4-146-24 Fawcett

Crisis ready - how longitudinal data helps to make sense of crises and how to prepare for the next one

Tina Fawcett
Environmental Change Institute
University of Oxford
Oxford OX1 3QY, UK

Eoghan McKenna
UCL Energy Institute
University College London
London WC1H 0NN, UK

Phil Grunewald
Department of Engineering Science
University of Oxford
Oxford OX1 3PJ, UK

Abstract

During the winter 2022-23 residential energy prices were exceptionally high in Europe. In the UK, the electricity retail market was temporarily suspended and replaced with the government's 'energy price guarantee' and other financial support costing an estimated £69bn (€80.7bn). Despite this significant intervention, UK households experienced unprecedentedly high gas and electricity prices. How did they respond?

While in aggregate, prices rose and demand fell, the distribution of these effects was dramatically uneven among different societal groups. We present results from three sources of data: the Smart Energy Research Lab (SERL), the Energy Demand Observatory and Laboratory (EDOL) and Utilita. The data span the period 2019 to 2023 for over 17,000 UK households and include gas and electricity consumption, tariff data, demographics and contextual information.

The results highlight diversities and complexities in customer responses to price changes. We found that high prices put pressure on the most vulnerable households in different ways. Among the Utilita data for 11,500 prepayment meter customers, a group where fuel poverty is highly concentrated, annual gas use per household fell by 20%, while electricity use fell by 3%. When specifically comparing high resolution price elasticities for electricity among the EDOL sample, many low-income households were not able to reduce their demand further. The SERL studies showed that more affluent households are more responsive to increases in electricity price while those struggling financially are more responsive to rising gas prices. They also explored what actions were taken to reduce energy demand and by whom.

These studies have proved to be valuable, yielding novel and valuable insights in times of crises. They have also demonstrated that collection of energy and contextual data and its evaluation are important roles for academic research in the net zero transition. By investing in longitudinal studies, governments have the means swiftly to understand future crises and to take the necessary action to avert serious social consequences.

Introduction

During winter 2022/23 residential gas and electricity prices were exceptionally high in Europe. Household energy bills increased significantly due to factors including an increased global demand for gas following the pandemic and later the impact of Russia’s invasion of Ukraine on energy markets. In the UK, average annual household bills for gas and electricity increased from £1,277 in winter 2021/22 to £3,549 in winter 2022/23 (NAO 2023). The government responded by subsidising prices for all households, and similar decisions were made across Europe, where governments provided unprecedented energy support payments. In total, EU Member States spent up to €646 billion on emergency measures in 2022 (ACER 2023). Despite the huge expenditure of public money, many millions of households still suffered from inadequate access to energy and had to 'self-ration' their use of energy. When the next energy-related crisis arises, it is vital to have learnt lessons from this one, to have understood how, why and for whom energy use changed, and for governments to be ready with better quality policy interventions which effectively target help to the most vulnerable.

This paper brings together longitudinal energy data on three different samples of UK households to explore the effects of the energy price crisis on different groups, particularly in terms of use of electricity and gas (used by >85% of households for heating). These studies are:

- the Smart Energy Research Lab (SERL) which analyses gas and electricity use change and its association with energy saving actions, household characteristics, and indicators of fuel poverty,
- the Energy Demand Observatory and Laboratory (EDOL) Cost of Living study, which analyses electricity use change and its association with electricity price changes and
- the Utilita study – which analyses gas and electricity use change for pre-payment meter users and its association with household characteristics, and energy price changes.

Collectively, the data span the period 2019 to 2023 for over 17,000 UK households and include gas and electricity consumption, tariff data, demographics and contextual information.

The aim of the paper is to highlight key common findings from the studies and to explore any significant differences, and situate the new findings within the existing literature. Where studies vary significantly in their findings, this is investigated, considering the extent to which these are based on sampling and methodological differences. Using this analysis, the paper draws out lesson for research and policy, and makes the case for greater use of smart meter data and longitudinal studies in expanding knowledge, improving policy design and being ready to respond to future crises.

UK energy price and policy context

The dramatic rise in prices is illustrated by the 'energy price cap', introduced by the UK energy regulator, Ofgem, in January 2019. The cap is communicated as annual gas plus electricity costs for an average household (**Error! Reference source not found.**) but is actually a cap on costs per kWh, and many households pay more than this average value (Ofgem 2023). The price cap in Q1 2024 is almost double the amount it was in Q4 2020.

