Q1 2023)	Income	0.29	0.06	0	0.23	0.07	0	NA	NA
Oil (Q4 2021 - Q1 2023)	Price	-0.28	0.11	0.01	-0.04	0.19	0.85	NA	NA

Note: Electricity and gas consumption based on actual meter data provided from random sample of Combined audit and NEED for GB. Random sample of Gas meters = 158,143, model sample = 70,351. Random sample of Electricity meters = 236,500, model sample = 19,544. Oil consumption based on LCFS dataset at UK level.

2.4. Model Results for energy spend

This section summarises the output of model results, mainly the elasticities for income and price; as well as the predicted quantities and shares of goods consumed. It compares the actual figures with the energy affordability schemes, to the counterfactual in the absence of energy affordability schemes. The results show that energy affordability schemes had a positive effect; meaning they increased the quantity of goods consumed and lowered the share of spending devoted to energy.

A summary of the number of households available in the LCFS for analysis of each energy type is provided in Table 2.2 below. Importantly, the number of observations used in the model is slightly lower than the total number of available observations.

Table 2.2 Sample size in the LCFS data for gas, electricity, and oil heating households, for UK, GB and NI

LCFS data sample size	UK-wide	GB	NI
Gas heating households (N)	5,754	5,565	189
Electricity heating households (N)	469	462	7
Oil heating households (N)	645	298	347
Oil heating households (longer timeline, N)	1,855	973	882

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179. The figures in the table describe the observations, while the figures in the note describe the observations in the model .

Table 2.3 summarises the R^2 figure, or the portion of variance explained for each model. For models which considered electricity and gas heated households, the approach explained roughly 35% of the variance in goods consumed. For models which considered oil heated households, the approach explained roughly 53% if the variance in goods consumed. Because of the small sample of oil heated homes in the LCFS dataset between Q4 2021 and Q1 2023, the analysis of oil heated homes was expanded to a wider timeline (Q1 2019-Q1 2023). In general, the approach of adding more observations from earlier periods fit the data well, even given the limited sample for oil heated homes.

Table 2.3 R-Squared values for each model

Main source of central heating	LES	QUAIDS	Difference
Electricity (Q4 2021 - Q1 2023)	0.34	0.36	0.02
Gas (Q4 2021 - Q1 2023)	0.35	0.36	0.01
Oil (Q4 2021 - Q1 2023)	0.55	0.54	-0.01
Oil (Q1 2019-Q1 2023)	0.51	0.49	-0.02

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179.

Table 2.4 presents the predicted elasticities between household income and each energy type. It also presents the predicted elasticities between its price and each energy type. As expected, a change in income was associated with a positive change in energy consumed. For LES models of gas, a 1% increase in income was associated with a 0.39% increase in the consumption of gas. For LES models of electricity, a 1% increase in income was associated with a 0.42% increase in the consumption of electricity.

A change in price of energy was associated with a negative change in the quantity energy consumed (negative own price elasticities). For the LES gas model, a 1% increase in the price of natural gas was associated with a 0.57% decrease in the consumption of gas. For the LES electricity model, a 1% increase in the price of electricity was associated with a 0.67% decrease in the consumption of electricity.

Table 2.4 Elasticities between income and price for each energy group, by model

Model		LES			QUAIDS		
Main source of central heating		**Elasticity**	**SE**	**P-value**	**Elasticity**	**SE**	**P-value**
Electricity (Q4 2021 - Q1 2023)	Income	0.42	0.05	0.00	0.23	0.07	0.00
	Price	-0.67	0.12	0.00	-0.50	0.23	0.03
Gas (Q4 2021 - Q1 2023)	Income	0.39	0.01	0.00	0.24	0.02	0.00
	Price	-0.57	0.02	0.00	-0.44	0.04	0.00
Oil (Q4 2021 - Q1 2023)	Income	0.29	0.06	0.00	0.23	0.07	0.00
	Price	-0.28	0.11	0.01	-0.04	0.19	0.85
Oil (Q1 2019-Q1 2023)	Income	0.35	0.03	0.00	0.19	0.05	0.00
	Price	-0.53	0.04	0.00	-0.30	0.07	0.00

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179.

The LCFS provides data on energy consumption alongside data on income expenditure on other goods and services to estimate the proportion of energy consumed as part of a household's budget and wider bundle of good consumed. By combining energy spending with wider spending data, LCFS allows for prediction of how household's energy consumption behaviour responds to increases in prices, controlling for households' other budgetary consumption demands. The LCFS allows for analysis of energy burden, the proxy variable used for this analysis to investigate fuel poverty.

Table 2.5 shows the estimated quantity of the gas, electricity and oil consumed by households at the UK level over Q4 2022 and Q1 2023 (with the schemes) and predicted consumption in a no intervention scenario. Break downs of energy spend by scheme (UK-level), and GB vs NI level are provided in Tables 2.5 to 2.10.

The implication of this energy demand modelling of LCFS data[20] is that, in the absence of the energy affordability schemes:

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[20] The LCFS data allows estimation of the predicted share of household income on each energy type, with a comparison of the percentage point (p.p.) difference in predicted share of income in the actual compared to the

The average gas heated household in the UK would have seen a +2.9 percentage point greater share of income (before housing costs) being spent on gas, without the energy affordability scheme intervention.[21] As a result, the energy affordability scheme contributed to a reduction of £195.44 on gas expenditure per household over the intervention period (Q4 2022 and Q1 2023) compared to the counterfactual.

The average electricity heated household in the UK would have seen a +2.1 percentage point greater share of income being spent on electricity, without the energy affordability scheme intervention.[22] The energy affordability scheme resulted in a reduction of £132.70 on electricity expenditure per household over the intervention period compared to the counterfactual.

- The oil expenditure model estimates a +1.2 percentage point greater share of income being spent on oil in a scenario without the energy affordability schemes.
- The implication of LCFS modelling is that, due to the energy affordability schemes, the average household was able to spend between £133 and £195 less on energy over the period that the energy affordability schemes were in place, while being better able to avoid reducing their consumption of energy, compared to a counterfactual with no intervention.

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counterfactual scenario. Percentage changes in weekly expenditure provided in the LCFS dataset are then used to estimate the impact in monetary terms.

[21] For comparison with the combined audit and NEED data, LCFS modelling predicts that gas heated households in the UK would have reduced their energy consumption by 16%, which is lower than the audit and NEED data reported in Section 4.1 (25% in the case of gas heating homes).

[22] LCFS modelling predicts that electricity heated households in the UK would have reduced their energy consumption by 21%, which is closely comparable to the administrative data reported in Section 4.1 (25% in the case of gas heating homes and 26% in the case of electricity heating homes).

Table 2.5 Energy demand modelling results for gas, electricity and oil heated households in the UK (LCFS Q4 2022- Q1 2023)

	Actual: Intervention	Counterfactual No Intervention	Difference (actual – counterfactual)
Gas heating homes			
Predicted Quantity (implicit quantities indexed to energy prices in period)	26.30	22.00	-16.3%
Predicted share of total income spent (p.p.)	9.2	12.1	2.9 p.p.
Spending (weekly £)	£36.42	£43.94	-£7.52
Spending (intervention period £) Q4 2022- Q1 2023	£946.95	£1,142.40	-£195.44
Electricity heating homes			
Predicted Quantity (implicit quantities indexed as for gas)	29.41	23.37	-20.6%
Predicted share of total income spent (p.p.)	8.7	10.8	2.1 p.p.
Spending (weekly £)	£35.69	£40.79	-£5.10
Spending (intervention period £) Q4 2022- Q1 2023	£927.93	£1,060.64	-£132.70
Oil heating homes			
Predicted Quantity (implicit quantities indexed as for gas)	40.70	40.16	Figure
Predicted share of total income spent (p.p.)	11.0	12.2	1.2 p.p.
Spending (weekly £)	£40.01	£39.48	+£0.53
Spending (intervention period £) Q4 2022- Q1 2023	£1,040.26	£1,026.48	+£13.78

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179. LCFS only provides data on how much households spent on energy, which must then be 'reverse-engineered' into a quantity index by using ONS national statistics on energy prices in the period. No data for EPG effect on oil households, which were only eligible for the EBSS and AF payment scheme.

Table 2.6 Energy demand modelling results split by EBSS and EPG for gas, electricity and oil heated households in the GB and NI (LCFS Q4 2022- Q1 2023)

	EBSS			EPG		
	Actual: Intervention	Counterfactual: No Intervention	Difference (actual – counterfactual)	Actual: Intervention	Counterfactual: No Intervention	Difference (actual – counterfactual)
Gas						
Predicted Quantity (LES model) (implicit quantities indexed to energy prices in period)	26.30	26.03	1.01%	26.30	22.24	-15.41%
Predicted share of total income spent (p.p.)	9.24	9.70	-0.45 p.p.	9.24	11.41	-2.16 p.p.
Spending difference (weekly £)	£36.42	£36.05	£0.37	£36.42	£44.36	-£7.94
Spending (intervention period £) Q4 2022- Q1 2023	£946.95	£937.39	+£9.56	£946.95	£1,153.39	-£206.43
Electricity						
Predicted Quantity (LES model) (implicit quantities indexed to energy prices in period)	29.41	29.00	-1.38%	29.41	23.65	-19.59%

	EBSS			EPG		
Predicted share of total income spent (p.p.)	8.71	9.14	-0.43 p.p.	8.71	10.27	-1.56 p.p.
Spending (weekly £)	£35.69	£35.20	£0.49	£35.69	£41.29	-£5.60
Spending (intervention period £) Q4 2022- Q1 2023	£927.93	£915.15	£12.79	£927.93	£1,073.42	-£145.49
Oil (only eligible for EBSS AFP)						
Predicted Quantity (LES model) (implicit quantities indexed to energy prices in period)	40.69	40.15	1.33%	NA	NA	NA
Predicted share of total income spent (p.p.)	11.03	12.24	-1.21 p.p.	NA	NA	NA
Spending (weekly £)	£40.01	£39.48	£0.53	NA	NA	NA
Spending (intervention period £) Q4 2022- Q1 2023	£1,040.26	£1,026.48	+£13.78	NA	NA	NA

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409;.

Table 2.7 Energy demand modelling results for gas and electricity heated households in the GB and NI (LCFS Q4 2022- Q1 2023)

	GB only			NI only		
	Actual: Intervention	Counterfactual: No Intervention	Difference (actual – counterfactual)	Actual: Intervention	Counterfactual: No Intervention	Difference (actual – counterfactual)
Gas heating households						
Predicted Quantity (LES model) (implicit quantities indexed to energy prices in period)	26.5	22.2	-16.17%	22.0	18.9	-14.35%
Predicted share of total income spent (p.p.)	9.32	12.21	-2.89 p.p.	7.62%	9.63%	-2.01 p.p.
Spending (weekly £)	£36.70	£44.30	-£7.50	£30.50	£35.20	-£4.60
Spending (intervention period £) Q4 2022- Q1 2023 (LCFS)	£954.20	£1,151.80	-£195.00	£793.00	£915.20	-£119.60
Electricity: GB only (NI unavailable due to sample size constraints)						
Predicted Quantity (LES model) (implicit quantities indexed to energy prices in period)	29.46	23.39	-20.60%	NA	NA	NA

GB only			NI only			
Predicted share of total income spent (p.p.)	8.7	10.8	-2.1 p.p.	NA	NA	NA
Spending (weekly £)	£35.75	£40.84	-£5.10	NA	NA	NA
Spending (intervention period £) Q4 2022- Q1 2023	£929.52	£1,061.80	-£132.60	NA	NA	NA

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179. Note: Oil not available at NI split due to low sample size. Sample size for oil households is too low at GB and NI level to include in Tables 2.7 to 2.9.

Table 2.8 Percentage change in weekly expenditure: Actual to counterfactual- - Gas Heated Homes, Northern Ireland

Predicted Quantity	Actual	Counterfactual	Difference (Actual - Counterfactual)	Difference in Share (Actual Share - Counterfactual share)
Food, water, and health	£84.1	£81.1	£3.3	-0.6%
Alcohol, narcotics, and recreation	£146.0	£136.1	£10.5	1.4%
Communication, transport, and education	£149.3	£139.7	£10.3	1.3%
Rent and housing without energy	£63.8	£60.5	£3.5	<0.1%
Gas	£30.5	£35.2	-£4.6	-2.1%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179. Note: Oil not available at NI split due to low sample size. Sample size for oil households is too low at GB and NI level to include in Tables 2.7 to 2.9.

Table 2.9 Percentage change in weekly expenditure: Actual to counterfactual - by EBSS vs EPG schemes, GB, LES model

	EBSS				EPG			
Predicted Quantity	**Actual**	**Counter-factual**	**Difference (Actual – C'factual)**	**Difference in Share (Actual Share – C'factual share)**	**Actual**	**Counter-factual**	**Difference (Actual – C'factual)**	**Difference in Share (Actual Share – C'actual share)**
Gas heated homes								
Food, water, and health	£81.1	£79.5	£1.8	-0.4%	£81.1	£80.3	£0.9	0.3%
Alcohol, narcotics, and recreation	£160.5	£155.4	£5.7	0.6%	£160.5	£158.0	£3.0	0.9%
Communication, transport and education	£161.2	£156.2	£5.6	0.5%	£161.2	£158.8	£3.0	0.8%
Rent and housing without energy	£67.1	£65.3	£1.9	-0.1%	£67.1	£66.2	£1.0	0.3%
Gas	£36.7	£36.3	£0.4	-0.5%	£36.7	£44.7	-£8.0	-2.2%
Electricity heated homes								
Food, water, and health	£73.6	£72.3	£1.4	-0.5%	£73.6	£73.1	£0.5	0.1%
Alcohol, narcotics, and recreation	£130.5	£126.0	£4.4	0.3%	£130.5	£128.8	£1.7	0.5%

Communication, transport, and education	£139.1	£134.5	£4.7	0.3%	£139.1	£137.4	£1.7	0.5%
Rent and housing without energy	£129.0	£124.6	£4.4	0.3%	£129.0	£127.3	£1.7	0.5%
Electricity	£35.8	£40.8	-£5.1	-2.1%	£35.8	£41.3	-£5.6	-1.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179. Note: Oil not available at NI split due to low sample size. Sample size for oil households is too low at GB and NI level to include in Tables 2.7 to 2.9.

Table 2.10 below, shows that:

- spending on energy as a share of household income would have been higher across all income deciles in the absence of the energy affordability schemes.
- The proportion of household income spent on energy with and predicted to be spent without the energy affordability schemes (i.e. in the actual and counterfactual scenarios) is higher the lower down the income distribution.
- The biggest predicted differences in proportion of household income spent on energy between the actual and counterfactual scenarios are at the lower income deciles.

This is in part expected, due to the fact that energy is an essential commodity which takes up a higher proportion of lower household incomes.

Table 2.10 Share of spending by household income decile for gas, electricity and oil heated households UK-wide (LCFS Q4 2022- Q1 2023)

	Gas heated homes (UK)			Electricity heated homes (UK)			Oil heated homes (UK)		
Income decile	Actual	Counterfactual	Difference	Actual	Counterfactual	Difference	Actual	Counterfactual	Difference
Lowest	19.3%	28.6%	-9.3 p.p.	17.0%	23.9%	-6.9 p.p.	23.5%	28.8%	-5.3 p.p.
2	12.9%	17.6%	-4.7 p.p.	11.8%	15.1%	-3.3 p.p.	13.2%	14.2%	-1.0 p.p.
3	11.1%	14.7%	-3.6 p.p.	10.3%	12.9%	-2.6 p.p.	9.7%	10.2%	-0.5 p.p.
4	9.6%	12.5%	-2.9 p.p.	9.1%	11.1%	-2.0 p.p.	7.5%	7.7%	-0.2 p.p.
5	8.8%	11.3%	-2.5 p.p.	8.4%	10.3%	-1.9 p.p.	NA	NA	NA
6	8.1%	10.2%	-2.1 p.p.	7.8%	9.4%	-1.6 p.p.	NA	NA	NA
7	7.4%	9.3%	-1.9 p.p.	7.3%	8.7%	-1.4 p.p.	NA	NA	NA
8	6.6%	8.1%	-1.5 p.p.	6.6%	7.6%	-1.0 p.p.	NA	NA	NA
9	6.0%	7.3%	-1.3 p.p.	6.1%	7.0%	-0.9 p.p.	NA	NA	NA
Highest	4.9%	5.7%	-0.8 p.p.	5.1%	5.6%	-0.5 p.p.	5.3%	5.4%	-0.1 p.p.
Total	9.2%	12.1%	-2.9 p.p.	8.7%	10.8%	-2.1 p.p.	11.0%	12.2%	-1.2 p.p.

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179. Total expenditure is treated as a measure of total income, assuming that all income is spent (more specifically, it assumes that households do not save and do not borrow to cover spending). NA due to low sample size.

Annex 3. Fuel Poverty and Energy Burden

Definition of Fuel Poverty/Energy Burden

The energy affordability schemes were designed in response to a sharp increase in energy prices, which resulted in higher household energy tariffs and bills. This increase presented a risk that energy would become unaffordable to many households without support and increase rates of fuel poverty. It is therefore important to measure the extent to which the energy affordability schemes improved affordability of energy bills and helped avoid fuel poverty relative to the counterfactual of no intervention. Fuel poverty is challenging to assess as it is defined differently in each of the nations of the UK:

- In England if they live in a house that has a Fuel Poverty Energy Efficiency Rating below band D and if after subtracting their energy and housing costs their residual income is below the poverty line.[23]
- In Wales and Northern Ireland if their required fuel costs are at least 10% of their income before housing costs.
- In Scotland if both a) after housing costs, the total fuel costs needed to maintain a satisfactory heating regime are more than 10% of the household's adjusted net income and b) if, after deducting fuel costs, housing costs, benefits received for a care need or disability, and childcare costs, the household's remaining adjusted net income is insufficient to maintain an acceptable standard of living.[24]

Across all common definitions, the main factors driving fuel poverty (aside from energy efficiency of the home) are household income and energy prices. If, compared to the counterfactual scenario of no energy support, the energy affordability schemes can be seen to have reduced household expenditure on energy, or made the cost of heating homes to an adequate level more affordable relative to households' incomes, then this suggests they did limit the increase in fuel poverty that would have occurred if the energy crisis had been unmitigated.

One way of assessing this is through the measure of energy burden, or the share of income a household spends on its energy needs, which is commonly used as a measure of energy affordability.[25] In this evaluation, the working definition of fuel poverty is indicated by energy

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[23] England is the only nation to include a property's energy efficiency as part of its definition. This means that households with high energy efficiency in their homes are not identified as fuel poor. Scotland and England also have requirements so that higher income households are not identified as fuel poor: How fuel poverty is measured in the UK: March 2023

[24] Applying each nation's definition, the number of households living in fuel poverty is: 3.17m in England across 2023, accounting for 13% of all households; 196,000 in Wales across 2021, accounting 14% of all households; 791,000 in Scotland across 2022, accounting 31% of all households; 179,000 in Northern Ireland across 2021, accounting 24% of all households. Fuel poverty modelled estimates for Wales: as at October 2021, here and Estimates of fuel poverty in Northern Ireland in 2020+2021, respectively

25 Nock, D., Jones, A. J., Bouzarovski, S., Thomson, H., & Bednar, D. J. (2024). Reducing energy burden in the power sector: Metrics for assessing energy poverty. IEEE Power and Energy Magazine, 22(4). Accessible

burden. Specifically, households using more than 10% of their total disposable income (after housing costs) on energy being defined as being under energy burden, and therefore likely to be in fuel poverty.

Energy Burden analysis in LCFS

As previously mentioned, energy burden is defined as an instance where more than 10% of a household's after-housing-cost disposable income or expenditure goes towards energy and fuel. In order to assess the impact of the interventions, energy burden was calculated twice: once with the energy affordability schemes (actual) and once without (modelled counterfactual). The first rate considered total energy expenditure, expressed as a portion of total expenditure less housing cost. This rate is referred to as the actual level of energy burden.

$$\frac{X_{fuel}}{Totex - X_H}$$

Where,

X_{fuel}- is the household's weekly spend on energy/fuel

$Totex$ – is the household's weekly total expenditure

X_H – is the household's total weekly expenditure on housing costs (includes rent, mortgage repayments, council tax, service charge etc. but minus unrelated costs like rubbish disposal).

This ratio was used to create a binary measure of energy burden; homes that paid more than 10% of their total expenditure after housing costs to energy were classified as in energy burden; homes that paid less than 10% of their total expenditure after housing costs to energy were classified as not in energy burden. Since the actual expenditure data during the intervention period will have been impacted by the interventions, to estimate the impact a measure of energy burden that removes the energy affordability schemes (counterfactual) had to be considered. Specifically,

$$\frac{(X_{fuel} - w_e Totex)(Totex' - X_H) + w_e{}' Totex'(Totex - X_H)}{(Totex - X_H)(Totex' - X_H)}$$

Where,

X_{fuel}- is the household's weekly spend on energy

w_e – is the household's predicted share of weekly expenditure devoted to energy (estimated on our demand systems models)

$w_e{}'$ – is the household's counterfactual-predicted share of weekly expenditure devoted to energy (estimated in our demand systems models)

$Totex$ – is the household's weekly total expenditure

$Totex'$ - is the household's counterfactual weekly total expenditure. For gas and electricity heated households in Great Britain, this measure is $(Totex - (\frac{£400}{26}))$. For oil heated households or households in the Northern Ireland, this measure is $(Totex - (\frac{£600}{26}))$

X_H – is the household's total weekly amount spent on housing costs minus unrelated costs such as rubbish disposal.