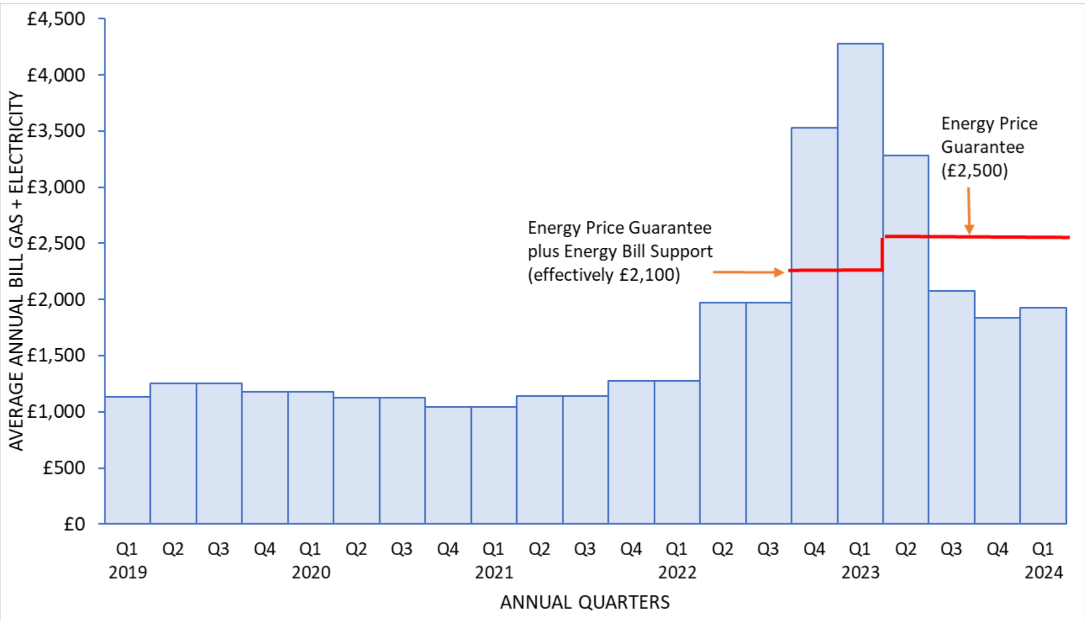


Figure 1: Ofgem price cap for average gas and electricity dual fuel customers, GB, by quarter, Q1 2019 – Q1 2024, plus effect of government intervention

The predictions of energy analysts are that UK energy prices will remain significantly higher than typical until at least 2030 (Cornwall Insight 2022).

To reduce the impact of energy bill increases, the UK government introduced the Energy Price Guarantee on 1st October 2022, designed to be a temporary, additional measure to protect consumers (Table 1). A further £400 (€470) was provided to every household, through the Energy Bills Support Scheme. There were additional schemes for businesses and to support users of other fuels (NAO 2023). The current estimate of the schemes' cost is £69 billion (€80.7bn), of which almost £50bn (€58.5bn) was spent on the Energy Bills Support Scheme and Energy Price Guarantee (NAO 2023).

Table 1: Additional energy price support, 2022/23, all UK households

Name of scheme	Amount	Payment type
Energy Bills Support Scheme (EBSS)	£400 (€470)	Paid via 6 monthly payments direct to bills / smart prepayment electricity meters from October 2022 to March 2023. Traditional PPM customers got vouchers through the post, 13% of which not redeemed by October 2023 (DESNZ 2023)
Energy Price Guarantee (EPG)	Limited Energy Price Cap to £2,500 (€2930) per annum in GB, £2,100 in Northern Ireland	Customers faced lower than market price unit costs per kWh of gas and electricity, either through bills or via meters. From 1 October 2022.

Source: (NAO 2023)

Literature review

Smart metering

The prevalence of smart metering varies considerably across Europe. By the end of 2022, thirteen EU countries had an electricity smart meter penetration rate of 80 % or more. However, many markets have yet to make smart meters available to their consumers (ACER 2023). In addition to providing better information and feedback to customers, energy companies and system operators, and enabling new, flexibile pricing models (e.g. peak or time-of-use prices), there is growing interest in using smart meter data to alleviate fuel poverty. Utilita produced a report, 'Smart Energy Data for Fuel Poverty Avoidance', which called for urgent action to alleviate fuel poverty (Utilita Energy 2023). Smart prepayment meter data has been used in an exploratory project in the UK to facilitate better identification and targeting of fuel poor households, with methods under development (Urban Tide 2022). However, such use of smart data is in its infancy.

Pre-payment meter users

Prepayment energy metering – where customers must make payments or have credit before they can use energy – is significant in some countries, but absent or rarely used in others. (Kambule, Yessoufou et al. 2018) find that South Africa and the UK are the two countries where this technology is most adopted. Approximately 4.5 million UK households, around 15% of all households, have one or more prepayment meters (Palmer, Boardman et al. 2023). PPMs can either be chosen voluntarily by customers (the majority), while others may have a PPM installed to repay debts at the request of their supplier. Households with prepayment meters are known to be a group where fuel poverty is highly concentrated. Fuel poverty results from a combination of income, the energy requirements and efficiencies of homes and heating equipment, and the cost of energy (Boardman 1991). Figures for England in 2022 show 27% of gas and 28% of electricity PPM users being in fuel poverty, using the government definition, three times the rate for customers paying by direct debit (DESNZ 2023). Research in 2022 showed 55% of UK PPM households are in receipt of a means-tested benefit, i.e. have low incomes (Utilita Energy 2022).

Pre-payment meters have both advantages and disadvantages. The key advantages are that they are a useful way to budget and control expenditure, to avoid going into debt, or to pay back a debt to the energy company over a manageable period. However, this pay-as-you-go method means that households experience significant seasonal variations in energy expenditure. In the UK this variation relates especially to gas, the main heating fuel. A major and longstanding criticism of PPMs is that customers who run out of credit are allowed to 'self-disconnect' from their energy supply. The disconnection of household energy supply by energy companies has effectively been banned in the UK (Citizens Advice 2023), but many PPM household experience self-disconnection. Empirical research internationally suggests that despite its drawbacks, prepayment metering remains a popular payment method among consumers, who appreciate the feedback and sense of control over their budgets and electricity use it provides (Telles Esteves, Cyrino Oliveira et al. 2016).

Elasticity of energy demand

The literature on the price elasticity of residential electricity and heating fuels is limited and contested. A 2017 meta-analysis assessed 11 reviews dating between 1975 and 2012, of which only two explicitly addressed electricity, rather than gasoline and car fuels (Labandeira, Labeaga et al. 2017). (Espey and Espey 2004) estimated the short-term elasticity of residential electricity demand to be -0.35 short term and -0.85 long term. However, (Zhu, Li et al. 2018) conclude after extensive meta-analysis of international reviews that residential electricity demand is almost inelastic in the short term. It is generally agreed that long-term elasticity is greater than short-term price elasticity; households are able to invest in energy efficiency and make other changes to reduce energy use in the longer term, with fewer options available in the short term. The European energy price crisis in winter 2022/23 can best be described as a short-term issue.

Research shows considerable flexibility in terms of significant changes in energy use over the very short-term (e.g. shifting demand from peak hours in response to information or monetary incentives). However, that is not relevant to the energy price crisis, which is unfolding over months and years.

Research on crises

Unfortunately, the world has not been short of crises affecting the energy system in recent years. Some of these have operated at a country-level – e.g. the Fukushima nuclear disaster in Japan – but others have had global effects from the financial system crisis in 2008/09 to Covid 2020/21 and now the energy price crisis. In each case, there has been a narrative around 'building back better' and learning from the crisis. There has been thinking about how to do research in crises (Parag, Fawcett et al. 2023) and considerable opportunistic research on the impacts of Covid by building on existing programmes (e.g. (Zapata-Webborn, McKenna et al. 2023)). However, without the research methods and data collection infrastructure in place to investigate crises, quickly analyse results and communicate findings to policy makers, there remains the likelihood that lessons will not be learned.

Smart Energy Research Lab

Smart meter data for all types of households is available from the Smart Energy Research Lab (SERL) Observatory dataset, a research resource which consists of smart meter and contextual data from approximately 13,000 homes that are broadly representative of the GB population in terms of region and Index of Multiple Deprivation quintile (Few, Pullinger et al. 2022). Compared to the national average, the sample is over-representative of households that are owner-occupiers and financially well-off, and buildings that are larger and detached (Webborn, Few et al. 2021). In terms of energy use, the sample had an average gas use of 14,118 kWh/year per household in 2021, slightly higher than the national average of 13,300 in 2019, but a similar average electricity use of 3,588 kWh/year per household versus the national average for 2019 of 3,600 kWh/year (Few, Pullinger et al. 2022).