To implement this measure, the analysis relied on the data analysis and models estimated from the LCFS and demand system models, which are described in Annex A2.2 above. As noted, LCFS contained the needed data on housing and related costs and expenditures. For example, the households weekly spend on energy in the actual and counterfactual scenario were first estimated using LES and QUAIDS, before being used in the estimates below.

Models using demand systems were estimated for each fuel type: gas, electricity and oil/liquid fuel from LCFS. Two types of demand system models were used, namely, the linear expenditure system (LES) and QUAIDS (Quadratic Almost Ideal Demand System)[26]. LCFS contained an indicator variable whether the primary heating source was gas, electricity or oil/liquid fuel, and separate models were estimated for each of these household types. More granular estimates for fuel types such as solid fuel and wood, etc, were not possible due to small subsample numbers.

The demand system approach allowed to predict expenditures and expenditure shares by category, and thus the overarching approach was to calculate the energy burden indicator for each household in the sample, estimate the models and predict the expenditure patterns in the absence of the energy affordability schemes and recalculate the energy burden measure for the counterfactual, thus producing estimates of energy burden with and without the energy affordability schemes. As LCFS also contained many demographic variables and was nationally representative, estimates of impacts on subgroups for main groups could be made, such as by income or expenditure decile, house tenure type, and region, etc. While the LCFS pooled sample over time included many thousand observations, a single year contains only c. 5,000 observations and then the intervention period roughly half of that. Given that models were run for specific fuel types, and the results of these were further divided by demographic groups, this led to certain issues with cell/sample sizes. As a result, the estimates presented here for more detailed demographic subcategories should only be viewed as indicative and not statistically robust. Importantly, this report does not present results for cross-tab cells with fewer than 10 observations. This limitation mostly applies to oil heated homes, although there was enough data to estimate elasticities and some measures of energy burden.[27]

The sections below present the findings on energy burden analysis for three different energy types. The hypothesis states "the schemes contributed towards limiting the increase in the proportion of households experiencing fuel poverty", while the evaluation question states "to

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[26] In our previous work on the interim report, we studied a variety of models including Translog and AIDS. The LES and QUAIDS models nest these models between them.

[27] Oil-heated homes in the UK are <10% of the total and the energy support schemes were only for ½ the year, and the total sample size per year is circa 5,000.

what extent have the domestic schemes limited the breadth and depth of fuel poverty compared to a ‘no intervention’ scenario?” For the results presented here LES is the preferred model because LES is more restrictive, in that it requires the assumption that all goods would be normal and have elasticities within expected ranges from the literature.

3.1. Gas Heated Homes

This section considers only homes heated primarily by gas. Considering the intervention period, Table 3.1 shows there was an energy burden rate of 44% when the energy affordability schemes were in place. When considering the counterfactual, an increase in energy burden was noticeable. In the LES counterfactual, the energy burden was 60%.

Table 3.1 Gas Heated Homes- Energy Burden by Survey Year: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Survey Year	LES estimates		
	Actual	Counterfactual	Differential
2022	37.8%	52.2%	-14.4%
2023	49.8%	68.6%	-18.8%
Total	43.8%	60.4%	-16.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households

Table 3.2 and Figure 3.1 present this difference by income decile. There are three trends worth noting explicitly. First, the actual energy burden rate differed by income decile, with lower earners showing higher rates of energy burden (79% for the lowest decile and 8% for the highest). Second, in all cases the counterfactual rate was higher for each decile, suggesting that all deciles benefitted from energy affordability schemes measures in some way. Third, the differential (Figure 3.2) showed that low- and middle-income homes were the most likely to benefit from the energy affordability schemes, when compared to higher-income homes. In this way, the energy affordability schemes were most beneficial to low- and middle-income homes.

Table 3.2 Gas Heated Homes- Energy Burden by Income Decile: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Income Deciles	LES estimates		
	Actual	Counterfactual	Differential
Lowest	79.6%	97.8%	-18.2%
2	75.3%	96.8%	-21.5%
3	68.0%	87.6%	-19.6%
4	52.6%	76.6%	-24.0%
5	50.3%	71.1%	-20.8%
6	40.5%	61.3%	-20.8%
7	41.7%	58.3%	-16.6%
8	19.1%	33.7%	-14.6%
9	19.7%	28.1%	-8.4%
Highest	8.9%	14.2%	-5.3%
Total	43.8%	60.4%	-16.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179 households.

Figure 3.1 Gas Heated Homes - Energy Burden by Income Decile: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

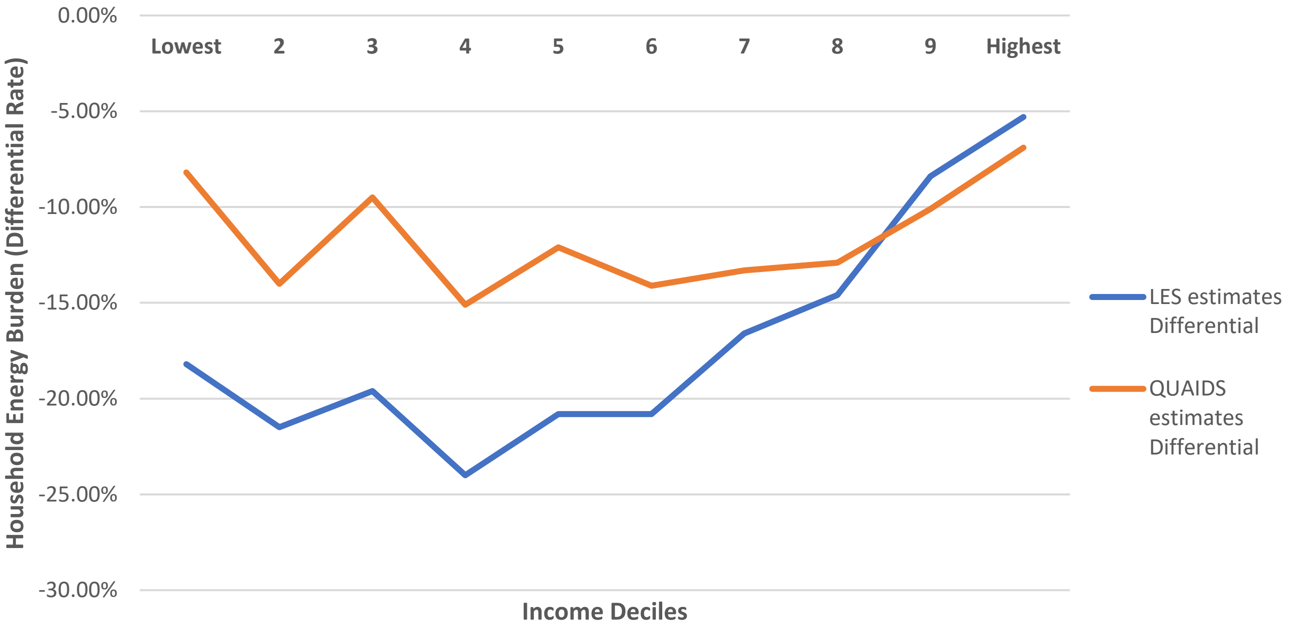

Figure 3.2 Energy burden by income Decile: Actual and Counterfactual

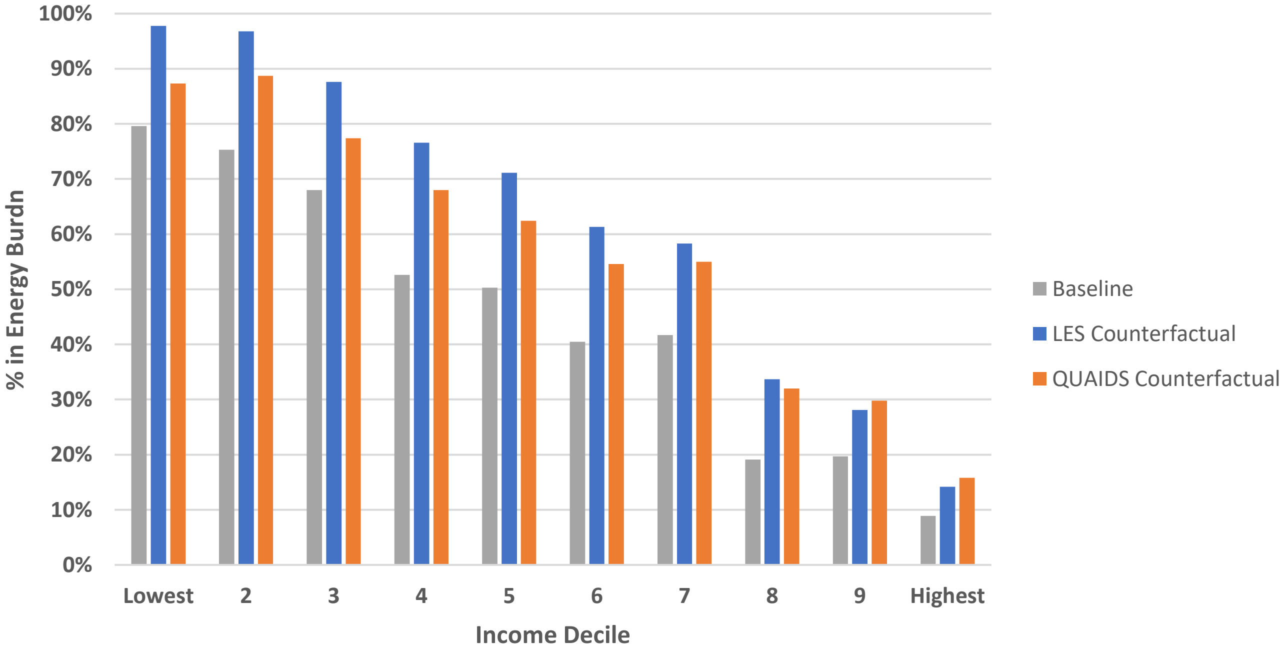

Table 3.3 shows the share of homes which avoided energy burden with the help of the energy affordability schemes. 39% of homes were not in energy burden with or without the energy affordability schemes, while 43% would have remained in energy burden both with and without the energy affordability schemes. However, 16% of homes would have been in energy burden without the energy affordability schemes, but were not in energy burden once the energy affordability schemes were considered. Although this rate is higher for low earning households,

in every decile some portion of people avoided going into energy burden, although this was the least common outcome for any given decile.

Table 3.3 Gas Heated Homes- Avoidance of Energy Burden by Income

Income Deciles	LES estimates		
	Remained out of energy burden	Remained in energy burden	Avoided energy burden
Lowest	2.2%	79.6%	18.2%
2	3.2%	75.3%	21.4%
3	12.4%	68.0%	19.5%
4	23.4%	52.6%	24.0%
5	28.9%	50.3%	20.8%
6	38.7%	40.5%	20.9%
7	41.7%	41.7%	16.7%
8	66.3%	19.1%	14.6%
9	71.9%	19.7%	8.4%
Highest	85.8%	8.9%	5.3%
Total	39.6%	43.8%	16.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households

Heterogenous analysis: Gas

Table 3.4 shows regional differences in energy burden for the actual and counterfactual scenarios. With the schemes, energy burden among gas heated homes was most common in Urban Scotland (48%) and least common in Northern Ireland (32%). The estimates suggest that without energy affordability schemes, energy burden would have been higher. Differential values suggest that all regions benefitted from the energy affordability schemes. Rural Scotland reported the highest differential (27%) and Rural England and Wales reported the lowest differential (14%).

Table 3.4 Gas Heated Homes- Energy Burden by Urban-Rural: Differential effects between actual (with energy affordability schemes) and counterfactual (without energy affordability schemes)

Urban-Rural	LES estimates		
	Actual	Counterfactual	Differential
England Wales - Urban	44.8%	61.6%	-16.8%
England Wales - Rural	38.9%	53.1%	-14.2%
Scotland - Urban	47.9%	62.9%	-15.0%
Scotland - Rural	45.5%	72.7%	-27.2%
Northern Ireland	32.0%	49.3%	-17.3%
Total	43.8%	60.4%	-16.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households.

Table 3.5 considers the share of homes which avoided energy burden after energy affordability schemes. The rate of people who were in energy burden despite the schemes was highest in Urban Scotland (47%) and lowest in Northern Ireland (32%). Meanwhile the rate of people who avoided energy burden with the energy affordability schemes was highest in Urban Scotland (27%) and lowest in Rural England and Wales (14%). Lastly, the rate of people who would not have been affected by energy burden in either scenario was highest in Northern Ireland (51%). Note that according to the NI Census data, 50% of households use oil as their only central heating, followed by 31.6% using mains gas, 15% using two or more types of central heating, and 1.6% using electric only.

Each region benefitted from schemes to some degree. However, the least common outcome for all regions was for a household that would have been in energy burden without the schemes to avoid it with them. In each group the most common outcome was either to remain out of energy burden, or to remain in energy burden, regardless of the schemes.

Table 3.5 Gas Heated Homes- Avoidance of Energy Burden by Urban-Rural

Urban-Rural	LES estimates		
	Remained out of energy burden	Remained in energy burden	Avoided energy burden
England Wales - Urban	38.4%	44.8%	16.7%
England Wales - Rural	46.9%	38.9%	14.2%
Scotland - Urban	37.1%	47.9%	15.0%
Scotland - Rural	27.3%	45.5%	27.3%
Northern Ireland	50.7%	32.0%	17.3%
Total	39.6%	43.8%	16.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179.

Table 3.6 lists these measures by tenure status. There are three trends are worth noting. First, there were differences between tenure types in actual energy burden, which was most common in social housing (58%). This result was expected, given that occupants in social housing often have low incomes and limited access to the labour market. Actual energy burden was also high for people in private rented accommodation (52%), but lowest in owned homes with a mortgage (33%). Second, for all groups, there was a higher rate of energy burden without energy affordability schemes. This rate was particularly high for social housing occupants and those in the private rented sector. Third, the differential suggests that those in social housing and those who own their home with a mortgage benefitted the most from energy affordability schemes.

Table 3.6 Gas Heated Homes- Energy Burden by Tenure: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Tenure type - harmonised	LES estimates		
	Actual	Counterfactual	Differential
Social Housing or Associations	58.3%	76.5%	-18.2%
Private rented	52.1%	68.2%	-16.1%
Owned with Mortgage or Rental Purchase	33.3%	51.2%	-17.9%
Owned Outright	44.1%	58.9%	-14.8%
Total	43.8%	60.4%	-16.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households.

Table 3.7 considers tenure differences in the rate of homes which avoid energy burden due to energy affordability schemes. People who own their home with a mortgage were the most likely to avoid energy burden in either scenario, while those in social housing were the least likely to avoid energy burden. When considering homes that remained in energy burden despite energy affordability schemes, most people in social housing fit into this category (58% of homes) while those who owned their own home with a mortgage were the least likely to fit into this category (33%). Finally, when considering households who avoided energy burden because of energy affordability schemes, those in social housing tenancies and those who own their home benefitted the most from energy affordability schemes. The number of households in energy burden is higher for those who own their home outright, compared to those with a mortgage or rental purchase, which may be explained by the older age on average of those who own their homes outright (typically those who have spent 20-30 years paying off a mortgage).

Table 3.7 Gas Heated Homes- Avoidance of Energy Burden by Tenure

Tenure type - harmonised	LES estimates		
	Remained out of energy burden	**Remained in energy burden**	**Avoided energy burden**
Social Housing or Associations	23.5%	58.3%	18.2%
Private rented	31.8%	52.1%	16.1%
Owned with Mortgage or Rental Purchase	48.8%	33.3%	17.9%
Owned Outright	41.1%	44.1%	14.8%
Total	39.6%	43.8%	16.6%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households.

In sum, the schemes limited the increase in the proportion of households experiencing energy burden. The effect was found across the income distribution, the regional categories, and across tenure types. However, the analysis found that certain groups (like lower- and middle-income homes) benefitted more than others (high income homes).

Although there was a positive effect in the energy affordability schemes, it is important to note that many homes remained in energy burden despite energy affordability schemes, and these homes were more common than the number of homes which avoided energy burden thanks to the schemes. Despite this, it is likely that homes which were in energy burden either with or without the schemes, would have experienced far higher energy burden without the schemes considered here.

3.2. Electricity heated homes

This section considers the rate of energy burden in electricity-heated homes. Considering the intervention period, there was an energy burden rate of 41% with the schemes. For the counterfactual (no energy affordability schemes), there was an energy burden rate of 54% in both models. These estimates suggest there is a 13% percentage point difference in energy burden rates with the energy affordability schemes in place.

Table 3.8 Electricity Heated Homes- Energy Burden by Year: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Survey Year	LES estimates		
	Actual	**Counterfactual**	**Differential**
2022	37.9%	48.2%	-10.3%
2023	44.6%	60.2%	-15.6%
Total	41.2%	54.2%	-13.0%

Source: LCFS, based on LES model. Sample size for Electricity = 409 households

There are three key trends shown in Table 3.9. First, there were large differences between income groups in energy burden with the schemes, with high earners having progressively lower burden rates (80% for the lowest income decile and 8% for the highest income decile) when moving up the income distribution. Second, there were similar differences between income groups in counterfactual energy burden rates and, as shown in the previous table, these were consistently higher than the stress rate with the schemes. Third, the differential was greater for lower- and middle-income groups, when compared to higher income groups.

Table 3.9 Electricity Heated Homes- Energy Burden by Income Decile: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Income Deciles	LES estimates		
	Actual	Counterfactual	Differential
Lowest	80.6%	95.7%	-15.1%
2	71.9%	90.6%	-18.7%
3	65.7%	80.7%	-15.0%
4	49.5%	67.5%	-18.0%
5	46.5%	61.0%	-14.5%
6	37.1%	55.4%	-18.3%
7	33.8%	47.6%	-13.8%
8	18.3%	25.8%	-7.5%
9	17.4%	24.9%	-7.5%
Highest	8.3%	12.2%	-3.9%
Total	41.2%	54.2%	-13.0%

Source: LCFS, based on LES model. Sample size for Electricity = 409 households

Table 3.10 shows that 45% of people who heat their homes with electricity would not have been affected by energy burden in the counterfactual scenario or with energy support. However, a similar rate of people would have been affected by energy burden on with or without support (41%). There were additional differences between income deciles. In the first five deciles (the lower income half), remaining in energy burden was the most common outcome. Looking at the next five deciles (the upper half), avoiding energy burden was the most common outcome. Although it was more frequent that people stayed in energy burden or would never have been in energy burden according to the modelling, avoiding energy burden due to the schemes was more common among lower income deciles.

Table 3.10 Electricity Heated Homes- Avoidance of Energy Burden by Income Decile

Income Deciles	LES estimates		
	Remained out of energy burden	**Remained in energy burden**	**Avoided energy burden**
Lowest	4.3%	80.5%	15.2%
2	9.4%	71.9%	18.8%
3	19.3%	65.7%	15.0%
4	32.5%	49.5%	18.0%
5	39.0%	46.5%	14.4%
6	44.6%	37.1%	18.3%
7	52.4%	33.8%	13.8%
8	74.2%	18.3%	7.5%
9	75.1%	17.4%	7.5%
Highest	87.8%	8.3%	3.9%
Total	45.8%	41.2%	13.0%

Source: LCFS, based on LES model. Sample size for Electricity = 409 households

Heterogenous analysis: Electricity

Table 3.11 shows the regional differences for electrically heated homes in energy burden for the actual and counterfactual. energy burden was more common in Scotland (46%) but least common in Northern Ireland (24%). Once again, the counterfactual energy burden rate suggests that without energy affordability schemes energy burden would have been much higher, with rates of 62% in rural Scotland, and 41% in Northern Ireland. Differential values suggest that all regions benefitted from energy affordability schemes. Northern Ireland reports the highest differential (17%) and Rural England and Wales report the lowest differential (10%), but in general, the schemes benefitted all regions to some degree, suggesting all regions were “included” in the benefits.

Table 3.11 Electricity Heated Homes- Energy Burden by Region: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Urban-Rural	LES estimates		
	Actual	Counterfactual	Differential
England Wales - Urban	44.0%	57.3%	-13.3%
England Wales - Rural	36.5%	46.5%	-10.0%
Scotland - Urban	46.4%	57.5%	-11.1%
Scotland - Rural	46.9%	61.5%	-14.6%
Northern Ireland	23.8%	41.1%	-17.3%
Total	41.2%	54.2%	-13.0%

Source: LCFS, based on LES model. Sample size for Electricity = 409 households

Table 3.12 shows that in rural England and Wales, as well as Northern Ireland, most homes were not and would not have been in energy burden. In urban England and Wales, as well as urban and rural Scotland most homes were in energy burden. In every region, the least common outcome was of homes moving out of energy burden due to energy affordability schemes. However, note that each region experienced the benefits from the schemes.

Table 3.12 Electricity Heated Homes- Avoidance of Energy Burden by Region

Urban Rural	LES estimates		
	Remained out of energy burden	**Remained in energy burden**	**Avoided energy burden**
England Wales - Urban	42.7%	44.0%	13.3%
England Wales - Rural	53.5%	36.5%	10.0%
Scotland - Urban	42.5%	46.4%	11.2%
Scotland - Rural	38.5%	46.9%	14.6%
Northern Ireland	58.9%	23.8%	17.3%
Total	45.8%	41.2%	13.0%

Source: LCFS, based on LES model. Sample size for Electricity = 409 households

Table 3.13 considers energy burden rate differences by tenure, showing three trends. As before, there were differences in energy burden with the schemes. The proportion was highest in social housing (60%), and lowest in owned homes with a mortgage or rental agreement (30%). Those in private rented accommodation had above average rates of energy burden (46%), while people who own their home outright (41%) had average levels of energy burden. As with other tables, the counterfactual rate of energy burden was higher in the table below, suggesting energy burden would have been more common without energy affordability schemes. Further, the differential figure suggests that people in social housing benefitted most from the energy affordability schemes.

Table 3.13 Electricity Heated Homes- Energy Burden by Tenure: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Tenure type - harmonised	LES estimates		
	Actual	Counterfactual	Differential
Social Housing or Associations	60.0%	76.1%	-16.1%
Private rented	46.0%	58.9%	-12.9%
Owned with Mortgage or Rental Purchase	30.5%	44.0%	-13.5%
Owned Outright	41.5%	52.8%	-11.3%
Total	41.2%	54.2%	-13.0%

Source: LCFS, based on LES model. Sample size for Electricity = 409 households

Table 3.14 considers these differences further by showing that energy burden was most common in social housing (59%) but less common in homes that are owned outright with a mortgage or purchase agreement (30%). Despite this**,** homes of all tenure types benefitted from measures, in that each tenure category contains homes which avoided energy burden. According to LES estimates, the tenure type with the highest proportion of people avoiding energy burden due to the energy affordability schemes was Social Housing.

Table 3.14 Electricity Heated Homes- Avoidance of Energy Burden by Tenure

Tenure type - harmonised	LES estimates		
	Remained out of energy burden	Remained in energy burden	Avoided energy burden
Social Housing or Associations	23.9%	59.9%	16.2%
Private rented	41.1 %	46.0%	12.9%
Owned with Mortgage or Rental Purchase	56.0%	30.5%	13.6%
Owned Outright	47.2%	41.5%	11.3%
Total	45.8%	41.2%	13%

Source: LCFS, based on LES model. Sample size for Electricity = 409 households

This section summarised the effects of energy affordability schemes on energy burden in homes heated by electricity. It presented evidence showing that the schemes limited the increase in the proportion of households experiencing energy burden. The effect was found across the income distribution, across regional categories, and across tenure types. Although certain groups (such as lower- and middle-income homes) benefitted more than others (high income homes), the analysis found benefits in all categories considered.

As with the previous section despite a positive effect in energy affordability schemes, it is important to note that energy burden was still prevalent despite the support. Homes which remained in energy burden were more common than the number of homes which avoided energy burden due to the schemes. Despite this, it is likely that homes which remained in energy burden, would have experienced far worse stress without support considered here.

3.3. Oil heated homes

This section focuses on oil heated homes and their rate of energy burden. The number of homes heated exclusively using oil in the data was small, and focusing only on the intervention period limited the number of observations to 158. As a result, many of the cells presented in this section are omitted (cells with less than 10 observations are not presented).

Considering the intervention period, there was an energy burden rate of 55% with the schemes. When considering the counterfactual with no energy affordability schemes, there was a rate of 59%. Estimates suggest that these reduced energy burden by 3.8%. in both LES.

This suggests that most oil heated homes were in energy burden (55%), although the rate would have been higher without energy affordability schemes (59%).

Table 3.15 Oil Heated Homes- Energy Burden by Year: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Survey Year	LES estimates		
	Actual	Counterfactual	Differential
2022	53.7%	56.1%	-2.4%
2023	57.9%	63.2%	-5.3%
Total	55.7%	59.5%	-3.8%

Source: LCFS, based on LES model. Sample size for Oil=1,179 households.

When considering group differences in income quartiles (Table 3.16), support measures influenced the second- and third-income quartile in our LES models. The highest and the lowest quartiles were not affected by energy affordability schemes, suggesting that middle incomes benefitted the most from measures tied to oil heating. In both models, both quartiles saw a reduction in energy burden when energy affordability schemes were accounted for.

Table 3.16 Oil Heated Homes- Energy Burden by Income: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Income quartiles	LES estimates		
	Actual	Counterfactual	Differential
1	100.0%	100.0%	0.0%
2	88.4%	95.3%	-6.9%
3	50.0%	56.5%	-6.5%
4	17.6%	17.6%	0.0%
Total	55.7%	59.5%	-3.8%

Source: LCFS, based on LES model. Sample size for Oil=1,179 households.

Given low sample sizes for oil heating houses, analysis could not be split into more detailed categories (deciles).

Heterogenous analysis: Oil

Table 3.17 considers these measures by region. For areas where data was available, it was found that for oil heated households, energy burden was highest in Northern Ireland (57%), and lowest in Rural Scotland (43%). The differential, or the effect of measures was likely highest in Rural Scotland, where the energy burden rate would have been higher without energy affordability schemes.

Table 3.17 Oil Heated Homes- Energy Burden by Region: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Urban-Rural	LES estimates		
	Actual	**Counterfactual**	**Differential**
England Wales - Urban	Omitted	Omitted	Omitted
England Wales - Rural	56.8%	61.4%	-4.6%
Scotland - Urban	No data	No data	No data
Scotland - Rural	43.8%	50.0%	-6.2%
Northern Ireland	57.1%	60.2%	-3.1%
Total	55.7%	59.5%	-3.8%

Source: LCFS, based on LES model. Sample size for gas = 5,203 households; Electricity = 409; Oil=1,179 households.

By the available categories for tenure type, energy burden with the schemes (actual) was highest among homes owned outright (62%) (noting the high correlation between age and outright home ownership) and lowest among homes with a mortgage (42%), though private rented homes also had above average rates of energy burden (53%). The differential was highest for homes in the private rented sector, suggesting these homes benefitted most from energy affordability schemes. As mentioned previously, the number of households in energy burden is higher for those who own their home outright, compared to those with a mortgage or rental purchase. This may be explained by the demographic and age differences between people who own their own home outright and people who don't (typically those who own the home outright have spent 20-30 years paying off a mortgage, as a result they are older).

Table 3.18 Oil Heated Homes- Energy Burden by Tenure type: Differential effects between actual with energy affordability schemes and counterfactual without energy affordability schemes

Tenure	LES estimates		
	Actual	**Counterfactual**	**Differential**
Social Housing or Associations	Omitted	Omitted	Omitted
Private rented	53.8%	61.5%	-7.7%
Owned with Mortgage or Rental Purchase	42.6%	44.7%	-2.1%
Owned Outright	62.5%	65.9%	-3.4%
Total	55.7%	59.5%	-3.8%

Source: LCFS, based on LES model. Sample size for Oil=1,179 households.

This section summarised the effects of energy affordability schemes on energy burden in homes heated by oil. It presented evidence showing that the schemes had only a small effect in limiting the increase in the proportion of oil heating households experiencing energy burden. The effect was found only for middle income groups, and it did not affect the lowest and the highest earning home. The schemes did have a positive effect on private rented apartments heated by oil, but its magnitude was small. Most importantly, most oil heated homes (55%) experienced energy burden during this time.

3.4. Estimating the number of households in energy burden across all models

To estimate the equivalent number of households that might have experienced energy burden the proportions estimated through the modelling were aggregated to national population figures based on the number of households in each UK nation that used each energy source for central heating. The data sources were

- Census data on central heating type for proportions by gas, electric or oil heating. Note that there was a delay to the census in Scotland due to the pandemic, so data from Scotland’s Census 2022 was used, for other nations 2021 data was used.
- Census data on number of households from each nation’s census for aggregation up to a combined UK population figure.

Table 3.19 Percentage of households experiencing energy burden: estimated differential rates of energy burden between actual and counterfactual scenarios, including aggregation to number of households in UK

Heating Type/Total	Actual	Counterfactual	Difference (Actual - Counterfactual)
Gas-heated households			
Proportion above energy burden threshold 2022/23	43.8%	60.4%	-16.6%
Total number of gas-heated households above energy burden threshold	9,081,155	12,522,871	-3,441,716
Total number of gas-heated households (UK census)	20,733,230	20,733,230	
Electricity-heating households			
Proportion above energy burden threshold 2022/23	41.20%	54.20%	-13.00%
Total number of electricity-heated households above energy burden threshold	973,498	1,280,670	-307,172
Total number of electricity-heated households (UK census)	2,362,860	2,362,860	
Oil-heating households			
Proportion above energy burden threshold 2022/23	55.7%	59.5%	-3.8%
Total number of oil-heating households above the energy burden threshold	1,079,164	1,152,788	-73,623
Total number of oil-heating households (UK census)	1,937,458	1,937,458	
Total number of households above energy burden threshold			**-3,822,511**

Table Note: the LCFS dataset is representative of the UK, enabling aggregation to the total number of impacted households in the actual compared to counterfactual model without the energy affordability schemes.. Note, this aggregation excludes other heating types in the census: Multiple types of central heating (i.e., combine gas with other methods like electric or oil, N=2,693,815 UK households) and other central heating (including renewable, solid fuel, wood and district or communal heat networks), no central heating, or tank or bottled gas (N=1,468,311 UK households), meaning that this can be considered a slight underestimation of the total impact of the energy affordability schemes on energy burden. LES is the preferred model because LES is more restrictive, in that it requires the assumption that all goods to be normal and have elasticities within expected ranges from the literature.

Table 3.20 Percentage of households experiencing energy burden: estimated differential rates of energy burden between actual (with energy affordability schemes) and counterfactual (without energy affordability schemes), differential effects of EPG and EBSS (LES estimates)

Heading Type/Total	EBSS estimates			EPG estimates		
	Actual	**Counterfactual**	**Differential**	**Actual**	**Counterfactual**	**Differential**
Gas-heated homes						
% of households above the energy burden threshold in 2022/23	43.8%	47.3%	-3.5%	43.5%	57.8%	-14.0%
Total number of gas households above the energy burden threshold (UK rep.)	9,081,155	9,806,818	-725,663	9,018,955	11,983,807	-2,964,852
Total number of gas-heated households (UK census)	20,733,230	20,733,230		20,733,230	20,733,230	
Electricity-heated homes						
% of households above energy burden threshold in 2022/23	41.2%	44.4%	-3.2%	41.0%	52.3%	-11.1%
Total number of electricity households above the energy burden threshold (UK rep.)	973,498	1,049,110	-75,612	968,773	1,235,776	-267,003
Total number of electricity-heated households (UK census)	2,362,860	2,362,860		2,362,860	2,362,860	

Oil-heated homes (only eligible for EBSS £600)						
% of households above the energy burden threshold in 2022/23	55.7%	59.5%	-3.8%	NA	NA	NA
Total number of oil-heating households above the energy burden threshold (UK rep.)	1,079,164	1,152,788	-73,623	NA	NA	NA
Total number of oil-heating households (UK census)	1,937,458	1,937,458		NA	NA	NA
Total gas, electricity and oil			**-874,898**			**-3,231,855**

Table Note: the LCFS dataset is representative of the UK, enabling aggregation to the total number of impacted households in the actual compared to counterfactual model without the energy affordability schemes. Note, this aggregation excludes other heating types in the census: Multiple types of central heating (i.e., combine gas with other methods like electric or oil, N=2,693,815 UK households) and other central heating (including renewable, solid fuel, wood and district or communal heat networks), no central heating, or tank or bottled gas (N=1,468,311 UK households), meaning that this can be considered a slight underestimation of the total impact of the energy affordability schemes on energy burden. NA due to EPG not applicable to oil-heated homes. LES is the preferred model because LES is more restrictive, in that it requires the assumption that all goods to be normal and have elasticities within expected ranges from the literature.

3.5. Supporting evidence tables from interim evaluation

The tables below are relevant in understanding the proportion of income (after rent/mortgage expenses) spent on energy by different groups, as captured in the Nationally Representative surveys from the Domestic energy affordability support schemes in Great Britain: interim evaluation.[28] This provides additional evidence on the fuel poverty contribution claim for subgroups which are not available in the energy demand modelling due to low sample size or lack of incidence.

The interim evaluation considered households who spent more than 10% of their income (after rent or mortgage expenses) on energy. In total, 19% of households in GB were deemed to have been in energy burden. This differed by the household's energy tariff, with fixed tariff households experiencing energy burden more often (20%) when compared to non-fixed tariff households. This also differed by benefit receipt, with households who received Universal Credit experiencing energy burden most often (46%) and households who did not receive benefits or tax credits experiencing energy burden least often (15%). Similar tenancy differences also emerged, with owners and private renters showing the lowest rate of energy burden (16% and 21%) and those rent from the local council or a housing association showing the highest rates of energy burden (38%). Finally, there are similar income effects in the interim evaluation, with the lowest income group having the highest share of energy burden (37%) and the highest income group having the lowest share of energy burden (8%).

Table 3.21 Proportion of income (after rent/mortgage expenses) spent on energy among nationally representative sample of GB households – Nationally Representative wave 1 survey

Household group		Over 10%	0-10%
All (total)		19%	81%
Energy Tariff	Those on fixed term tariff for gas/electricity	20%	80%
	Those not a fixed term tariff for gas/electricity	17%	83%
Benefits	Universal Credit	46%	54%
	Personal Independence Payment	36%	64%

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[28] Domestic energy affordability support schemes in Great Britain: interim evaluation.

	Tax credits	41%	59%
	Not on benefits/ tax credits	15%	85%
Tenants or homeowners	Owned outright/buying on mortgage	16%	84%
	Rent from private landlord	21%	79%
	Rent from council/housing association	38%	62%
Annual household income	Below £26,000	37%	63%
	£26,000 up to and including £51,999	14%	86%
	£52,000 up to and including £99,999	5%	95%
	£100,000 and above	8%	92%

These results also emerge in Northern Ireland as shown in the table below, where overall energy burden is higher but group differences are similar. In total, 34% of households in NI were deemed to have an energy burden. This differed by the household's energy tariff, with fixed tariff households experiencing energy burden more often (34%) when compared to non-fixed tariff households (31%). This again differed by benefit receipt, with households who received Universal Credit experiencing energy burden most often (69%) and households who did not receive benefits or tax credits experiencing energy burden least often (24%). As before, tenancy differences emerged, with owners and renters showing the lowest rate of energy burden (28%) and those rent from the local council or a housing association showing the highest rates of energy burden (63%). Finally, there are similar income effects in the interim evaluation for NI, with the lowest income group having the highest share of energy burden (54%) and the highest income group having no experience of energy burden (0%).

Table 3.22 Proportion of income (after rent/mortgage expenses) spent on energy among nationally representative sample of NI households – Nationally Representative wave 1 survey

Household group		Over 10%	0-10%
All (total)		34%	66%
Energy Tariff	Those on a fixed term tariff for gas/electricity[29]	31%	26%
	Those not a fixed term tariff for gas/electricity	34%	43%
Benefits	Universal Credit	69%	31%
	Personal Independence Payment	59%	41%
	Tax credits	53%	47%
	Not on benefits/ tax credits	24%	76%
Tenants or homeowners	Owned outright/buying on mortgage	28%	72%
	Rent from private landlord	49%	51%
	Rent from council/housing association	63%	37%
Annual household income	Below £26,000	54%	46%
	£26,000 up to and including £51,999	11%	89%
	£52,000 up to and including £99,999	1%	99%
	£100,000 and above	–	100%

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[29] The percentages reported under 'those on a fixed term tariff for gas/electricity' and 'those not a fixed term tariff for gas/electricity' are taken from Q S5a ("Is your household currently on a fixed term tariff for electricity and gas?"); we have reported the percentage of participants who said 'yes' (i.e., on a fixed term tariff) / 'no' (i.e., not on a fixed term tariff) and who also spend 0-10% / +10% of their income on bills.

Annex 4. Health and wellbeing modelling

The domestic energy affordability schemes aimed to mitigate the potential physical and mental health issues that could be caused or exacerbated by underheating as a result of rising energy bills. The University College London (UCL) Health Impact of Domestic Energy Efficiency Measures (HIDEEM) model was used to assess the impact of the energy affordability schemes on physical and mental health, compared to the counterfactual of no support. The HIDEEM model estimates changes in indoor temperature conditions as a result of a change in energy efficiency or expenditure, and translates these into health impacts using Quality Adjusted Life Years (QALYs) and cost savings to the health service. This creates an estimate of the relationship between consumption, or underconsumption, and physical and mental ill health, and has been used in previous government evaluations, such as the Warm Homes Discount Scheme.[30]

HIDEEM provides an established exposure-response model methodology based on academic studies. It is a building physics model that characterises the indoor environmental conditions of English houses for indoor winter temperatures.[31] The model estimates the change in indoor conditions due to energy efficiency or changes in energy expenditure. These changes in condition are then used to estimate health impacts based on a combination of life table methods and directly modelled changes in disease prevalence (in this case relevant diseases are Cardiovascular (winter), Heart Attack, Stroke, Common mental disorder). More details can be found in Hamilton et al. (2015). The health impacts are quantified as Quality Adjusted Year (QALY) values. The consequent overall change in health resulting from the increase in predicted temperature is calculated as a monetary benefit using HMT Green Book approved methods of valuing health impacts using QALYs valued at £70,000 per year with HIDEEM outputs set for a single year (the closest temporal period to the intervention period) using HMT Green Book (2022) figures.

In the case of the energy affordability schemes, the policy intervention was composed of a mix of ‘rebate’ style payments (EBSS and AFP) and maximum energy unit price (EPG). For inclusion in the HIDEEM model it was necessary to combine the EPG and support payments into a single input. In the case of EBSS and AFP payments of £600 to oil heated households, there was no need to include the EPG. For EBSS and EPG households, the Equivalent Variation estimated in Annex A Tables 3.6 and 3.7 were taken as representative of the average combined income effect of the EPG and the EBSS payment.

- HIDEEM model 1: GB gas households: EBSS and EPG payment: Takes the welfare value estimated as Equivalent Variation of for gas households in Annex A Table 3.6 as

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[30] Evaluation of the Warm Home Discount Scheme Synthesis Report

[31] Based on indoor environmental conditions of English houses for indoor winter temperatures, exposures to particle pollution, second hand tobacco smoke (STS), radon, mould growth and energy demand in relation to the energy performance of the dwelling.

representative of the combined income and price effect of EPG and EBSS as the differential between counterfactual and capped energy cost for electricity households over 2 quarters.

- HIDEEM model 2: Electricity households: EBSS and EPG: Takes the welfare value estimated as Equivalent Variation of £721.20 for electricity households in Annex A Table 3.6 as representative of the combined income and price effect of EPG and EBSS as the differential between counterfactual and capped energy cost for electricity households over 2 quarters
- HIDEEM model 3: EBSS and AFP administered as a combined £600 payment to oil heated houses.

4.1. Literature Review: Health and Wellbeing impacts from household underheating

A key aim of the energy affordability schemes was to limit the potential negative consequences on physical and mental health that are associated with underheating. There are numerous studies investigating the relationship between low indoor temperature and health. Evidence suggest that living in a cold home is a risk factor for several negative health conditions such as respiratory illnesses, cardiovascular diseases, sleeping patterns and mental health. Middlemiss et al., 2023[32] presented a systematic literature review on the existing evidence on interventions for energy poverty and health, with a specific focus on how public policies aimed at reducing fuel poverty, have worked to produce their outcomes. The authors identified 16 quantitative evaluations based in the UK, focussed to assess the impacts of energy efficiency measures.

Other studies, focussed on reduced indoor temperature / humidity and improved health, derived from the installation of energy efficiency measures in homes following the Carmarthenshire Home Standard programme in Wales, were conducted by Peralta et al[33.], 2017 and Poortiga et al., 2017[34]. These articles found that:

- **Reduced cold** led to a decreased effect of cold on blood viscosity, decreasing the risk of thrombus formation and the occurrence of cardio-/cerebrovascular diseases. Additionally, diminished cold decreases the risk of infection, such as bronchitis.
- **Reduced humidity** diminished the incidence or worsening of respiratory illness (e.g. asthma) and it is associated with reduced exposure to indoor pollutants and dampness-related allergic agents.

Another systematic review conducted in 2016[35], covering studies from 1973-2014, found that underheating (i.e. a home temperature below 18°C) was related to negative cardiovascular and

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[32] How do interventions for energy poverty and health work?

[33] Impact of energy efficiency interventions in public housing buildings on cold-related mortality: a case-crossover analysis

[34] Social and health outcomes following upgrades to a national housing standard: a multilevel analysis of a five-wave repeated cross-sectional survey

[35] Cold indoor temperatures and their association with health and well-being: a systematic literature review

respiratory diseases. Another more recent work from Janssens et al. 2023, produced another review of all scientific research about the effects of cold indoor temperature on general physical and mental health. The key findings from this paper are:

- **Cardiovascular health**: 10 of the papers under review found negative effects on cardiovascular health, finding an association between low indoor temperature and higher blood pressure.
- **Respiratory health**: Three studies assessed associations between cold indoor temperature and respiratory health, and one found that indoor temperatures colder than 18.2°C can increase the severity of symptoms of patients already affected by Chronic Obstructive Respiratory Disease.
- **Sleeping problems**: 2 other studies found that low indoor temperature can cause sleep disturbances such as increased nocturnia, particularly among older people.
- **Physical performance in older people**: 2 papers investigated the impact of cold indoor temperature on physical performance of older people, necessary for independent living. One paper found that, an indoor temperature of 15°C, compared with 25°C, can cause a decreased of between 2% and 10% of physical performance measures in the strength of lower limbs.
- **General self-rated health**: Finally, 3 studies examining the effects of cold indoor temperatures on general health, found mixed results. In two instances cold indoor temperatures were associated with decreasing self-reported general health and in 1 research, an increase in temperature was associated to a negative perception of general health.
- **Mental health:** Bentley et al. (2023)[36] in their paper on the effect of energy poverty on mental health and cardiovascular diseases, estimated that fuel poverty has significant negative effects on mental health, specifically people who cannot afford to heat their properties at an acceptable level are:
    - 49% more likely to report depression/anxiety
    - They report a decrease of 4.93 points on a mental health scale going from 0 to 100 (where 0 means bad and 100 is good mental health)
    - 71% more likely to report having hypertension

The research was not able to establish with confidence if energy poverty has a statistically significant effect on the onset of asthma or chronic bronchitis.