The studies using SERL data drawn on here focus on analysis of the energy price crisis in winter 2022/23. The main focus is the findings from (Zapata-Webborn, Hanmer et al. 2024), which undertakes analysis of energy (gas and electricity) use change and its association with energy saving actions, household characteristics, including indicators of fuel poverty, and tariff to a certain extent. This study made comparisons of gas and electricity use between winter 2021/22 (October – March) and winter 2022/23. This was done by comparing metered energy use in 2022/23 with a counterfactual calculated using a machine learning algorithm trained on data prior to the cost-of-living crisis that is then run with the weather during the cost-of-living crisis. The method is explained in detail elsewhere (Zapata-Webborn, McKenna et al. 2023).

Median consumers reduced their electricity consumption by 0.6kWh/day (8.4%) and their gas consumption by 4.9 kWh/day (10.8%). While most households reduced their energy consumption compared with the previous winter, some saw energy consumption rise by up to 50%. Conversely, some households saw very large reductions of over 50%. Median total energy bill increased from around £125 per month to £158 per month (taking account of the effect of government subsidies) – an increase of 26%.

Price elasticity for winter 2022/23 compared with winter 2021/22 was -9.9% for electricity and -7.1% for gas, respectively. The price elasticity was then calculated by fuel and 'financial wellbeing'. Opposite trends were found for electricity and gas elasticities: more affluent households are more responsive to increases in electricity price while those struggling financially are more responsive to rising gas prices.

(Huebner, Hanmer et al. 2023) analysed self-reported energy saving behaviour and wellbeing for the SERL Observatory sample during the winter of 2022/2023 and its change compared to previous winters. The analysis found that thermostat set-points were about 1°C lower during energy price crisis than in previous winters and that the participants were more likely to switch off their heating when the home was unoccupied. Evidence was found of a link between lower wellbeing and households that found it difficult to keep comfortably warm or those struggling to meet heating costs.

(Hanmer and Zapata-Webborn 2023) analysed in detail the characteristics of the households who reported reducing thermostat set-points and found of evidence of households in fuel poverty reducing thermostat set-points more than other types of households, as well as an increased proportion of households potentially under-heating their home (15.2% of households reported a thermostat set-point below 18°C versus 6.7% pre-energy price crisis).

EDOL Cost of Living Lab

The Energy Demand Observatory and Laboratory (www.edol.ac.uk), a project linked to SERL, seeks to establish a longitudinal and detailed energy data resource for the benefit of researchers, policy makers and the public. Alongside an observatory with n=2,000 UK households, currently in development, smaller scale 'laboratories' seek to investigate specific technologies and policy relevant questions. Among these is the 'cost of living lab', for which survey information is combined with real-time energy and tariff data (Grunewald 2023).

The EDOL cost of living lab sample consists of participants recruited via a proprietary online research panel of 100,000 members who are demographically, geographically and attitudinally representative of Great Britain. To improve the representativeness of the sample for the GB population with a smart meter, quotas by gender, region and work status were applied at the recruitment stage. For participating in the study, installing a Consumer Access Device and sharing their data for research purposes, participants receive a total annual reward of £15 in 2022, increasing to £20 in 2023. They were also rewarded with £2 for completing a survey covering socio-demographic and energy-use relevant questions, including affordability of energy. The sample has a good representation of household sizes, an over-representation of the 45 to 75 age group, and fewer households in privately rented accommodation. The survey was completed by 248 respondents. Of these, 200 have a valid smart meter ID and 157 provided consent and valid data, the final sample size.

The analysis focusses on the period between January 2022 and July 2023. In particular, the periods January-July are used as like-for-like comparison. The data is not temperature corrected. December 2022 was unusually cold and is not included in the comparison to reduce distortions. Values are based on half-hourly readings of electricity consumption (measured in kWh) and the incurred cost, which is recorded as pence per period and converted to a rate (p/kWh) for that same period.

With the highly resolved longitudinal data for each household, it is possible to establish how each of them responds to changes in price.