Overall, the evidence strongly indicates a clear link between living in a cold home and poor general health, particularly amongst the most vulnerable groups in society, such as those with pre-existing health conditions, people on low incomes, and older individuals. The affordability schemes introduced by the government, were intended to support those segments of the

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[36] Bentley R., Daniel L., Yuxi L., Baker E., and Li A., “The effect of energy poverty on mental health, cardiovascular disease and respiratory health: a longitudinal analysis”. The Lancet Regional Health, 2023;35:100734.

population most likely to be affected by high energy costs and who, consequently, might be forced to underheat their homes.

4.2. Aggregation of QALY and NHS Savings to UK population

HIDEEM models provided health and wellbeing impacts in terms of QALYs and NHS savings at the individual level for the total population in England (second column Table 4.1, HIDEEM Model Results). These were valued at £70,000 per year using HMT Green Book (2022) figures, which gives a national annual level estimate of the total health and wellbeing impacts of the energy affordability schemes to England (third column Table 4.1). Savings to the NHS based on the health and wellbeing impacts were estimated using National Cost Collection (NCC) data (2021/22)[37] which includes services provided by the NHS in England. These costs include primary (limited to NCC data), secondary, emergency, and community care. Social care, full primary care and public health and prevention are not included.

Model inputs were based on the Equivalent Variation attached to each of the main energy heating sources at the household level. Therefore, it was necessary to divide QALYS by the national population of England during the intervention period, through a per person value. The HIDEEM model only applied to England. With caveats around differences in average outdoor temperature levels and underlying population health dynamics, the UCL model could be extrapolated to the UK as a whole.

Winter 22/23 lies between the two ONS mid-year population estimates for 2022 (57,112,500) and 2023 (57,690,300). The mid-point English population for winter 22-23 was therefore 57,401,400. All QALY and NHS values were divided by this figure in the fourth column for an annual per person value for each energy type.

This was then multiplied by the number of households primarily heating with each energy type in the fifth column to provide the aggregate UK-level health and wellbeing impacts of the energy affordability schemes in terms of QALYs and NHS cost savings.

UK-level scaling took census-level statistics for UK nations and scaled them to the UK-level by energy type:

- HIDEEM model 1: Gas households: EBSS and EPG: Aggregated to 80.2% of the population who heat with gas, including 71.0% of the UK population who used gas as their primary energy sources for heating and 9.2% of the population who used multiple types of central heating (i.e. combines gas with other methods like electric or oil).
- HIDEEM model 2: Electricity households: EBSS and EPG: Aggregated to 8.1% of the UK population who used electricity as their primary energy sources for heating.

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[37] NHS England » National Cost Collection for the NHS

- HIDEEM model 3: EBSS and AF administered as a combined £600 payment to oil heated houses, aggregated to 11.7% of the UK population who used oil and other (non-electricity and gas) as their primary energy sources for heating.

The final column estimates the non-monetary number of QALYs at the UK-wide level by taking the per person annual QALY value and multiplying it by the relevant energy heating household type.

Table 4.1 HIDEEM Modelling Outputs and National (UK) aggregation

HIDEEM model	HIDEEM Model Results	QALY value (£70k): annual, national	QALY value (£70k): annual, per person	QALY value by national population of heating type	UK-wide QALY (per person*population)
HIDEEM model 1: EPG+£400 to Gas households based on EV of £775.50				**Gas (& multiple source) users UK: 80.24%; 54,511,257 households**	
Standardised Indoor Temperature (SIT) increase	0.6 C				
% of homes with mould severity index >1:	-0.3%				
Total Mortality QALYs (weighted)	124	£8,680,000	£0.15	£8,242,965	118
Total Morbidity QALYs (weighted)	16,496	£1,154,720,000	£20.12	£1,096,580,191	15665
Total QALY (mortality & morbidity) per year (valued at £70k per QALY)	16620	£1,163,400,000	£20.27	£1,104,823,156	15783
Total Health Cost Saving(weighted)	-287,424,761	£287,424,761	£5.01	£272,953,010	-£272,953,010
HIDEEM model 2: EPG+£400 to Electricity households based on EV of £721.20				**Electricity users UK: 8.09%, 5,498,024 households**	

HIDEEM model	HIDEEM Model Results	QALY value (£70k): annual, national	QALY value (£70k): annual, per person	QALY value by national population of heating type	UK-wide QALY (per person*population)
Standardised Indoor Temperature (SIT) increase	0.6 C				
% of homes with mould severity index >1	-0.3%				
Total Mortality QALYs (weighted)	112	£7,840,000	£0.14	£750,931	11
Total Morbidity QALYs (weighted)	14,902	£1,043,140,000	£18.17	£99,914,089	1427
Total QALY (mortality & morbidity) per year (valued at £70k per QALY)	15,014	£1,050,980,000	£18.31	£100,665,020	1438
Total Health Cost Saving (weighted)	-260,068,636	£260,068,636	£4.53	£24,909,907	-£24,909,907
HIDEEM model 3: Oil households EBSS and AFP administered as a combined £600 payment				**Oil and other users UK: 11.67%, 7,924,720 households**	
Standardised Indoor Temperature (SIT) increase	0.4 C				
% of homes with mould severity index >1	-0.2%				

HIDEEM model	HIDEEM Model Results	QALY value (£70k): annual, national	QALY value (£70k): annual, per person	QALY value by national population of heating type	UK-wide QALY (per person*population)
Total Mortality QALYs (weighted)	85	£5,950,000	£0.10	£821,444.80	12
Total Morbidity QALYs (weighted)	11,396	£797,720,000	£13.90	£110,131,587.34	1573
Total QALY (mortality & morbidity) per year (valued at £70k per QALY)	11481	£803670000	£14.00	£110,953,032.14	1585
Total Health Cost Saving (weighted)	-199,770,776	£199,770,776	£3.48	£27,579,943.67	-£27,579,944
Total, all heating types					
Total Mortality QALYs				£9,815,341	140
Total Morbidity QALYs				£1,306,625,868	18,666
Total QALY (mortality & morbidity) per year				£1,316,441,209	18,806
Total Health Cost Saving				£325,442,861	-£325,442,861

Table Aggregation Note: Gas and multiple sources of heating households: Aggregated to 80.2% of the population who heat with gas, including 71.0% of the UK population who use gas as their primary energy sources for heating and 9.2% of the population who use multiple types of central heating (i.e. combines gas with other methods like electric or oil). Electricity households: Aggregated to 8.1% of the UK population who use electricity as their primary energy sources for heating. Oil and other heating households administered as a combined £600 payment to oil heated houses, aggregated to 11.7% of the UK population who use oil and other (non-electricity and gas) as their primary energy sources for heating. Figures in the table may not sum exactly due to rounding.

Annex 5. Household non-energy expenditure, borrowing and saving: secondary analysis

5.1. Household borrowing, including on energy

The energy affordability schemes aimed to maintain disposable income and prevent additional increases in energy or non-energy debt amid the increases in energy prices. To measure the impact of the schemes on household borrowing, the evaluation team analysed Ofgem energy debt indicators and measures of arrears in household billing. This was complemented by additional secondary analysis of surveys of household and individual finances and a review of evidence from the interim evaluations to assess the energy affordability schemes' impact on household borrowing on energy. The evaluation also explored to what extent effects on borrowing were heterogenous, since pressures on borrowing were expected to be greater for lower income groups who had lower existing savings to absorb increased prices.

Data sources

This evaluation drew on evidence from four key data sources to assess energy and wider household borrowing and debt:

- **Ofgem debt indicators**: A series of published Ofgem indicators was used to provide granular insights into the landscape of energy debt within the GB domestic energy market. By distinguishing between debt with and without repayment plans, it highlighted consumer repayment behaviours and potential areas of financial strain. However, its primary limitation was the lack of direct attribution to the schemes as it didn't account for other variables impacting debt levels, such as broader economic conditions or other policies. Nevertheless, these indicators proved useful for assessing energy debt among households before, during and after the energy affordability schemes[38].
- **Financial Lives Survey (FLS):** Conducted approximately every two years, the FLS has gathered data from nationally representative samples in 2017, 2020, 2022, and 2024[39]. The FLS offers a broader view of consumer financial behaviour, which was valuable for seeing overall trends in debt and financial attitudes over time. Data on unpaid credit card balances and personal loans were used to infer overall debt levels across the UK. Given the surveys is run every two years, only before and after comparisons were made to assess changes in the overall debt landscape.
- **Family Resources Survey (FRS):** The FRS is an annual survey that samples 25,000 households across Great Britain and Northern Ireland, focusing on the

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[38] Ofgem Debt and arrears indicators.

[39] FCA, Financial Lives survey. Surveys of interest were conducted in May 2022 and May 2024.

proportion of households in arrears across various bills, such as energy, council tax, rent, and loans[40]. By focusing on a wide range of arrears, the FRS is positioned to provide insights into households struggling with any kind of payments. Its large sample size enhances representativeness, and its inclusion of households from both Great Britain and Northern Ireland offers a comprehensive overview. The data from the 2022/23 financial year included data on household bill arrears during the intervention period, and comparisons were made to the previous year (2021/23). The results were cross-referenced by income, tenure, and region, to explore heterogeneity of scheme effects.

All three datasets faced the challenge of not having a counterfactual or control group to attribute debt changes directly and causally to the energy affordability schemes. The absence of experimental or quasi-experimental design methods meant these datasets alone could not definitively establish causal impact. As such, contribution claims have been further examined using self-reported data on debt acquired through the surveys and qualitative research conducted as part of the interim evaluations.

5.2. Secondary analysis of household non energy expenditure and borrowing.

This section includes charts on credit and borrowing referenced in Section 4.3 of the main report but not included there.

As well as the modelling of household expenditure discussed in Section B1.2, some secondary analysis of household expenditure was undertaken using the LCFS. This looked at longer term trends, changes in spend by households between the financial years of 2021/22 and 2022/23, and differences by income deciles. Further information on the LCFS is set out in Section 2.

Ipsos conducted analysis of microdata from the Financial Lives Survey[41] on adults’ credit and store card account balances not paid in full in the last month (a proxy to measure overall debt). The levels of unpaid balances remained generally unchanged between 2022-2024, with only a slight increase in the percentage of adults with unpaid balances of £1,500 to £1,999 between 2022 and 2024 (see Figure 5.1).

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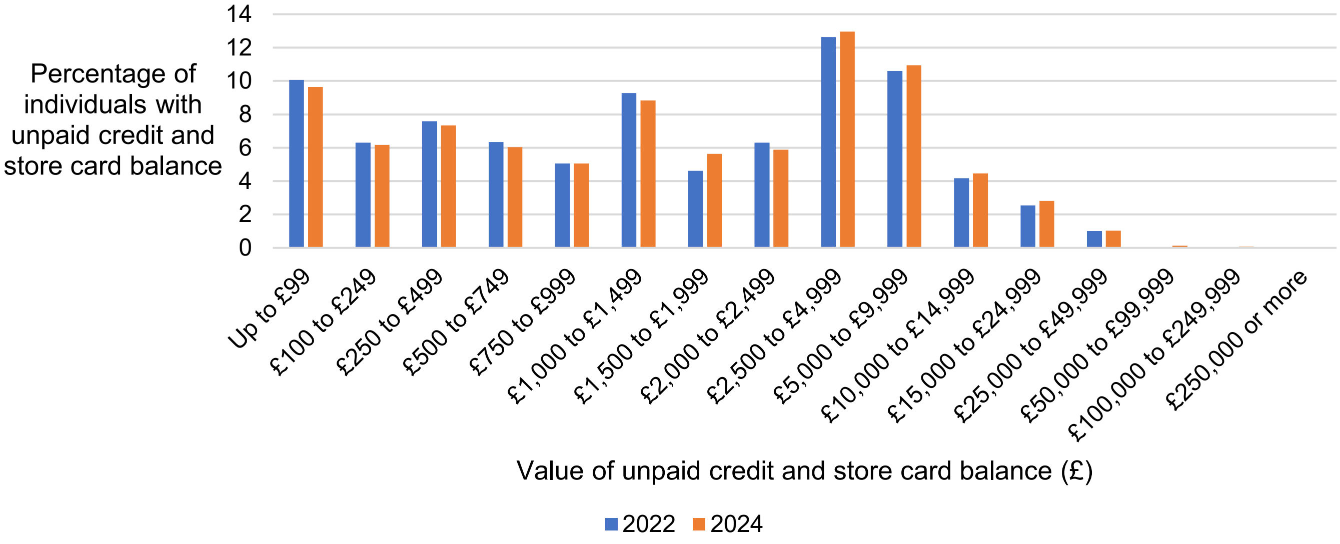
[40] ONS Family Resources Survey.

[41] The Financial Lives survey provides information about consumers' attitudes towards managing their money, the financial products they have and their experiences.

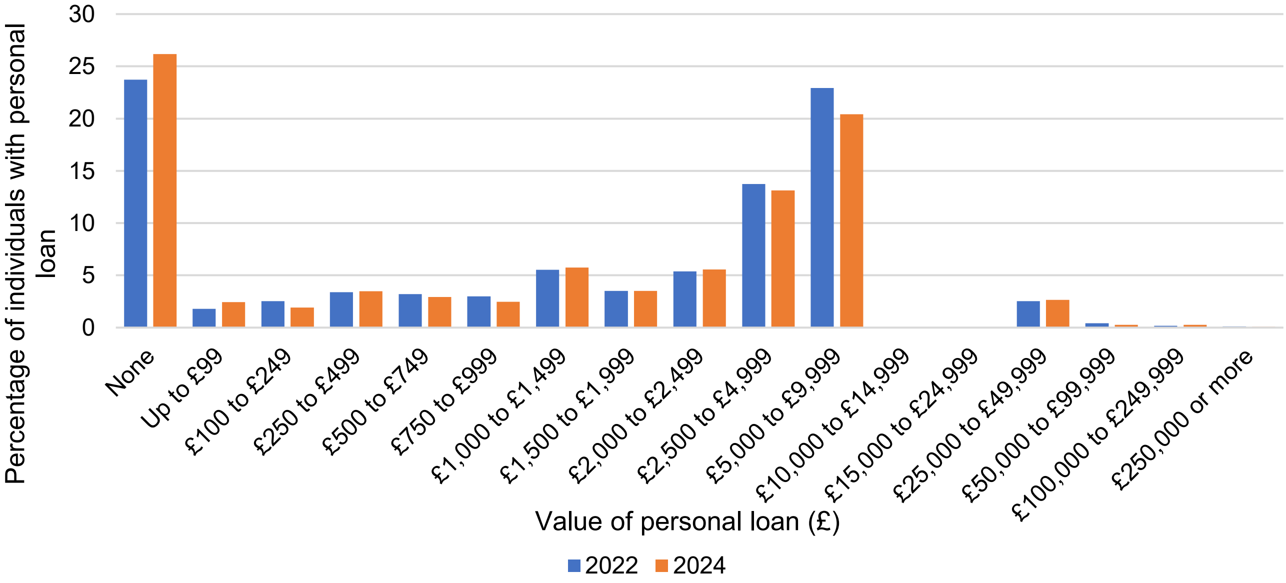
Figure 5.1 Proportion of individuals with unpaid credit and store card account balances by unpaid balance amount – 2022 -2024



Source: Ipsos Analysis of Financial Lives Survey (Microdata)

Personal loan values also remained broadly stable over the same period (see Figure 5.2).[42] The only statistically significant differences in the proportion of people reporting personal loan amounts between the May 2022 survey and the May 2024 survey were observed in two categories: those reporting that they had loans between £100 and £249, and those reporting that they had loans between £5,000 and £9,999. From this analysis, there appears to be little evidence that non-energy debt grew substantially between 2022 and 2024.

Figure 5.2 Proportion of individuals with personal loan by value of personal loan amount (£) – 2022 -2024



Source: Ipsos Analysis of Financial Lives Survey (Microdata)

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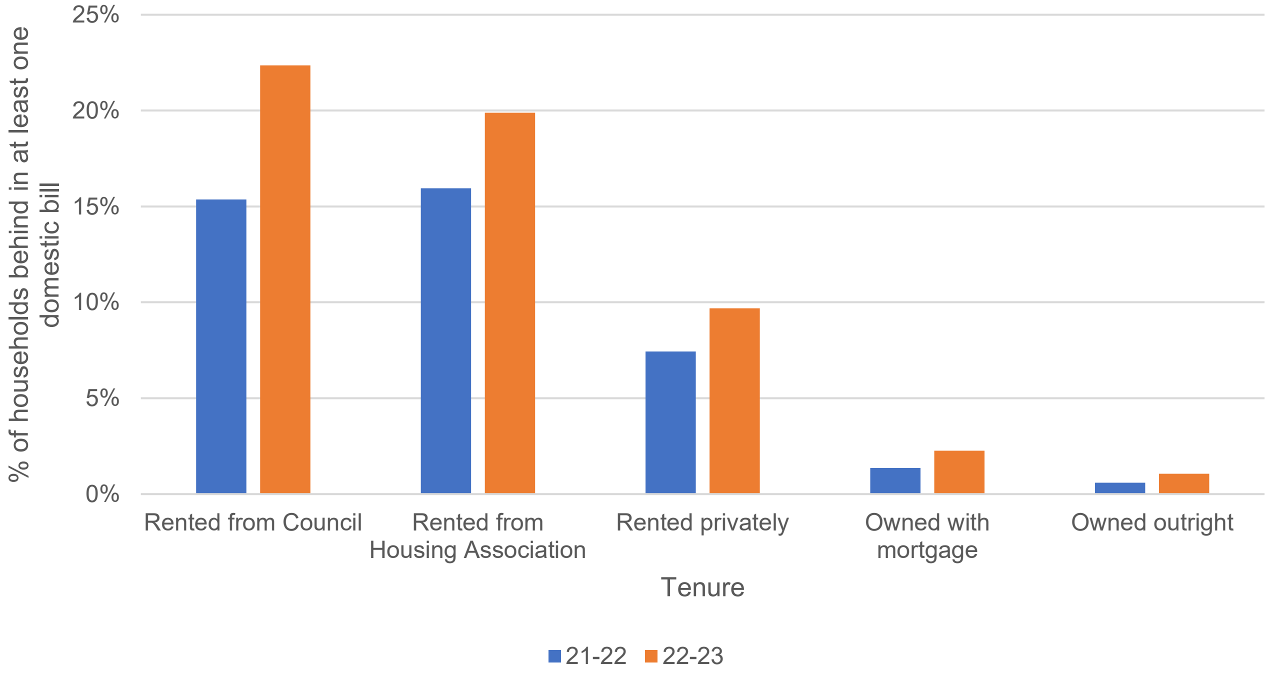
[42] FCA Financial Lives Survey - Dataset - Geographic Data Service

Microdata from the Family Resources Survey was analysed to assess the levels of debt and arrears on household bills. Figure 5.3 shows the proportion of households that reported that they were behind on at least one domestic bill[43] between FYs 2021-22 and 2022-23, analysed by tenure.

Tenure: Those who rented saw a greater proportional increase compared to homeowners. Amongst renters:

- Households renting from the council saw the largest increase, with a 7-percentage point rise in those behind on at least one bill.
- Those renting from Housing Associations experienced a 3.9 percentage point increase.
- Those renting privately saw a 2.2 percentage point increase.
- In contrast, those who owned outright and those who owned with a mortgage experienced a 0.5 and 0.9 percentage point increase, respectively.

Figure 5.3 Percentage of households reporting that they were behind with at least one domestic bill in FY 21-22 and FY22-23, by Tenure



Source: Family Resources Survey Microdata (Ipsos Analysis). FY21-22 N=17,496. FY22-23 N=26,929.

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[43] Household bills included electricity, gas, council tax, insurance policies, telephone bill, television/video rental or hire purchase, other hire purchase payments and water.

Annex 6. Supplier insolvency: Use of Ofgem Modelling

Ofgem shared their analysis on supplier market stability and supplier insolvency risks with the evaluation team. Their approach is briefly summarised below. More information on the implementation and purpose of Ofgem's retail stress testing can be found in their Action plan on financial resilience[44] and Financial Resilience in the energy retail market report[45].

6.1. Ofgem scenario analysis approach

To ensure resilience of the energy supply market, in January 2022, Ofgem designed and adopted a series of measures to monitor GB supplier solvency risk (see their Action Plan on financial resilience referenced above), with the aim of ensuring a secure energy supply in a period of sharp rise of energy prices. Alongside establishing the principles of (a) Financial Responsibility and (b) the Operational capability[46], Ofgem's action plan introduced a programme of stress testing assessments, to understand the extent to which suppliers were robust to a range of scenarios.

The stress test involved a number of "what if" scenarios aimed at assessing the resilience of energy suppliers in case of:

- Price volatility
- Differing levels of customer bad debt
- Significant acquisitions or loss of customers.

The data produced by suppliers included a two-year forecast of profit and loss, balance sheet and cashflow. These tests set out the forecast position of companies against four different price shock scenarios: 1) central price (most likely outcome), 2) low price, 3) high price and 4) very high price. The results of the stress tests reported in the report are based on the analysis of the central price scenario and comprise a forecast of the energy suppliers' financial position at the beginning of winter 2022/23 and at the end of it.

The implementation of these stress tests entailed an exchange of financial information between suppliers and Ofgem (with the intermediation of Energy UK), from January 2022 and

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[44] Action plan on retail financial resilience

[45] Financial resilience in the energy retail market | Ofgem

46 The Financial Responsibility Principle states that: "All energy suppliers must have sufficient financial resources as part of their energy licence conditions. They must also operate responsibly. This helps to lower the likelihood of energy suppliers going out of business. It also lowers the cost to consumers should an energy supplier leave or exit the market." The operating Capability principle, instead, states that: "Licensed energy companies must make sure they have systems and processes in place so that they can serve their customers effectively, mitigate risks and comply with their legislative and regulatory obligations. They must also have sufficient control over the assets they rely on to run their businesses such as their premises, facilities, and staff."

throughout the year. The assessment was aimed to be iterative, with multiple stress testing exercises conducted in 2022 for each energy supplier. The reason behind this was to ensure a continuous supplier monitoring as well as prioritisation of those suppliers most at risk.

Annex 7. Sensitivity Analysis: Price and income effects

7.1. Predictions and Price Change/Income Change Analysis

Households using gas and electricity for heating were provided £400 over six months off their energy bills (EBSS), as well as a price reduction of approximately 36% (EPG), which for a typical household, would imply an annual bill of £2,500. The EBSS was modelled as an income effect in predictions, whereby households were £400 richer over six months and the EPG as a price effect, whereby the price of energy was cut. An important part of the analysis was a counterfactual comparison, which is what would have happened had the households not been provided the EPG nor the EBSS. In this counterfactual ("Counterfactual 1"), income would have been lower due to no £400 contribution and energy prices would have been higher due to no price cut.

To break it out by energy type, the unit price of gas would have gone from an average of 10p (actual unit price) to 15p (counterfactual 1 unit price) during the intervention period without the schemes. In addition, annual income would have fallen from an average of approximately £39,240 (actual income) to approximately £38,140 (counterfactual 1 income) during the intervention period without the schemes.[47]

Table 7.1 Actual and Counterfactual 1 Income and Price of Gas During Intervention Period

	Logged Income	Income	Logged Unit Price	Unit Price
Actual	10.58	£39,241	2.28	9.8p
Counterfactual 1	10.55	£38,136	2.72	15.2p

Source: Combined audit and NEED dataset. Random sample of Gas meters = 158,143, model sample = 70,351.

Predictions were made from the parameters estimated in the Random Effects model, which estimated the predicted actual daily quantity of gas consumed, which should have been in line with the actual quantity consumed per day, and the counterfactual daily gas consumed, under the Counterfactual 1 scenario. To predict the actual observed values, the same model as described in Annex B1 was run; however, quantity consumed per day was used as the dependent variable rather than quantity consumed over a time period. The counterfactual values were then predicted by swapping the actual income for the Counterfactual 1 income and the actual price for gas for the Counterfactual 1 price for gas in the regression. Table 7.2 highlights the average predicted values for quantity consumed of gas per day during the intervention period.

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[47] Since income is annualised, the £400 over six months was extrapolated to be £800 over one year. In addition, since the income variable used is logged, unlogged income is subject to rounding.

Table 7.2 Actual and Counterfactual 1 Predictions for Daily Consumption of Gas

	Logged	Levels (Units per Day)
Actual Daily Consumption	3.45	38.7 kWh
Counterfactual 1 Daily Consumption	3.16	28.9 kWh
Average Percent Difference between Actual and Counterfactual 1[48]	24.7%	

Source: Combined audit and NEED dataset. Random sample of Gas meters = 158,143, model sample = 70,351.

The figures suggest that in the Counterfactual 1 scenario, daily consumption of gas would have dropped 25% without the measures, with the average households' consumption falling from 39 kWh to 29 kWh.

While the EBSS was expressed as an income effect, there is argument that it could be a price effect instead, as most households received it as a discount off their energy bill. A discount on energy bills could have been interpreted as a price change rather than a cash transfer, which could impact how households spent and distributed this transfer. To examine the effect of this, the analysis was re-run but rather than a combined maximum energy unit price of £2,500 and a £400 transfer of income, only a maximum energy unit price of £2,100 (£2,500 minus the £400 EBSS transfer) was assumed.

To compare the predicted levels of the counterfactual in this case to the actual scenario, another counterfactual scenario ("Counterfactual 2") was created, whereby households experienced the EBSS as a price change rather than an increase in income. Therefore, when looking at the new Counterfactual 2 scenario where the measures did not occur, there was no income change in Counterfactual 2, meaning the actual and counterfactual income were the same. The only factor that changed in this scenario is the price of gas, which was now capped at £2,100. This represented a 49% reduction in price. Since the maximum energy unit price was considered £2,100 rather than £2,500, in the Counterfactual 2 scenario, prices were higher per unit of gas than in Counterfactual 1.

Table 7.3 Actual and Counterfactual 2 Income and Price of Gas During Intervention Period

	Logged Income	Income	Logged Unit Price	Unit Price
Actual	10.58	£39,241	2.28	9.8p
Counterfactual 2	10.58	£39,241	2.90	18.1p

Source: Combined audit and NEED dataset. Random sample of Gas meters = 158,143, model sample = 70,351.

Predictions were made from the parameters estimated in the Random Effects model, which estimated the actual daily quantity of gas consumed and the counterfactual daily gas

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[48] This figure reflects the average of the percent differences between the actual daily quantities and the predicted counterfactual 1 daily quantities.

consumed, under the Counterfactual 2 scenario. The counterfactual values were predicted by swapping the actual price for gas for the Counterfactual 2 price for gas in the regression. Income remained the same for this counterfactual analysis. Table 7.4 highlights the average predicted values for quantity consumed of gas per day during the intervention period.

Table 7.4 Actual and Counterfactual 2 Predictions for Daily Consumption of Gas

	Logged	Levels (Units per Day)
Actual Daily Consumption	3.45	38.7 kWh
Counterfactual 2 Daily Consumption	3.01	24.8 kWh
Average Percent Difference between Actual and Counterfactual 2[49]		35.2%

Source: Combined audit and NEED dataset. Random sample of Gas meters = 158,143, model sample = 70,351.

The figures suggest that in the Counterfactual 2 scenario, daily consumption of gas would have dropped 35% without the policy intervention, with the average households' consumption falling from 39 kWh to 25 kWh per day. Counterfactual 2 indicated a bigger impact from the measures than Counterfactual 1. This shows that the proportional effect of EBSS would be higher if treated as a price rather than an income effect (Table 7.5). Note, this should be interpreted cautiously, since there is no conceptual backing in the literature to adopt that approach, even accounting for the fact that most people got it paid into their energy accounts. Regardless of how the cash is paid, income is fungible, meaning it frees up more money in their bank accounts, to spend on other non-energy goods and services. As such it does not matter where the voucher shows up in terms of the ability to consume either energy and non-energy goods, and so by design, the cash transfer is an income effect, and the income component will have more leakage out into other non-consumption spend than the EPG reduction in energy price.

Table 7.5 Actual, Counterfactual 1 and Counterfactual 2 Comparison for Gas

	Average Quantity Consumed of Gas per Day	Average Percent Difference from Actual Daily Consumption
Actual Daily Consumption	38.7 kWh	
Counterfactual 1 Daily Consumption	28.9 kWh	24.7%
Counterfactual 2 Daily Consumption	24.8 kWh	35.2%

Source: Combined audit and NEED dataset. Random sample of Gas meters = 158,143, model sample = 70,351.

Considering the EBSS as an income effect rather than a price effect led to more conservative impact results of the measures (25% rather than 35%). To further investigate this, different counterfactuals were explored. Counterfactual 1 is where households received no

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[49] This figure reflects the average of the percent differences between the actual quantities and the predicted counterfactual 2 daily quantities.

interventions. This scenario considers the EBSS as income and EPG as price cap, so in this scenario, income is lower and price is higher relative to the actual scenario. This means that counterfactual 1 can be used to show the impact of the interventions if they are considered a price change (EPG) and an income effect (EBSS)

Counterfactual 2 is another scenario where households did not receive the interventions, but in this case, EBSS is considered as a price change rather than an income. Under counterfactual 2, in the absence of the intervention, income remains the same and only the price is changed, so yes showing the impact of the interventions should they both be considered price changes

Counterfactual 1b is a modification of counterfactual 1, but income remains unchanged, while only price changes. Given that counterfactual 1 and 1b are essentially the same, this suggests a prevailing effect of price over income in this context.[50]

As Table 7.6 indicates, Counterfactual 1 and Counterfactual 1b led to essentially the same predicted daily consumption of gas, highlighting that the income effect and the added price effect were similar.

Table 7.6 Actual, Counterfactual 1, Counterfactual 1b, and Counterfactual 2 Comparison for Gas

	Average Quantity Consumed of Gas per Day
Actual Daily Consumption	38.7 kWh
Counterfactual 1 Daily Consumption	28.9 kWh
Counterfactual 1b Daily Consumption	28.9 kWh
Counterfactual 2 Daily Consumption	24.8 kWh

Source: Combined audit and NEED dataset. Random sample of Gas meters = 158,143, model sample = 70,351.

The same method was carried out for electricity, starting by looking at Counterfactual 1 for electricity. In Counterfactual 1, income would have been lower due to no £400 contribution and energy prices would have been higher due to no price cut. The unit price of electricity would have gone from an average of 33p (actual unit price) to 51p (Counterfactual 1 unit price) during the intervention period without the measures. In addition, annual income would have fallen from an average of approximately £40,600 to approximately £39,500 during the intervention period without the measures.[51]

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[50] Counterfactual 1 was considered again, however this time income was kept constant (actual income) and the only change was for the price of gas to be capped at £2,500 (Counterfactual 1b”). This was intended to isolate and compare the effects of only the decrease in the maximum energy unit price from £2,500 to £2,100, keeping all else equal.

51 Since income is annualised, the £400 over six months was extrapolated to be £800 over one year. In addition, since the income variable used is logged, unlogged income is subject to rounding.

Table 7.7 Actual and Counterfactual 1 Income and Price of Electricity During Intervention Period

	Logged Income	Income	Logged Unit Price	Unit Price
Actual	10.61	£40,634	3.48	32.5p
Counterfactual 1	10.58	£39,504	3.94	51.3p

Source: Combined audit and NEED dataset. Random sample of Electricity meters = 236,500, model sample = 19,544.

Predictions were made from the parameters estimated in the Random Effects model, which estimated the actual daily quantity of electricity consumed and the counterfactual daily electricity consumed, under the Counterfactual 1 scenario. To predict the actual observed values, the main model depicted in Annex B1 was run, however quantity consumed per day was used as the dependent variable rather than quantity consumed over a time period. The counterfactual values were predicted by swapping the actual income for the Counterfactual 1 income and the actual price for electricity for the Counterfactual 1 price for electricity in the regression. Table 7.8 highlights the average predicted values for quantity consumed of electricity per day during the intervention period.

Table 7.8 Actual, Counterfactual 1 Predictions for Daily Consumption of Electricity

	Logged	Levels (Units per Day)
Actual Daily Consumption	2.39	13.8 kWh
Counterfactual 1 Daily Consumption	2.05	11.1 kWh
Average Percent Difference between Actual and Counterfactual [52]		26.8%

Source: Combined audit and NEED dataset. Random sample of Electricity meters = 236,500, model sample = 19,544.

The figures suggest that in the Counterfactual 1 scenario, when comparing to the actual consumption, daily consumption of electricity would have dropped on average 27% without the measures, with the average households' consumption falling from 14 kWh to 11 kWh.

Another counterfactual scenario ("Counterfactual 2") was created, whereby households experience the EBSS as a price change rather than an increase in income. Therefore, when looking at the new Counterfactual 2 scenario where the policy intervention does not occur, there was no income change in Counterfactual 2, meaning the actual and counterfactual income were the same. The only factor that changed in this scenario was the price of electricity, which was now capped at £2,100. Since the maximum energy unit price was

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[52] This figure reflects the average of the percent differences between the actual daily quantities and the predicted counterfactual 1 daily quantities.

considered £2,100 rather than £2,500, in the Counterfactual 2 scenario, prices were higher per unit of electricity than in Counterfactual 1.

Table 7.9 Actual and Counterfactual 2 Income and Price of Electricity During Intervention Period

	Logged Income	Income	Logged Unit Price	Unit Price
Actual	10.61	£40,634	3.48	32.5p
Counterfactual 2	10.61	£40,634	4.11	61.0p

Source: Combined audit and NEED dataset. Random sample of Electricity meters = 236,500, model sample = 19,544.

Counterfactual values were predicted by swapping the actual price for electricity for the Counterfactual 2 price for electricity in the regression. Income remained the same for this counterfactual analysis. Table 7.10 highlights the average predicted values for quantity consumed of electricity per day during the intervention period.

Table 7.10 Actual and Counterfactual 2 Predictions for Daily Consumption of Electricity

	Logged	Levels (Units per Day)
Actual Daily Consumption	2.39	13.8 kWh
Counterfactual 2 Daily Consumption	1.81	9.8 kWh
Average Percent Difference between Actual and Counterfactual 2[53]	39.1%	

Source: Combined audit and NEED dataset. Random sample of Electricity meters = 236,500, model sample = 19,544.

The figures suggest that in the Counterfactual 2 scenario, daily consumption of electricity would have dropped on average 39% without the measures, with the average households' consumption falling from 14 kWh to 10 kWh per day.

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[53] This figure reflects the average of the percent differences between the actual daily quantities and the predicted counterfactual 2 daily quantities.

Table 7.11 Actual, Counterfactual 1 and Counterfactual 2 Comparison for Electricity

	Average Quantity Consumed of Electricity per Day	Average Percent Difference from Actual Daily Consumption
Actual Daily Consumption	13.8 kWh	
Counterfactual 1 Daily Consumption	11.1 kWh	26.8%
Counterfactual 2 Daily Consumption	9.8 kWh	39.1%

Source: Combined audit and NEED dataset. Random sample of Electricity meters = 236,500, model sample = 19,544.

Considering the EBSS as an income effect rather than a price effect led to more conservative impact results of the measures (27% rather than 39% on average). To further investigate this, Counterfactual 1 was considered again, however this time income was kept constant (actual income) and the only change was for the price of electricity to be capped at £2,500 ("Counterfactual 1b"). This was intended to isolate and compare the effects of the decrease in the maximum energy unit price from £2,500 to £2,100, keeping all else equal. As Table 7.12 indicates, Counterfactual 1 and Counterfactual 1b led to essentially the same predicted daily consumption of electricity, highlighting that the income effect and the added price effect were similar.

Table 7.12 Actual, Counterfactual 1, Counterfactual 1b, and Counterfactual 2 Comparison for Electricity

	Average Quantity Consumed of Electricity per Day
Actual Daily Consumption	13.8 kWh
Counterfactual 1 Daily Consumption	11.1 kWh
Counterfactual 1b Daily Consumption	11.1 kWh
Counterfactual 2 Daily Consumption	9.8 kWh

Source: Combined audit and NEED dataset. Random sample of Electricity meters = 236,500, model sample = 19,544.

Overall, converting the £400 to an equivalent price reduction could be seen as similar to the typical household bill analysis carried out by Ofgem and DESNZ at the outset of the ex-ante intervention evaluations. The impact of the measures in the counterfactual scenarios where EBSS is modelled as a price effect was larger than if EBSS was measured as an income effect. This was true for both gas and electricity. This indicates that if EBSS is measured as a price effect, in the counterfactual scenario without the energy affordability schemes, consumption would have fallen more than in the counterfactual scenario without the supports if

EBSS was measured as an income effect. Consequently, the price effect approach for the EPG and EBSS was less conservative, and therefore there was a higher risk of overestimating of the impacts of the energy affordability schemes' measures.

To err on the side of caution, this analysis chose to model the EBSS as an income effect in the counterfactual analysis and included the price effect approach as a sensitivity check.

However, no literature on households treating additional income or vouchers as a price cut was identified, with most standard theory suggesting cash-like income effect over price effect. The price cut approach however could be saved by appealing to "in-kind vs cash transfer" literature and "labelling effect" literature.

Conversely, appealing to the in-kind literature may not be the best approach as cash out studies tend to find no impact of in-kind/voucher as income compared to cash as income. Some studies did find differences between the two, however this may be due to the households in those studies being distorted and not inframarginal. However, it is unlikely that many UK households were distorted by the EBSS, as EBSS households were likely inframarginal, since the value of the voucher or reduction in bills (£400 over six months) in most cases was lower than the total value of the bill.

In addition, appealing to the labelling effect literature was not considered to be the best approach since they make up only a few of the studies relative to the widespread and long life of the canonical approach. Additionally, it poses questions around how to correctly measure the labelling effect and provides only the price effect approach as the answer. When reviewing labelling research, no one tends to take this approach.

7.2. Combined audit and NEED dataset Model Comparison and Sensitivity Checks

Table 7.13 Gas: Model Comparison - Regression Outputs for OLS, FE, BE, and RE Models

	(1)	(2)	(3)	(4)
VARIABLES	OLS	Fixed Effects	Between Effects	Random Effects
lnPrice	1.505***	1.303	1.746***	1.432***
	(0.176)	(1.023)	(0.244)	(0.222)
c.lnPrice#c.lnPrice	-0.440***	-0.340	-0.508***	-0.417***

	(0.0479)	(0.260)	(0.0665)	(0.0600)
lnIncome	0.0659***		0.0690***	0.0689***
	(0.00552)		(0.00740)	(0.00725)
2.EPC	-0.0409		-0.0340	-0.0377
	(0.0594)		(0.0829)	(0.0807)
3.EPC	0.100*		0.116	0.107
	(0.0590)		(0.0824)	(0.0802)
4.EPC	0.141**		0.162**	0.151*
	(0.0589)		(0.0823)	(0.0801)
5.EPC	0.133**		0.160*	0.149*
	(0.0594)		(0.0829)	(0.0807)
6.EPC	0.161***		0.181**	0.167**
	(0.0624)		(0.0871)	(0.0848)
7.EPC	0.0916		0.172*	0.149
	(0.0742)		(0.104)	(0.101)
lnFloorArea	0.289***		0.309***	0.301***
	(0.0108)		(0.0148)	(0.0144)
2.UsageSource	0.0390*	0.0335	0.0278	0.0468*
	(0.0221)	(0.0339)	(0.0412)	(0.0247)

3.UsageSource	0.421***	0.386***	0.449***	0.420***
	(0.0202)	(0.0291)	(0.0392)	(0.0217)
4.UsageSource	-0.172***		-0.169***	-0.175***
	(0.0311)		(0.0532)	(0.0482)
5.UsageSource	0.192		0.207	0.176
	(0.534)		(0.495)	(0.546)
2.GasCompany	-0.0517***		-0.0680***	-0.0587***
	(0.00744)		(0.0101)	(0.00968)
3.GasCompany	0.0713		0.0419	0.0554
	(0.0565)		(0.106)	(0.0939)
4.GasCompany	-0.186***		-0.157***	-0.199***
	(0.0178)		(0.0326)	(0.0223)
2.MonthMid	-0.0862***	-0.104***	-0.0711***	-0.100***
	(0.0109)	(0.00973)	(0.0214)	(0.00884)
3.MonthMid	-0.163***	-0.204***	-0.134***	-0.195***
	(0.0115)	(0.00983)	(0.0283)	(0.00924)
4.MonthMid	-0.491***	-0.135	-0.459***	-0.497***
	(0.0109)	(0.244)	(0.0172)	(0.0119)
5.MonthMid	-1.078***	-0.683***	-0.986***	-1.062***

	(0.0216)	(0.245)	(0.0442)	(0.0202)
6.MonthMid	-1.783***	-1.260***	-2.031***	-1.715***
	(0.0296)	(0.244)	(0.0864)	(0.0268)
7.MonthMid	-1.988***	-1.357***	-2.076***	-1.939***
	(0.0312)	(0.246)	(0.0440)	(0.0330)
8.MonthMid	-2.094***	-1.550***	-1.828***	-2.071***
	(0.0488)	(0.246)	(0.133)	(0.0425)
9.MonthMid	-1.489***	-0.877***	-1.619***	-1.430***
	(0.0453)	(0.246)	(0.101)	(0.0408)
10.MonthMid	-0.960***	-0.335	-0.821***	-0.907***
	(0.0350)	(0.262)	(0.0725)	(0.0386)
11.MonthMid	-0.388***	0.270	-0.324***	-0.318***
	(0.0349)	(0.262)	(0.0720)	(0.0385)
12.MonthMid	0.0978***	0.779***	0.0979	0.179***
	(0.0350)	(0.262)	(0.0724)	(0.0386)
2022.YearMid	-0.128	0.389*	-0.299	0.120
	(0.211)	(0.216)	(0.517)	(0.188)
2023.YearMid	-0.104	1.239***	-0.237	0.215
	(0.213)	(0.395)	(0.517)	(0.194)

AdultOccupants	0.0372***		0.0396***	0.0390***
	(0.00275)		(0.00373)	(0.00364)
2.Region	0.0309***		0.0494***	0.0428***
	(0.0114)		(0.0155)	(0.0152)
3.Region	0.0537***		0.0767***	0.0655***
	(0.0150)		(0.0200)	(0.0195)
4.Region	0.0152		0.0220	0.0175
	(0.0127)		(0.0172)	(0.0168)
5.Region	-0.0310**		-0.0316	-0.0349*
	(0.0150)		(0.0202)	(0.0198)
6.Region	0.00143		0.00814	0.00525
	(0.0127)		(0.0170)	(0.0166)
7.Region	-0.0493***		-0.0452**	-0.0463**
	(0.0152)		(0.0203)	(0.0199)
9.Region	-0.0156		0.000242	-0.00718
	(0.0135)		(0.0182)	(0.0178)
10.Region	-0.0597***		-0.0646***	-0.0644***
	(0.0174)		(0.0235)	(0.0229)
11.Region	0.0121		0.0200	0.0176