The scatter-plot in Figure 2 relates the relative changes in the tariff for electricity with the relative change in energy use between January 2022 and January 2023. Each data point represents one household. The majority of households are in the bottom right quadrant, meaning that their tariff increased, and average demand reduced. The linear regression fit has a negative slope, as would be expected for elastic prices. However, the correlation is weak with an R^2 of only 0.002. A repeat of this analysis for January to July inclusive showed no negative slope, i.e. zero price elasticity, and a very slight positive slope.

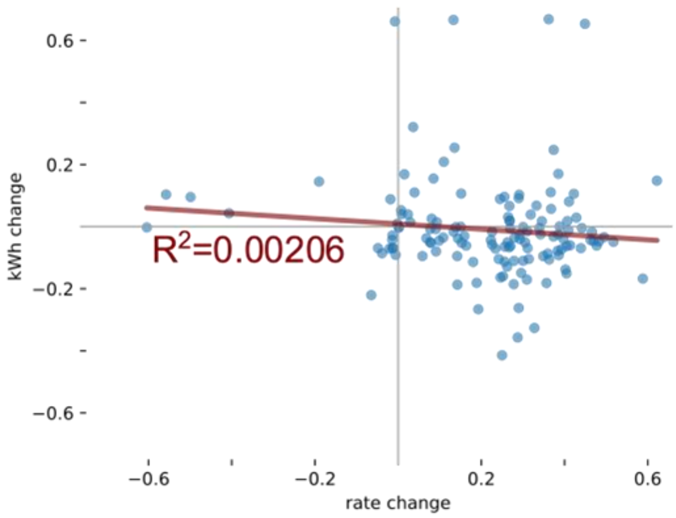


Figure 2: Comparing households in January 2022 with January 2023. (n=147 households)

If demand does not respond to price across the whole population, does it affect different income groups differently? Table 2 summarises figures for January 2022 and 2023 suggests that income groups were affected and responded differently.

Table 2: Relative electricity demand reduction and tariff increases between January 2022 and 2023 by household income band

Income [£k]	Demand [-%]	Tariff [%]
<21	5.7	21.4
21–41	5.0	24.9
41–62	8.0	13.8
62–76	19.6	25.1
>76	10.1	33.2

The top two income groups reduced demand the most, while also experiencing the greatest relative increases to their half-hourly tariffs. The lowest income group reduced demand the least.

Utilita, pre-payment meter users study

(Palmer, Boardman et al. 2023) provides evidence about the experience of GB households with prepayment meters in the years prior to and during the 2022/23 energy price crisis. The data was provided by Utilita, the UK's eighth largest domestic energy supplier which specialises in offering a smart-enabled prepayment service to 720,000 of its 760,000 customers. This compares with the UK as a whole, where 57% of all electricity and gas meters were smart (32.4 million out of 57.1 million), as at the end of March 2023 (NAO 2023). Utilita provided data on a random sample of dual fuel, i.e. gas and electricity, prepayment customers, intended to be representative of their customer base, over the period from January 2019 to May 2023. The sample was stratified to ensure adequate representation of building and householder population characteristics of interest.

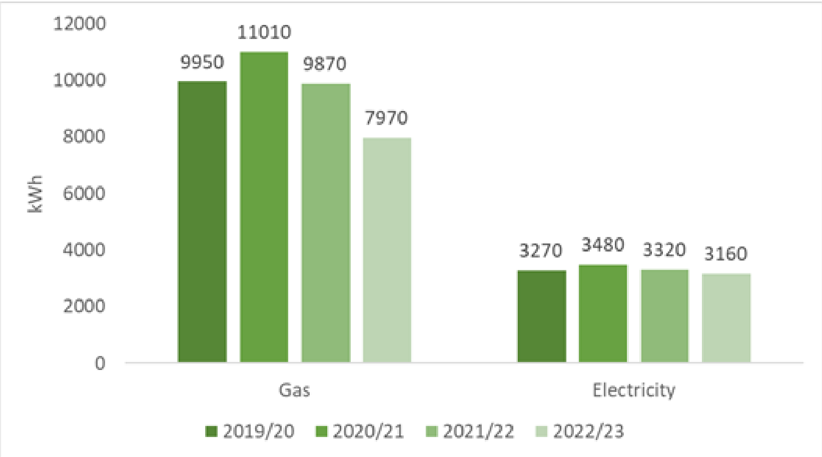
Initially, data was provided for 28,728 customers, on an anonymous basis. Excluding customers with incomplete data or missing data-sharing permissions reduced the sample size to 11,519. Of these, there was data from between 8,800 - 9,800 customers per year, with 7,600 available in all four heating seasons. The data included daily consumption of electricity and gas; self-disconnection events, time and duration; energy tariff details; age band of customers; Energy Performance Certificate data; Warm Homes Discount receipt (an annual payment of £150 to people on certain means-tested benefits); Priority Services Register status. The Priority Services Register is a free service which means households get advance warning of scheduled power cuts, priority support in an emergency and other support. There is no data on income levels, how many people live in each home, or whether there are children or people with disabilities in the household.