	(0.0120)		(0.0164)	(0.0160)
12.Region	0.359		0.366	0.370
	(0.228)		(0.286)	(0.286)
13.Region	-0.0678***		-0.0852***	-0.0800***
	(0.0151)		(0.0206)	(0.0200)
14.Region	-0.00190		-0.0164	-0.0164
	(0.0126)		(0.0171)	(0.0167)
2.MeterStatus	0.00857		0.00970	0.00166
	(0.00778)		(0.0101)	(0.00994)
1.Tenure	0.0362***		0.0387***	0.0401***
	(0.00799)		(0.0108)	(0.0105)
2.Tenure	0.0545***		0.0409***	0.0455***
	(0.00997)		(0.0131)	(0.0129)
2.PropType	-0.0529***		-0.0452**	-0.0471***
	(0.0134)		(0.0182)	(0.0178)
3.PropType	-0.0661***		-0.0673***	-0.0689***
	(0.0137)		(0.0184)	(0.0180)
4.PropType	-0.0330***		-0.0187	-0.0242
	(0.0115)		(0.0156)	(0.0152)

5.PropType	-0.0768***		-0.0804***	-0.0784***
	(0.0113)		(0.0152)	(0.0149)
lnGas21	0.571***		0.554***	0.561***
	(0.00399)		(0.00517)	(0.00511)
Constant	-22.94***	-16.95***	-23.03***	-23.20***
	(0.269)	(1.071)	(0.564)	(0.294)
Observations	70,351	70,351	70,351	70,351
R-squared	0.487			
Adjusted R-squared	0.487			
Within R-squared		0.308	0.292	0.307
Between R-squared		0.093	0.493	0.491
Overall R-squared		0.156	0.484	0.487
Number of meter_key		33,138	33,138	33,138

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1x

Table 7.14 Gas: Model Comparison - Own Price Elasticity for OLS, FE, BE, and RE Models

Model	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
OLS	51,949	-0.49	0.05	-10.87	0.00	-0.58	-0.40
RE	51,949	-0.46	0.06	-8.32	0.00	-0.57	-0.35
FE	51,949	-	-	-	-	-	-
BE	51,949	-0.56	0.06	-8.94	0.00	-0.68	-0.43

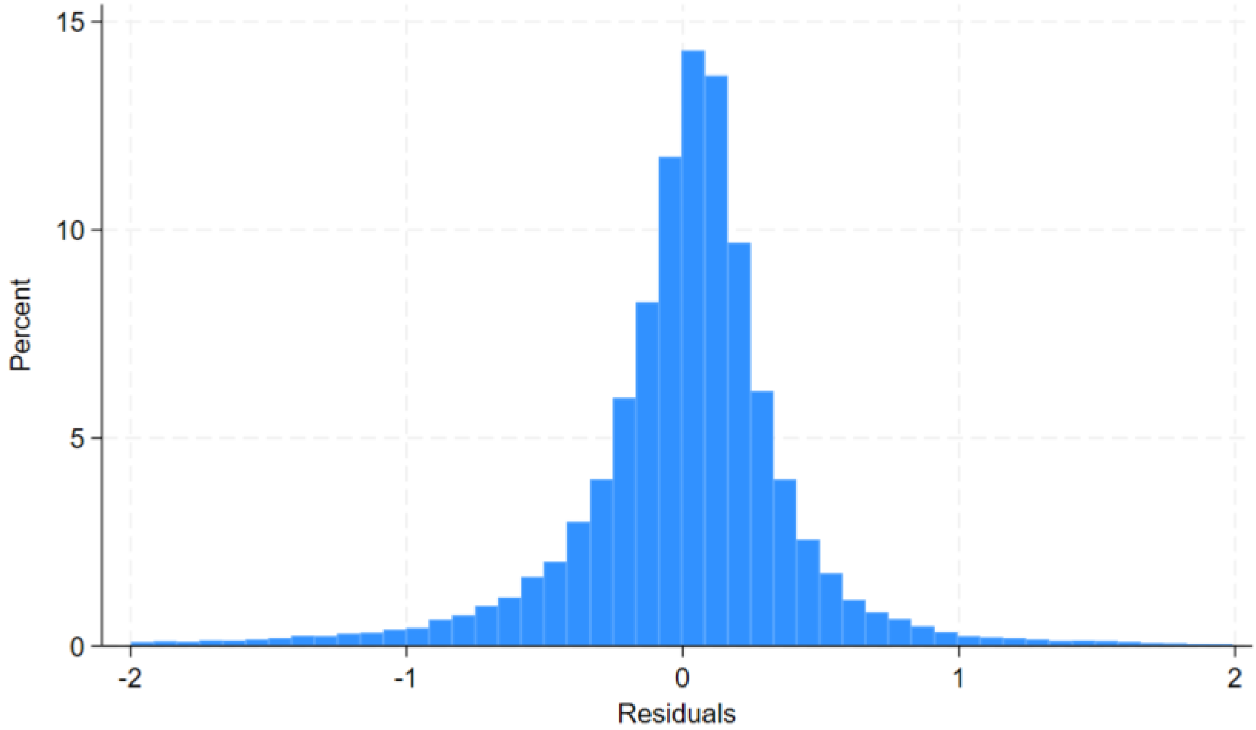
Source: Combined audit and NEED dataset Random sample of Gas meters

Table 7.15 Gas: Model Comparison – Income Elasticity for OLS, FE, BE, and RE Models

Model	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
OLS	51,949	0.07	0.01	11.93	0.00	0.06	0.08
RE	51,949	0.07	0.01	9.50	0.00	0.05	0.08
FE	51,949	-	-	-	-	-	-
BE	51,949	0.07	0.01	9.32	0.00	0.05	0.08

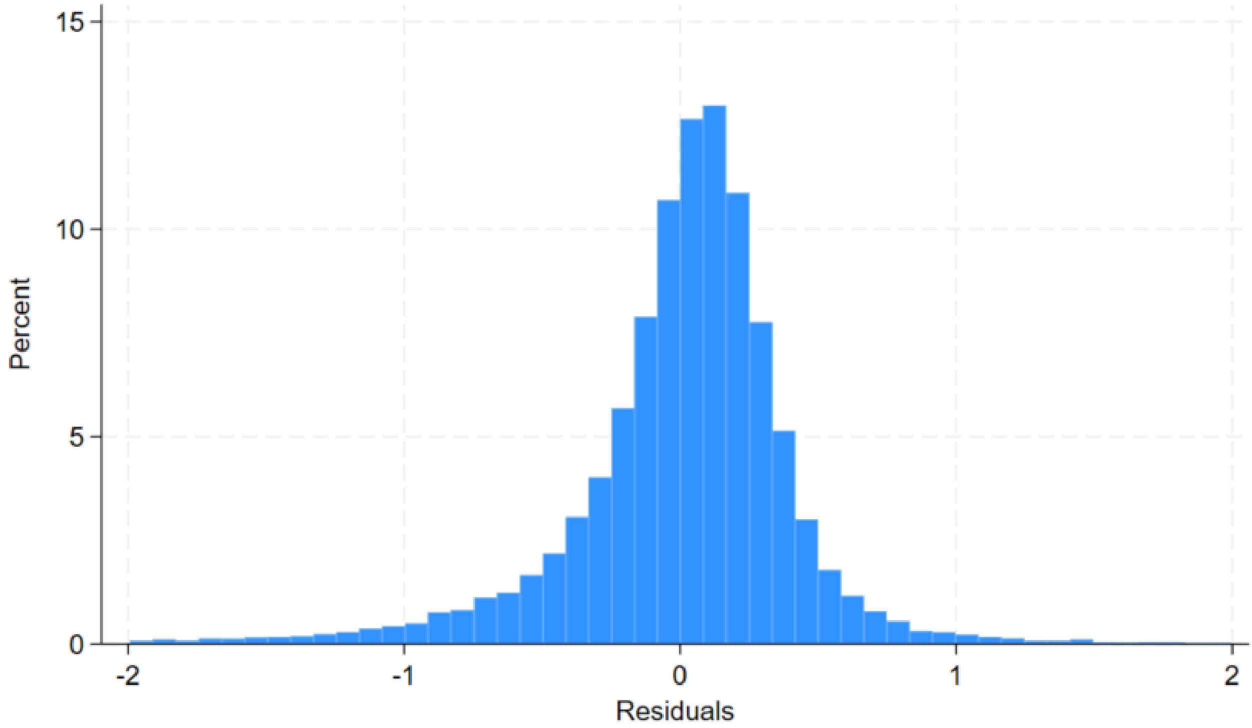
Source: Combined audit and NEED dataset: Random sample of Gas meters

Figure 7.1 Gas: Residual Comparison (e) – RE Model



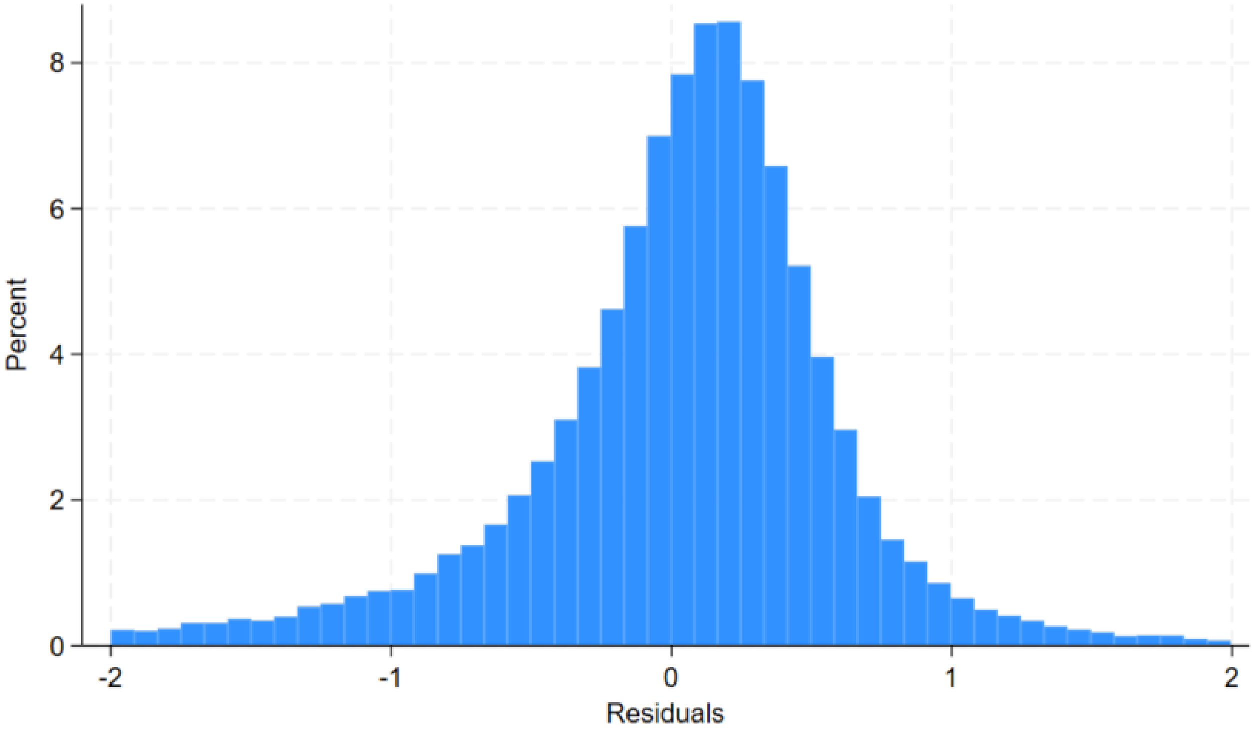
Source: Combined audit and NEED dataset: Random sample of Gas meters

Figure 7.2 Gas: Residual Comparison (u) – RE Model



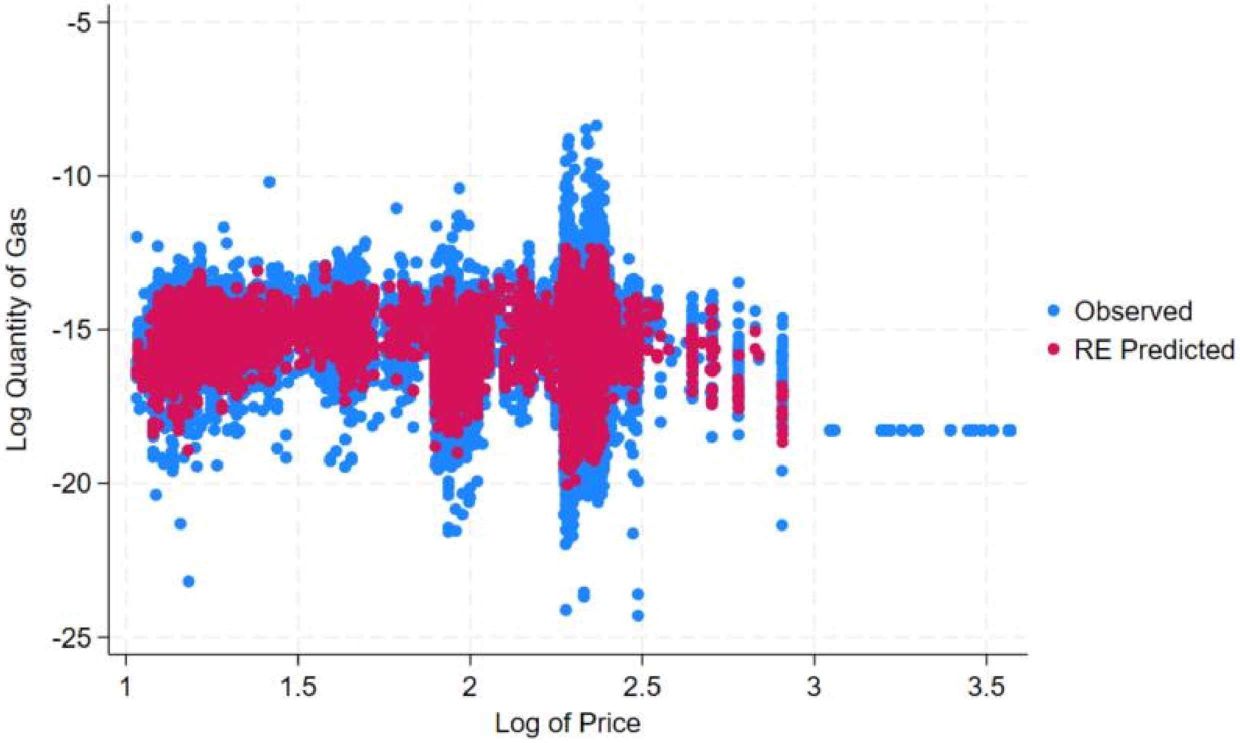
Source: Combined audit and NEED dataset: Random sample of Gas meters

Figure 7.3 Gas: Residual Comparison (manually programmed) – RE Model



Source: Combined audit and NEED dataset: Random sample of Gas meters

Figure 7.4 Gas: Observed vs Predicted – RE Model



Source: Combined audit and NEED dataset: Random sample of Gas meters

Table 7.16 Gas: Sensitivity Checks – RE Model

	(1)	(2)	(3)
VARIABLES	Random Effects - Income-Price Interaction	Random Effects - Income Squared	Random Effects - Normal
lnPrice	1.207***	1.432***	1.432***
	(0.378)	(0.222)	(0.222)
c.lnPrice#c.lnPrice	-0.413***	-0.417***	-0.417***
	(0.0603)	(0.0600)	(0.0600)
lnIncome	0.0246	0.0880	0.0689***
	(0.0608)	(0.0881)	(0.00725)
c.lnIncome#c.lnPrice	0.0196		
	(0.0267)		
2.EPC	-0.0364	-0.0379	-0.0377
	(0.0807)	(0.0807)	(0.0807)
3.EPC	0.108	0.107	0.107
	(0.0802)	(0.0802)	(0.0802)
4.EPC	0.153*	0.151*	0.151*
	(0.0802)	(0.0801)	(0.0801)
5.EPC	0.151*	0.149*	0.149*
	(0.0807)	(0.0807)	(0.0807)
6.EPC	0.168**	0.167**	0.167**
	(0.0848)	(0.0848)	(0.0848)
7.EPC	0.150	0.149	0.149
	(0.101)	(0.101)	(0.101)
lnFloorArea	0.301***	0.301***	0.301***
	(0.0144)	(0.0145)	(0.0144)
2.UsageSource	0.0469*	0.0469*	0.0468*

	(0.0247)	(0.0247)	(0.0247)
3.UsageSource	0.420***	0.420***	0.420***
	(0.0217)	(0.0217)	(0.0217)
4.UsageSource	-0.176***	-0.175***	-0.175***
	(0.0482)	(0.0482)	(0.0482)
5.UsageSource	0.177	0.177	0.176
	(0.546)	(0.546)	(0.546)
2.GasCompany	-0.0585***	-0.0588***	-0.0587***
	(0.00968)	(0.00968)	(0.00968)
3.GasCompany	0.0546	0.0555	0.0554
	(0.0939)	(0.0939)	(0.0939)
4.GasCompany	-0.199***	-0.199***	-0.199***
	(0.0223)	(0.0223)	(0.0223)
5o.GasCompany	-	-	-
6o.GasCompany	-	-	-
2.MonthMid	-0.100***	-0.100***	-0.100***
	(0.00884)	(0.00884)	(0.00884)
3.MonthMid	-0.195***	-0.195***	-0.195***
	(0.00924)	(0.00924)	(0.00924)
4.MonthMid	-0.497***	-0.497***	-0.497***
	(0.0119)	(0.0119)	(0.0119)
5.MonthMid	-1.062***	-1.062***	-1.062***
	(0.0202)	(0.0202)	(0.0202)
6.MonthMid	-1.714***	-1.715***	-1.715***
	(0.0268)	(0.0268)	(0.0268)
7.MonthMid	-1.938***	-1.939***	-1.939***
	(0.0331)	(0.0330)	(0.0330)

8.MonthMid	-2.070***	-2.071***	-2.071***
	(0.0425)	(0.0425)	(0.0425)
9.MonthMid	-1.428***	-1.430***	-1.430***
	(0.0409)	(0.0408)	(0.0408)
10.MonthMid	-0.908***	-0.907***	-0.907***
	(0.0386)	(0.0386)	(0.0386)
11.MonthMid	-0.318***	-0.318***	-0.318***
	(0.0385)	(0.0385)	(0.0385)
12.MonthMid	0.178***	0.179***	0.179***
	(0.0386)	(0.0386)	(0.0386)
2022.YearMid	0.122	0.120	0.120
	(0.188)	(0.188)	(0.188)
2023.YearMid	0.216	0.214	0.215
	(0.194)	(0.194)	(0.194)
AdultOccupants	0.0390***	0.0389***	0.0390***
	(0.00364)	(0.00365)	(0.00364)
2.Region	0.0430***	0.0429***	0.0428***
	(0.0152)	(0.0152)	(0.0152)
3.Region	0.0650***	0.0657***	0.0655***
	(0.0196)	(0.0196)	(0.0195)
4.Region	0.0176	0.0175	0.0175
	(0.0168)	(0.0168)	(0.0168)
5.Region	-0.0348*	-0.0349*	-0.0349*
	(0.0198)	(0.0198)	(0.0198)
6.Region	0.00547	0.00528	0.00525
	(0.0166)	(0.0166)	(0.0166)
7.Region	-0.0461**	-0.0464**	-0.0463**
	(0.0199)	(0.0199)	(0.0199)
9.Region	-0.00710	-0.00704	-0.00718

	(0.0178)	(0.0178)	(0.0178)
10.Region	-0.0642***	-0.0644***	-0.0644***
	(0.0230)	(0.0229)	(0.0229)
11.Region	0.0176	0.0177	0.0176
	(0.0160)	(0.0160)	(0.0160)
12.Region	0.370	0.370	0.370
	(0.286)	(0.286)	(0.286)
13.Region	-0.0800***	-0.0801***	-0.0800***
	(0.0200)	(0.0201)	(0.0200)
14.Region	-0.0162	-0.0164	-0.0164
	(0.0167)	(0.0167)	(0.0167)
2.MeterStatus	0.00179	0.00156	0.00166
	(0.00994)	(0.00995)	(0.00994)
3o.MeterStatus	-	-	-
1.Tenure	0.0400***	0.0400***	0.0401***
	(0.0105)	(0.0106)	(0.0105)
2.Tenure	0.0460***	0.0461***	0.0455***
	(0.0129)	(0.0132)	(0.0129)
2.PropType	-0.0465***	-0.0470***	-0.0471***
	(0.0178)	(0.0178)	(0.0178)
3.PropType	-0.0685***	-0.0686***	-0.0689***
	(0.0180)	(0.0181)	(0.0180)
4.PropType	-0.0240	-0.0245	-0.0242
	(0.0152)	(0.0153)	(0.0152)
5.PropType	-0.0782***	-0.0787***	-0.0784***
	(0.0149)	(0.0149)	(0.0149)
lnGas21	0.561***	0.561***	0.561***
	(0.00511)	(0.00511)	(0.00511)

c.lnIncome#c.lnIncome		-0.000914	
		(0.00418)	
Constant	-22.72***	-23.31***	-23.20***
	(0.722)	(0.553)	(0.294)
Observations	70,351	70,351	70,351
Number of meter_key	33,138	33,138	33,138

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7.17 Electricity: Model Comparison - Regression Outputs for OLS, FE, BE, and RE Models

	(1)	(2)	(3)	(4)
VARIABLES	Random Effects	OLS	Fixed Effects	Between Effects
lnPrice	3.442**	2.360	2.467	-2.512
	(1.425)	(1.468)	(1.564)	(4.998)
c.lnPrice#c.lnPrice	-0.527**	-0.343	-0.393*	0.437
	(0.213)	(0.221)	(0.233)	(0.768)
2.TariffType	-6.718**	-5.276	-8.271**	-11.67
	(3.076)	(3.600)	(3.262)	(22.96)
3.TariffType	3.642	1.414	2.223	-6.211
	(2.467)	(2.539)	(2.701)	(8.626)
4.TariffType	-7.598**	-2.194	-5.371	31.54*
	(3.059)	(3.361)	(3.298)	(17.01)
1b.TariffType#co.lnPrice	0	0	0	0
	(0)	(0)	(0)	(0)
2.TariffType#c.lnPrice	3.913**	3.120	4.847**	6.985

	(1.913)	(2.262)	(2.022)	(14.82)
3.TariffType#c.lnPrice	-2.704*	-1.187	-1.846	3.903
	(1.490)	(1.541)	(1.629)	(5.336)
4.TariffType#c.lnPrice	4.521**	1.623	3.043	-16.13
	(1.835)	(2.008)	(1.981)	(9.867)
1b.TariffType#co.lnPrice#co.lnPrice	0	0	0	0
	(0)	(0)	(0)	(0)
2.TariffType#c.lnPrice#c.lnPrice	-0.566*	-0.462	-0.698**	-1.030
	(0.295)	(0.352)	(0.310)	(2.365)
3.TariffType#c.lnPrice#c.lnPrice	0.456**	0.202	0.339	-0.633
	(0.223)	(0.232)	(0.243)	(0.821)
4.TariffType#c.lnPrice#c.lnPrice	-0.670**	-0.285	-0.431	2.031
	(0.274)	(0.299)	(0.296)	(1.434)
5.RegType	-0.0292***	-0.0318**	-0.0303***	0.494*
	(0.00967)	(0.0134)	(0.00965)	(0.253)
6.RegType	-0.00991	0.0165	-0.0349**	0.321***
	(0.0144)	(0.0151)	(0.0157)	(0.124)
8.RegType	-0.551***	-0.327***	-1.152***	1.075
	(0.212)	(0.126)	(0.324)	(1.083)
9.RegType	-0.269	-0.0807	-0.866***	2.345
	(0.212)	(0.125)	(0.320)	(1.588)
10.RegType	0.339	-0.484*		
	(0.345)	(0.291)		
11.RegType	-0.285*	-0.209**		1.641
	(0.163)	(0.103)		(1.162)
12.RegType	-0.0515	0.0464		1.978*
	(0.224)	(0.128)		(1.202)
lnIncome	0.0864***	0.0633***		0.0866***
	(0.0182)	(0.00892)		(0.0187)

2.EPC	-0.532***	-0.612***		-0.485**
	(0.190)	(0.109)		(0.191)
3.EPC	-0.498***	-0.572***		-0.454**
	(0.190)	(0.109)		(0.191)
4.EPC	-0.428**	-0.503***		-0.391**
	(0.190)	(0.109)		(0.191)
5.EPC	-0.451**	-0.530***		-0.420**
	(0.191)	(0.109)		(0.192)
6.EPC	-0.382*	-0.424***		-0.338*
	(0.197)	(0.112)		(0.198)
7.EPC	-0.356*	-0.509***		-0.262
	(0.212)	(0.118)		(0.215)
lnFloorArea	0.0168	0.102		0.000637
	(0.223)	(0.115)		(0.224)
c.lnFloorArea#c.lnFloorArea	0.0205	0.00871		0.0217
	(0.0255)	(0.0132)		(0.0256)
2.UsageSource	0.0228	0.0444	0.0217	0.101
	(0.0460)	(0.0444)	(0.0477)	(0.222)
3.UsageSource	0.227***	0.217***	0.227***	0.193
	(0.0405)	(0.0411)	(0.0419)	(0.201)
4.UsageSource	-0.0186	-0.106		-0.224
	(0.198)	(0.115)		(0.228)
5o.UsageSource	-	-	-	-
2.Company	-0.0341	0.0362**		0.0122
	(0.0306)	(0.0168)		(0.0389)
3.Company	-0.150***	-0.130***		-0.110**
	(0.0352)	(0.0215)		(0.0509)
4o.Company	-	-	-	

5.Company	-0.0274	-0.00654		0.208
	(0.0673)	(0.0408)		(0.241)
2.MonthMid	-0.0411***	-0.0280	-0.0449***	0.0267
	(0.0158)	(0.0206)	(0.0161)	(0.0884)
3.MonthMid	-0.0873***	-0.0556***	-0.0970***	-0.0561
	(0.0161)	(0.0207)	(0.0164)	(0.0908)
4.MonthMid	-0.161***	-0.152***	-0.154***	0.0297
	(0.0166)	(0.0211)	(0.0171)	(0.0899)
5.MonthMid	-0.277***	-0.333***	-0.251***	-0.138
	(0.0233)	(0.0269)	(0.0249)	(0.0998)
6.MonthMid	-0.370***	-0.335***	-0.365***	-0.611
	(0.0431)	(0.0590)	(0.0433)	(0.453)
7.MonthMid	-0.440***	-0.407***	-0.432***	0.282
	(0.0442)	(0.0605)	(0.0444)	(0.566)
8.MonthMid	-0.426***	-0.418***	-0.409***	-2.460**
	(0.0697)	(0.0958)	(0.0699)	(1.209)
9.MonthMid	-0.317***	-0.286***	-0.299***	-0.811
	(0.0668)	(0.0906)	(0.0672)	(1.193)
10.MonthMid	-0.226***	-0.147**	-0.220***	-0.327
	(0.0549)	(0.0727)	(0.0557)	(0.492)
11.MonthMid	-0.112**	-0.0455	-0.101*	-0.320
	(0.0549)	(0.0726)	(0.0557)	(0.494)
12.MonthMid	0.0453	0.0981	0.0598	-0.290
	(0.0548)	(0.0726)	(0.0556)	(0.499)
2022.YearMid	-25.26***			
	(2.418)			
2023.YearMid	-25.22***	0.0948	0.0454	-0.191

	(2.424)	(0.0696)	(0.0533)	(0.487)
o.lnIncome	-	-	-	-
AdultOccupants	0.0582***	0.0506***		0.0578***
	(0.0112)	(0.00554)		(0.0114)
2.Region	0.0444	0.0643***		0.0702
	(0.0449)	(0.0213)		(0.0487)
3.Region	-0.0167	0.0405		0.00307
	(0.0497)	(0.0248)		(0.0551)
4.Region	0.0111	-0.0172		0.0247
	(0.0528)	(0.0249)		(0.0551)
6.Region	0.0187	0.0211		0.0490
	(0.0601)	(0.0305)		(0.0647)
7.Region	0.125**	0.0976***		0.120**
	(0.0527)	(0.0259)		(0.0542)
8.Region	-0.0169	-0.0475		-0.0767
	(0.0661)	(0.0328)		(0.0681)
10.Region	0.0348	0.0248		0.0835
	(0.0501)	(0.0236)		(0.0540)
11.Region	-0.00583	-0.0406		0.0191
	(0.0725)	(0.0344)		(0.0758)
12.Region	0.0368	0.0689***		0.0414
	(0.0465)	(0.0221)		(0.0490)
13.Region	-0.348	-0.932***		-0.374
	(0.317)	(0.164)		(0.330)
14.Region	0.0647	0.0405*		0.0967*
	(0.0498)	(0.0237)		(0.0519)
15.Region	0.104*	0.105***		0.0751
	(0.0534)	(0.0257)		(0.0547)

2.MeterStatus	-0.0745***	-0.00195	-0.136***	0.0136
	(0.0185)	(0.0134)	(0.0239)	(0.0311)
3o.MeterStatus	-	-	-	-
1.Tenure	-0.0114	-0.0305**		-0.0167
	(0.0265)	(0.0130)		(0.0270)
2.Tenure	0.0536	0.0108		0.0362
	(0.0373)	(0.0178)		(0.0384)
2.PropType	-0.0491	-0.118***		-0.0210
	(0.0550)	(0.0272)		(0.0557)
3.PropType	0.0402	-0.0194		0.0588
	(0.0525)	(0.0252)		(0.0538)
4.PropType	-0.0485	-0.109***		-0.0357
	(0.0524)	(0.0254)		(0.0536)
5.PropType	-0.00942	-0.0924***		0.0104
	(0.0517)	(0.0250)		(0.0528)
lnElec21	0.331***	0.326***		0.333***
	(0.0106)	(0.00521)		(0.0109)
o._cons	0			
	(0)			
10o.RegType			-	-
11o.RegType			-	
12o.RegType			-	
2o.EPC			-	

3o.EPC			-	
4o.EPC			-	
5o.EPC			-	
6o.EPC			-	
7o.EPC			-	
o.InFloorArea			-	
co.InFloorArea#co.InFloorArea			0	
			(0)	
4o.UsageSource			-	
2o.Company			-	
3o.Company			-	
5o.Company			-	
o.AdultOccupants			-	
2o.Region			-	
3o.Region			-	
4o.Region			-	

6o.Region			-	
7o.Region			-	
8o.Region			-	
10o.Region			-	
11o.Region			-	
12o.Region			-	
13o.Region			-	
14o.Region			-	
15o.Region			-	
1o.Tenure			-	
2o.Tenure			-	
2o.PropType			-	
3o.PropType			-	
4o.PropType			-	

5o.PropType			-	
o.lnElec21			-	
4.Company				-1.391
				(1.130)
Constant		-23.57***	-19.87***	-16.45**
		(2.427)	(2.599)	(8.098)
Observations	19,544	19,544	19,544	19,544
R-squared		0.283		
Adjusted R-squared		0.281		
Within R-squared	0.076		0.077	0.001
Between R-squared	0.387		0.003	0.405
Overall R-squared	0.276		0.022	0.180
Number of meter_id	2,874		2,874	2,874

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7.18 Electricity: Model Comparison - Own Price Elasticity for OLS, FE, BE, and RE Models

Model	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
OLS	13,250	-0.18	0.06	-2.87	0.00	-0.30	-0.06
RE	13,250	-0.18	0.06	-3.19	0.00	-0.30	-0.07
FE	13,250	-	-	-	-	-	-
BE	13,250	-0.74	0.20	-3.67	0.00	-1.14	-0.35

Table 7.19 Electricity: Model Comparison – Income Elasticity for OLS, FE, BE, and RE Models

Model	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
OLS	13,250	0.06	0.01	7.09	0.00	0.05	0.08
RE	13,250	0.09	0.02	4.75	0.00	0.05	0.12
FE	13,250	-	-	-	-	-	-
BE	13,250	0.09	0.02	4.64	0.00	0.05	0.12

Source: Combined audit and NEED dataset: Random sample of Electricity meters

Table 7.20 Electricity: Own Price Elasticity at Different Prices of Electricity and Tariffs (per kWh) – RE Model

Price	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
Fixed Tariff							
31p	13,250	-0.19	0.10	-2.03	0.04	-0.38	-0.01
33p	13,250	-0.23	0.10	-2.23	0.03	-0.44	-0.03
35p	13,250	-0.30	0.12	-2.42	0.02	-0.53	-0.06
Multi-Rate Fixed							
31p	13,250	-0.18	0.15	-1.26	0.21	-0.47	0.10
33p	13,250	-0.27	0.16	-1.67	0.09	-0.58	0.05
35p	13,250	-0.39	0.18	-2.18	0.03	-0.75	-0.04
Multi-Rate Standard							
31p	13,250	0.25	0.03	9.47	0.00	0.19	0.30
33p	13,250	0.24	0.03	8.06	0.00	0.18	0.30
35p	13,250	0.23	0.04	6.41	0.00	0.16	0.30
Standard							
31p	13,250	-0.29	0.08	-3.60	0.00	-0.45	-0.13
33p	13,250	-0.38	0.09	-4.34	0.00	-0.56	-0.21
35p	13,250	-0.52	0.10	-5.14	0.00	-0.72	-0.32

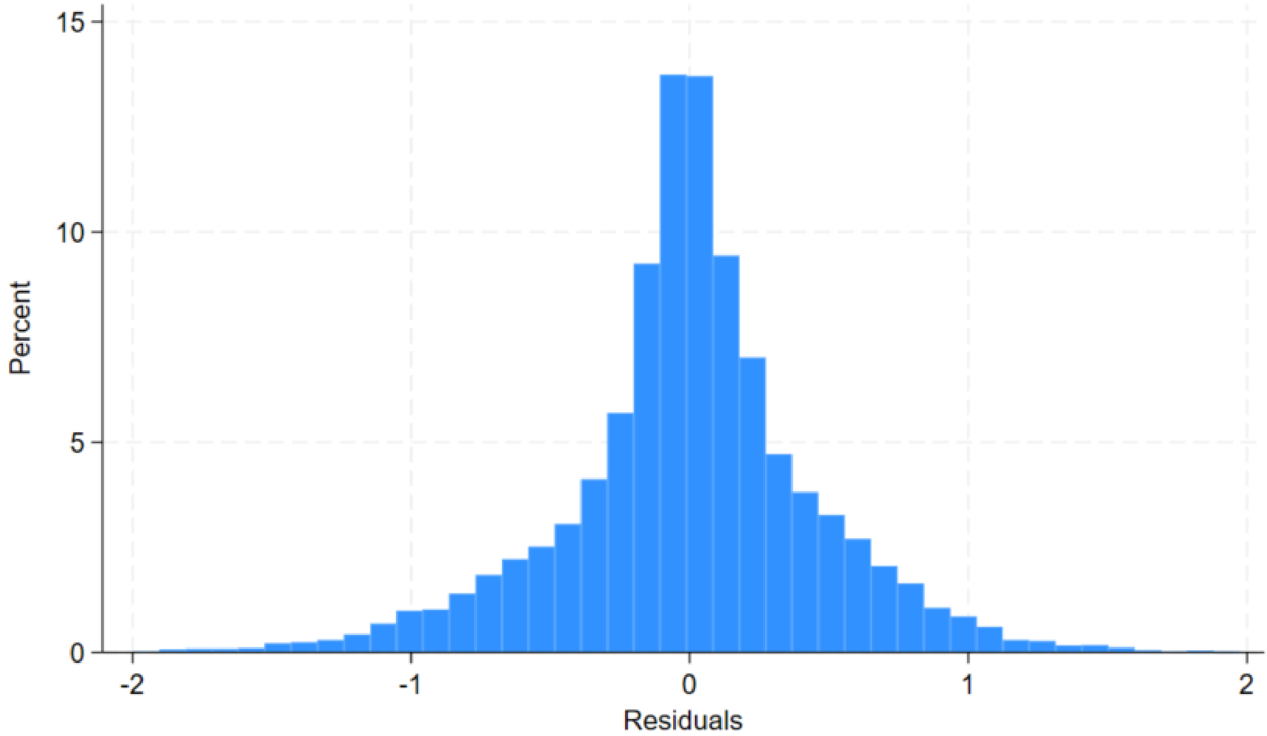
Source: Combined audit and NEED dataset: Random sample of Electricity meters

Table 7.21 Electricity: Own Price Elasticity at Different Register Descriptions and Tariff Type (per kWh) – RE Model

Tariff Type	No. of Observations	Elasticity	Standard Error	Z-Score	P-Value	95% Confidence Interval Lower bound	95% Confidence Interval Upper bound
Day							
Fixed	3,623	-0.20	0.10	-2.06	0.04	-0.39	-0.01
Multi-Rate Fixed	3,623	0.29	0.08	3.40	0.00	0.12	0.45
Multi-Rate Standard	3,623	0.24	0.03	10.14	0.00	0.20	0.30
Standard	3,623	-0.48	0.10	-4.94	0.00	-0.67	-0.29
Night							
Fixed	3,625	-0.20	0.10	-2.06	0.04	-0.39	-0.01
Multi-Rate Fixed	3,625	0.96	0.12	8.14	0.00	0.73	1.19
Multi-Rate Standard	3,625	0.26	0.02	16.11	0.00	0.23	0.30
Standard	3,625	-0.48	0.10	-4.94	0.00	-0.67	-0.29

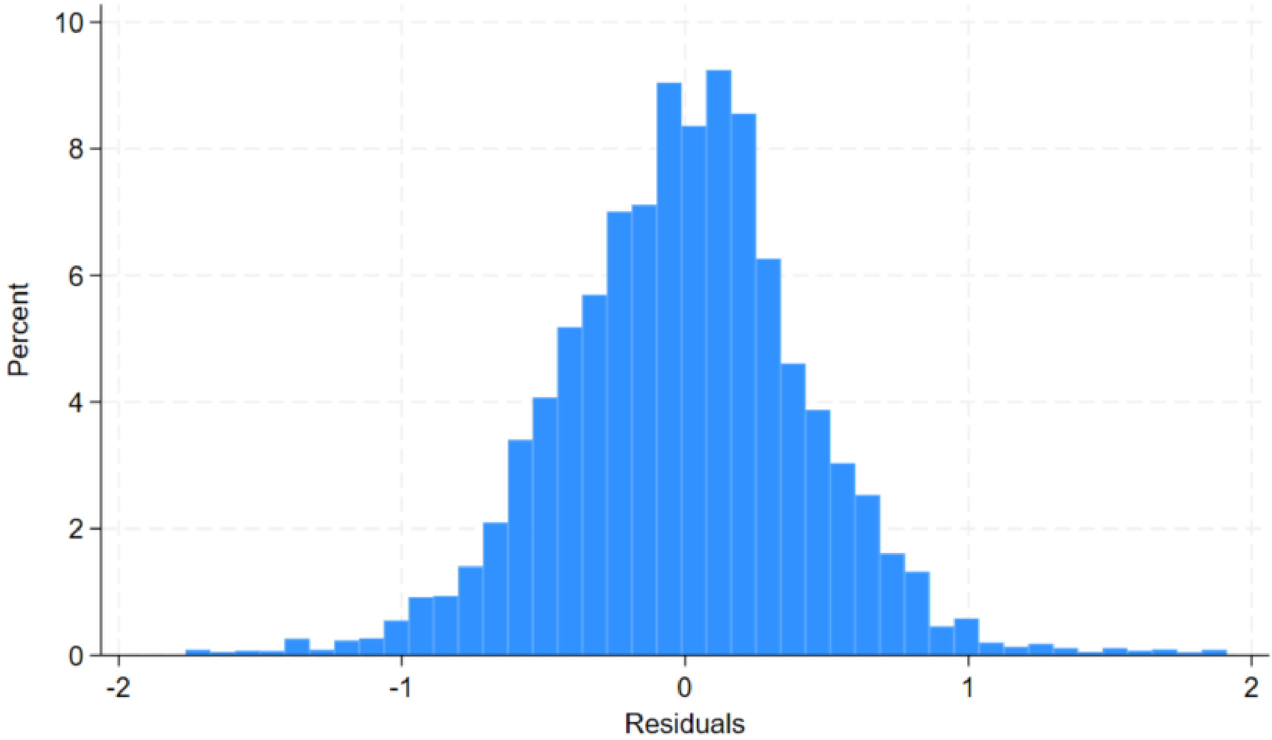
Source: Combined audit and NEED dataset: Random sample of Electricity meter

Figure 7.5 Electricity: Residual Comparison (e) – RE Model



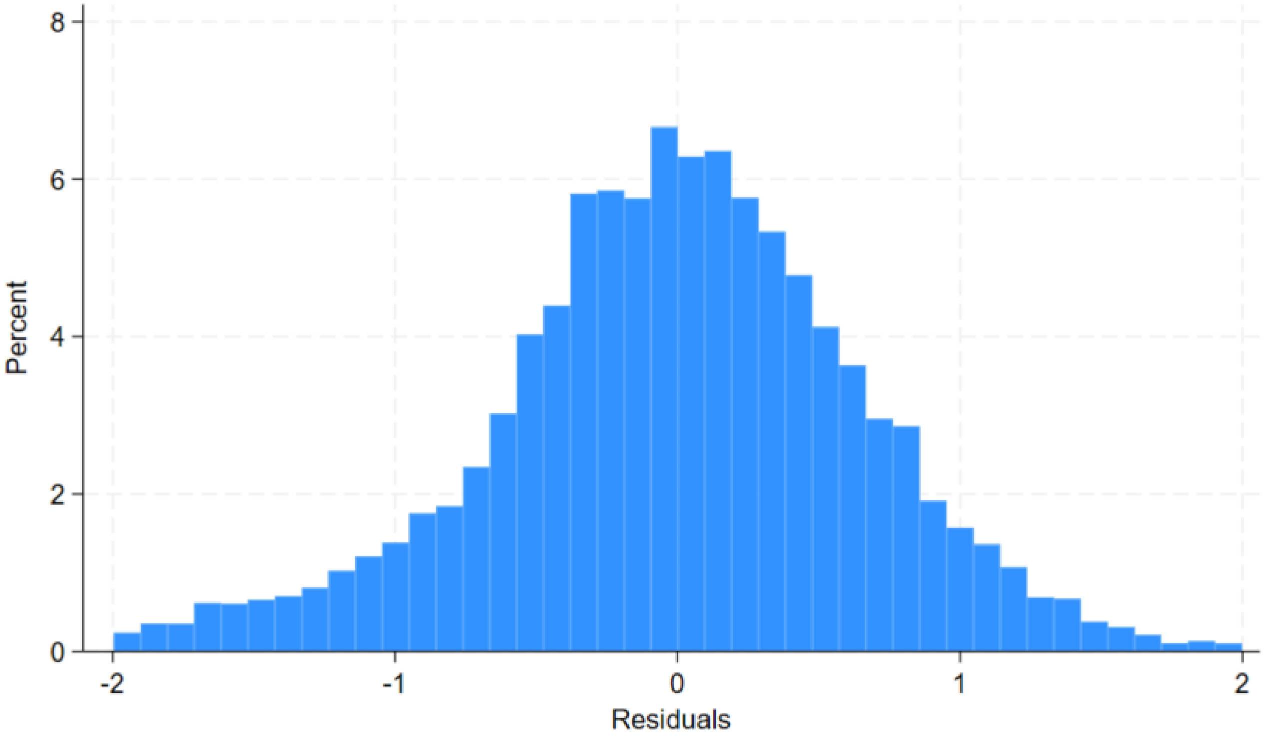
Source: Combined audit and NEED dataset: Random sample of Electricity meters

Figure 7.6 Electricity: Residual Comparison (u) – RE Model



Source: Combined audit and NEED dataset: Random sample of Electricity meters

Figure 7.7 Electricity: Residual Comparison (manually programmed) – RE Model



Source: Combined audit and NEED dataset: Random sample of Electricity meters

Figure 7.8 Electricity: Observed vs Predicted – RE Model

Source: Combined audit and NEED dataset: Random sample of Electricity meters

Table 7.22 Electricity: Sensitivity Checks – RE Model

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Random Effects - Income-Price Interaction	Random Effects - Income^2	Random Effects - Daily Q (1-110 kWh)	Random Effects - Ratio (0 - 0.050)	Random Effects - EPC Interaction	Random Effects - Only Price	Random Effects - Reg Type Interaction	Random Effects - Normal
lnPrice	-0.543	3.441**	3.087**	3.436**	838.6*	2.369***	1.974***	3.442**
	(1.443)	(1.426)	(1.449)	(1.422)	(473.0)	(0.346)	(0.477)	(1.425)
c.lnPrice#c.lnPrice	-0.335	-0.527**	-0.470**	-0.527**	-117.9*	-0.322***	-0.262***	-0.527**
	(0.213)	(0.213)	(0.217)	(0.213)	(67.60)	(0.0527)	(0.0726)	(0.213)
2.EPC	-0.533***	-0.532***	-0.526***	-0.531***	1,485*	-0.536***	-0.534***	-0.532***
	(0.190)	(0.190)	(0.195)	(0.190)	(827.4)	(0.191)	(0.191)	(0.190)
3.EPC	-0.492***	-0.499***	-0.491**	-0.499***	1,485*	-0.502***	-0.502***	-0.498***
	(0.190)	(0.190)	(0.195)	(0.190)	(827.4)	(0.191)	(0.191)	(0.190)

4.EPC	-0.423**	-0.429**	-0.424**	-0.429**	1,487*	-0.432**	-0.433**	-0.428**
	(0.190)	(0.190)	(0.195)	(0.190)	(827.4)	(0.191)	(0.191)	(0.190)
5.EPC	-0.449**	-0.452**	-0.428**	-0.456**	1,485*	-0.457**	-0.455**	-0.451**
	(0.190)	(0.191)	(0.196)	(0.190)	(827.4)	(0.191)	(0.191)	(0.191)
6.EPC	-0.380*	-0.382*	-0.375*	-0.376*	1,484*	-0.390**	-0.388**	-0.382*
	(0.197)	(0.197)	(0.202)	(0.197)	(827.4)	(0.198)	(0.198)	(0.197)
7.EPC	-0.357*	-0.356*	-0.329	-0.356*	1,485*	-0.369*	-0.367*	-0.356*
	(0.212)	(0.213)	(0.218)	(0.212)	(827.4)	(0.213)	(0.213)	(0.212)
1b.EPC#co.lnPrice					0			
					(0)			
2.EPC#c.lnPrice					-835.7*			
					(473.0)			
3.EPC#c.lnPrice					-836.0*			

					(473.0)			
4.EPC#c.lnPrice					-836.9*			
					(473.0)			
5.EPC#c.lnPrice					-835.9*			
					(473.0)			
6.EPC#c.lnPrice					-835.2*			
					(473.0)			
7.EPC#c.lnPrice					-836.1*			
					(473.0)			
1b.EPC#co.lnPrice#co.lnPrice					0			
					(0)			
2.EPC#c.lnPrice#c.lnPrice					117.5*			
					(67.60)			

3.EPC#c.lnPrice#c.lnPrice					117.5*			
					(67.60)			
4.EPC#c.lnPrice#c.lnPrice					117.7*			
					(67.60)			
5.EPC#c.lnPrice#c.lnPrice					117.5*			
					(67.60)			
6.EPC#c.lnPrice#c.lnPrice					117.4*			
					(67.60)			
7.EPC#c.lnPrice#c.lnPrice					117.6*			
					(67.60)			
2.TariffType	-9.981***	-6.718**	-8.046**	-6.757**	-0.0743	-0.0740	-0.0238	-6.718**
	(3.066)	(3.076)	(3.141)	(3.069)	(0.0497)	(0.0495)	(0.0499)	(3.076)
3.TariffType	0.466	3.641	3.202	3.481	-0.224***	-0.224***	-0.208***	3.642

	(2.463)	(2.467)	(2.513)	(2.462)	(0.0364)	(0.0364)	(0.0369)	(2.467)
4.TariffType	-10.01***	-7.597**	-7.711**	-7.654**	-0.0281	-0.0278	-0.0105	-7.598**
	(3.046)	(3.059)	(3.128)	(3.052)	(0.0313)	(0.0312)	(0.0315)	(3.059)
5.RegType	-0.0257***	-0.0292***	-0.0319***	-0.0283***	-0.0352***	-0.0345***	0.846	-0.0292***
	(0.00961)	(0.00967)	(0.00994)	(0.00960)	(0.00966)	(0.00965)	(0.882)	(0.00967)
6.RegType	-0.00793	-0.00993	-0.0116	-0.0107	-0.00379	-0.00411	-2.241	-0.00991
	(0.0144)	(0.0144)	(0.0148)	(0.0143)	(0.0144)	(0.0144)	(1.424)	(0.0144)
8.RegType	-0.540**	-0.551***	-0.593***	-0.552***	-0.516**	-0.514**	-32.21***	-0.551***
	(0.212)	(0.212)	(0.217)	(0.212)	(0.212)	(0.213)	(4.581)	(0.212)
9.RegType	-0.216	-0.270	-0.326	-0.268	-0.267	-0.266	-5.175***	-0.269
	(0.212)	(0.212)	(0.217)	(0.212)	(0.212)	(0.212)	(1.986)	(0.212)
10.RegType	0.303	0.339	0.275	0.341	0.486	0.504		0.339

	(0.344)	(0.345)	(0.356)	(0.345)	(0.344)	(0.344)		(0.345)
11.RegType	-0.272*	-0.285*	-0.280*	-0.284*	-0.295*	-0.302*	10.39*	-0.285*
	(0.163)	(0.163)	(0.167)	(0.163)	(0.163)	(0.164)	(6.167)	(0.163)
12.RegType	-0.0403	-0.0528	-0.0950	-0.0521	-0.0444	-0.0462	-80.39	-0.0515
	(0.223)	(0.224)	(0.229)	(0.223)	(0.224)	(0.224)	(98.47)	(0.224)
lnIncome	-0.807***	0.0469	0.0875***	0.0855***	0.0868***	0.0880***	0.0881***	0.0864***
	(0.0631)	(0.224)	(0.0186)	(0.0181)	(0.0182)	(0.0183)	(0.0183)	(0.0182)
lnFloorArea	0.00607	0.0219	-0.120	-0.00657	-0.0160	-0.000383	0.000679	0.0168
	(0.223)	(0.225)	(0.227)	(0.222)	(0.223)	(0.223)	(0.224)	(0.223)
c.lnFloorArea#c.lnFloorArea	0.0218	0.0199	0.0380	0.0230	0.0250	0.0227	0.0224	0.0205
	(0.0255)	(0.0258)	(0.0259)	(0.0254)	(0.0256)	(0.0256)	(0.0256)	(0.0255)
2.UsageSource	0.0214	0.0228	0.0237	0.0252	0.0169	0.0168	0.0149	0.0228

	(0.0457)	(0.0460)	(0.0463)	(0.0458)	(0.0461)	(0.0461)	(0.0460)	(0.0460)
3.UsageSource	0.234***	0.227***	0.217***	0.230***	0.223***	0.223***	0.219***	0.227***
	(0.0402)	(0.0405)	(0.0408)	(0.0403)	(0.0405)	(0.0405)	(0.0404)	(0.0405)
4.UsageSource	-0.0435	-0.0176	0.0184	-0.0190	-0.0795	-0.0865	-0.101	-0.0186
	(0.198)	(0.198)	(0.202)	(0.197)	(0.198)	(0.198)	(0.203)	(0.198)
5o.UsageSource	-	-	-	-	-	-	-	-
2.Company	-0.0330	-0.0340	-0.0174	-0.0342	-0.0419	-0.0466	-0.0349	-0.0341
	(0.0306)	(0.0307)	(0.0314)	(0.0304)	(0.0306)	(0.0306)	(0.0309)	(0.0306)
3.Company	-0.151***	-0.150***	-0.147***	-0.152***	-0.163***	-0.165***	-0.161***	-0.150***
	(0.0352)	(0.0352)	(0.0361)	(0.0350)	(0.0352)	(0.0353)	(0.0353)	(0.0352)
4o.Company	-	-	-	-	-	-	-	-

5.Company	-0.0315	-0.0275	0.0236	-0.0345	-0.0437	-0.0456	-0.0308	-0.0274
	(0.0672)	(0.0673)	(0.0687)	(0.0669)	(0.0674)	(0.0675)	(0.0678)	(0.0673)
2.MonthMid	-0.0422***	-0.0411***	-0.0400**	-0.0391**	-0.0402**	-0.0402**	-0.0389**	-0.0411***
	(0.0157)	(0.0158)	(0.0162)	(0.0157)	(0.0158)	(0.0158)	(0.0158)	(0.0158)
3.MonthMid	-0.0883***	-0.0873***	-0.0938***	-0.0850***	-0.0888***	-0.0888***	-0.0853***	-0.0873***
	(0.0160)	(0.0161)	(0.0165)	(0.0160)	(0.0161)	(0.0161)	(0.0161)	(0.0161)
4.MonthMid	-0.160***	-0.161***	-0.164***	-0.158***	-0.144***	-0.145***	-0.148***	-0.161***
	(0.0165)	(0.0166)	(0.0170)	(0.0165)	(0.0165)	(0.0164)	(0.0164)	(0.0166)
5.MonthMid	-0.271***	-0.277***	-0.287***	-0.274***	-0.260***	-0.259***	-0.264***	-0.277***
	(0.0232)	(0.0233)	(0.0239)	(0.0231)	(0.0232)	(0.0232)	(0.0232)	(0.0233)
6.MonthMid	-0.366***	-0.370***	-0.440***	-0.367***	-0.365***	-0.364***	-0.357***	-0.370***
	(0.0429)	(0.0431)	(0.0441)	(0.0430)	(0.0431)	(0.0431)	(0.0430)	(0.0431)

7.MonthMid	-0.430***	-0.440***	-0.491***	-0.437***	-0.413***	-0.411***	-0.410***	-0.440***
	(0.0439)	(0.0442)	(0.0452)	(0.0441)	(0.0438)	(0.0438)	(0.0437)	(0.0442)
8.MonthMid	-0.406***	-0.426***	-0.470***	-0.423***	-0.421***	-0.420***	-0.431***	-0.426***
	(0.0693)	(0.0697)	(0.0711)	(0.0694)	(0.0696)	(0.0695)	(0.0694)	(0.0697)
9.MonthMid	-0.301***	-0.317***	-0.364***	-0.314***	-0.313***	-0.313***	-0.313***	-0.317***
	(0.0664)	(0.0668)	(0.0682)	(0.0666)	(0.0664)	(0.0663)	(0.0663)	(0.0668)
10.MonthMid	-0.216***	-0.226***	-0.268***	-0.220***	-0.223***	-0.225***	-0.248***	-0.226***
	(0.0546)	(0.0549)	(0.0562)	(0.0547)	(0.0544)	(0.0543)	(0.0546)	(0.0549)
11.MonthMid	-0.103*	-0.112**	-0.148***	-0.108**	-0.110**	-0.111**	-0.134**	-0.112**
	(0.0546)	(0.0549)	(0.0562)	(0.0547)	(0.0544)	(0.0544)	(0.0546)	(0.0549)
12.MonthMid	0.0539	0.0453	0.0169	0.0466	0.0469	0.0456	0.0250	0.0453
	(0.0545)	(0.0548)	(0.0561)	(0.0546)	(0.0543)	(0.0543)	(0.0545)	(0.0548)
2022.YearMid	-13.77***	-0.0352	-24.48***	-0.0354	-0.0346	-0.0329	-0.0134	-25.26***

	(2.528)	(0.0526)	(2.462)	(0.0524)	(0.0521)	(0.0520)	(0.0523)	(2.418)
2023o.YearMid		-		-	-	-	-	
AdultOccupants	0.0581***	0.0582***	0.0594***	0.0592***	0.0587***	0.0585***	0.0591***	0.0582***
	(0.0112)	(0.0112)	(0.0115)	(0.0112)	(0.0113)	(0.0113)	(0.0113)	(0.0112)
2.Region	0.0409	0.0443	0.0333	0.0440	0.0185	0.0227	0.0245	0.0444
	(0.0449)	(0.0449)	(0.0460)	(0.0447)	(0.0449)	(0.0449)	(0.0450)	(0.0449)
3.Region	-0.0290	-0.0177	-0.0236	-0.0161	-0.0500	-0.0465	-0.0384	-0.0167
	(0.0497)	(0.0500)	(0.0509)	(0.0494)	(0.0496)	(0.0496)	(0.0497)	(0.0497)
4.Region	0.00527	0.0111	0.0263	0.0111	-0.000859	0.00173	0.00180	0.0111
	(0.0528)	(0.0528)	(0.0540)	(0.0524)	(0.0529)	(0.0530)	(0.0530)	(0.0528)
6.Region	0.0173	0.0188	0.0145	0.0255	-0.0212	-0.0109	-0.00139	0.0187
	(0.0601)	(0.0601)	(0.0616)	(0.0598)	(0.0601)	(0.0601)	(0.0602)	(0.0601)

7.Region	0.121**	0.125**	0.124**	0.126**	0.115**	0.120**	0.117**	0.125**
	(0.0526)	(0.0527)	(0.0540)	(0.0523)	(0.0527)	(0.0528)	(0.0529)	(0.0527)
8.Region	-0.0266	-0.0171	-0.0267	-0.0129	-0.00837	-0.00362	-0.00793	-0.0169
	(0.0661)	(0.0661)	(0.0678)	(0.0658)	(0.0662)	(0.0663)	(0.0664)	(0.0661)
10.Region	0.0290	0.0346	0.0285	0.0359	0.00967	0.0136	0.0200	0.0348
	(0.0501)	(0.0501)	(0.0513)	(0.0498)	(0.0501)	(0.0502)	(0.0502)	(0.0501)
11.Region	-0.00826	-0.00550	0.0221	-0.00474	-0.0144	-0.0203	-0.0181	-0.00583
	(0.0725)	(0.0726)	(0.0740)	(0.0723)	(0.0726)	(0.0727)	(0.0728)	(0.0725)
12.Region	0.0358	0.0367	0.0301	0.0386	0.0223	0.0276	0.0272	0.0368
	(0.0465)	(0.0465)	(0.0476)	(0.0462)	(0.0465)	(0.0466)	(0.0466)	(0.0465)
13.Region	-0.352	-0.349	-0.364	-0.345	-0.329	-0.341	-0.343	-0.348
	(0.317)	(0.317)	(0.325)	(0.317)	(0.319)	(0.318)	(0.318)	(0.317)
14.Region	0.0593	0.0648	0.0664	0.0674	0.0467	0.0551	0.0565	0.0647

	(0.0498)	(0.0498)	(0.0510)	(0.0495)	(0.0499)	(0.0500)	(0.0500)	(0.0498)
15.Region	0.0960*	0.104*	0.0954*	0.100*	0.101*	0.106**	0.103*	0.104*
	(0.0534)	(0.0534)	(0.0547)	(0.0530)	(0.0535)	(0.0536)	(0.0536)	(0.0534)
2.MeterStatus	-0.0709***	-0.0744***	-0.0797***	-0.0732***	-0.0676***	-0.0688***	-0.0687***	-0.0745***
	(0.0184)	(0.0185)	(0.0189)	(0.0184)	(0.0184)	(0.0184)	(0.0184)	(0.0185)
3o.MeterStatus	-	-	-	-	-	-	-	-
1.Tenure	-0.00935	-0.0112	-0.00435	-0.0107	-0.0153	-0.0140	-0.0137	-0.0114
	(0.0265)	(0.0265)	(0.0271)	(0.0263)	(0.0265)	(0.0266)	(0.0266)	(0.0265)
2.Tenure	0.0569	0.0520	0.0462	0.0520	0.0519	0.0557	0.0560	0.0536
	(0.0373)	(0.0384)	(0.0382)	(0.0371)	(0.0373)	(0.0374)	(0.0374)	(0.0373)
2.PropType	-0.0494	-0.0494	-0.0636	-0.0482	-0.0614	-0.0485	-0.0482	-0.0491

	(0.0550)	(0.0550)	(0.0563)	(0.0547)	(0.0551)	(0.0552)	(0.0552)	(0.0550)
3.PropType	0.0349	0.0400	0.0554	0.0416	0.0344	0.0378	0.0394	0.0402
	(0.0525)	(0.0525)	(0.0537)	(0.0520)	(0.0526)	(0.0527)	(0.0527)	(0.0525)
4.PropType	-0.0544	-0.0481	-0.0468	-0.0471	-0.0542	-0.0494	-0.0502	-0.0485
	(0.0524)	(0.0525)	(0.0537)	(0.0520)	(0.0525)	(0.0526)	(0.0527)	(0.0524)
5.PropType	-0.0123	-0.00901	0.00321	-0.00798	-0.0194	-0.0113	-0.00873	-0.00942
	(0.0517)	(0.0518)	(0.0530)	(0.0512)	(0.0518)	(0.0519)	(0.0519)	(0.0517)
lnElec21	0.330***	0.330***	0.335***	0.333***	0.331***	0.329***	0.329***	0.331***
	(0.0105)	(0.0106)	(0.0108)	(0.0105)	(0.0106)	(0.0106)	(0.0106)	(0.0106)
1b.TariffType#co.lnPrice	0	0	0	0				0
	(0)	(0)	(0)	(0)				(0)
2.TariffType#c.lnPrice	5.904***	3.913**	4.842**	3.936**				3.913**
	(1.907)	(1.913)	(1.953)	(1.909)				(1.913)

3.TariffType#c.lnPrice	-0.829	-2.703*	-2.403	-2.614*				-2.704*
	(1.487)	(1.490)	(1.517)	(1.487)				(1.490)
4.TariffType#c.lnPrice	5.995***	4.521**	4.607**	4.555**				4.521**
	(1.828)	(1.835)	(1.876)	(1.831)				(1.835)
1b.TariffType#co.lnPrice#co.lnPrice	0	0	0	0				0
	(0)	(0)	(0)	(0)				(0)
2.TariffType#c.lnPrice#c.lnPrice	-0.868***	-0.566*	-0.720**	-0.569*				-0.566*
	(0.294)	(0.295)	(0.301)	(0.294)				(0.295)
3.TariffType#c.lnPrice#c.lnPrice	0.181	0.456**	0.406*	0.444**				0.456**
	(0.223)	(0.223)	(0.227)	(0.223)				(0.223)
4.TariffType#c.lnPrice#c.lnPrice	-0.894***	-0.670**	-0.685**	-0.675**				-0.670**
	(0.273)	(0.274)	(0.280)	(0.274)				(0.274)
c.lnIncome#c.lnPrice	0.259***							

	(0.0175)							
2023.YearMid	-13.72***		-24.47***					-25.22***
	(2.534)		(2.468)					(2.424)
o._cons	0		0					0
	(0)		(0)					(0)
c.lnIncome#c.lnIncome		0.00190						
		(0.0107)						
10o.RegType							-	
2b.RegType#co.lnPrice							0	
							(0)	
5.RegType#c.lnPrice							-0.584	
							(0.546)	

6.RegType#c.lnPrice							1.557*	
							(0.879)	
8.RegType#c.lnPrice							19.08***	
							(2.837)	
9.RegType#c.lnPrice							2.810**	
							(1.266)	
10.RegType#c.lnPrice							0.123	
							(0.107)	
11.RegType#c.lnPrice							-5.891	
							(3.717)	
12.RegType#c.lnPrice							45.70	
							(53.67)	
2b.RegType#co.lnPrice#co.lnPrice							0	

							(0)	
5.RegType#c.lnPrice#c.lnPrice							0.0949	
							(0.0838)	
6.RegType#c.lnPrice#c.lnPrice							-0.262*	
							(0.135)	
8.RegType#c.lnPrice#c.lnPrice							-2.834***	
							(0.433)	
9.RegType#c.lnPrice#c.lnPrice							-0.394*	
							(0.201)	
10o.RegType#co.lnPrice#co.lnPrice							0	
							(0)	
11.RegType#c.lnPrice#c.lnPrice							0.809	
							(0.561)	

12.RegType#c.lnPrice#c.lnPrice							-6.489	
							(7.310)	
Constant		-25.03***		-25.17***	-1,510*	-23.89***	-23.28***	
		(2.667)		(2.419)	(827.4)	(0.790)	(0.953)	
Observations	19,544	19,544	19,750	19,718	19,544	19,544	19,544	19,544
Number of meter_id	2,874	2,874	2,880	2,899	2,874	2,874	2,874	2,874

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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