In comparison with the GB population, the households are younger and therefore likely to contain more children, use less energy, live in smaller homes, and are about three times more likely to be in receipt of Warm Homes Discount. The homes are averagely energy efficient, and experienced external winter temperatures very similar the national average.

Energy consumption and expenditure

Figure 3 shows how average annual consumption changed from 2019/20 to 2022/23. All annual data is presented for years from 1 May (in year 1) to 30 April (in year 2). The highest use was in 2020/21, this was the coldest year by some margin and also affected by multiple COVID lockdowns, with people spending more time at home. In 2022/23, gas use was 20% lower than 2019/20, while electricity use was 3% lower. The years 2019-20 and 2022/23 are used for comparison here because 2019/20 was pre-wholesale energy price rises, was not in the pandemic period and had similar winter temperatures to 2022-23. Figures are not temperature-corrected.

Figure 3: Mean annual gas and electricity consumption per home



Sample sizes: vary from 7,700 to 8,500 per year

This is a huge decrease in the key heating fuel in households that were already likely under-heated. The reduction in gas use is much greater than electricity. The interpretation from Palmer et al, 2023 is that this partly reflects the EBSS payment on the electricity meter, and partly the fact that households can reduce heating more easily than critical services such as refrigeration.

Average annual energy expenditure rose from £1,160 in 2019/20 to £2,130 per customer in 2022/23. The latter figure includes the £400 EBSS payment towards energy costs, so the household's own costs increased by 50% to £1,730.

Other findings

In total, 63% of households disconnected at least once a year over these four years. On average, there were five self-disconnection events a year totalling 28 hours. The highest levels of self-disconnection were found with young households, those in energy inefficient homes, people on the Priority Services Register and where electricity is used for heating. In 2022/23, gas disconnections lasted eight times longer than those for electricity. The 10% of households with the highest combined (gas and electricity) disconnections were without one or both fuels for 800 hours a year - over 2 hours a day.

Based on extensive analysis of the data for low gas-using households, around 7% of households with a gas connection have been found to be using electricity and/or a non-metered fuel instead of gas for heating. These households scarcely use any (metered) energy for heating and are very likely the households facing the greatest hardship.

Analysis of price elasticity of energy demand in winter 2022/23 was carried out. Figures are given with 95% confidence intervals following:

- Price elasticity for gas (homes using gas for heating) = -0.265 (-0.249, -0.325)
- Price elasticity for electricity (homes using gas for heating) = -0.058 (-0.025, -0.092)
- Price elasticity for electricity (homes using electricity for heating) = -0.207 (-0.123, -0.537)

Synthesis of findings across studies

All the studies used smart energy meter data to investigate household energy use and responses to high energy prices in winter 2022/23. They differ in some important respects, including sampling strategy and calculation methods (Table 3). For example, they took different approaches to year-on-year comparisons, and whether data or counterfactuals are temperature-corrected. While this complicates detailed comparisons, it does not prevent identification of common messages or key differences.

Table 3: Key characteristics of each study

	SERL – Zapata-Webborn et al, 2024	**EDOL – Cost of living**	**Utilita**
Sample size (households)	5,594	157	Total 11,519. 8,000 to 9,800 for each year with 7,600 for all four years.
Period of study	Oct 2022 – March 2023, compared with model predictions based on winter 2021/22 data	2020 - 2023	May 2019 – April 2023
Energy types included in analysis	Gas, electricity	Electricity	Gas, electricity
Smart meter types	All, but only around 1% are pre-payment	Credit meters only (no pre-payment)	Pre-payment only
Household income compared with GB average	Likely to be slightly higher than average, based on Index of Multiple Deprivation & location	Higher than average, based on reported values	Lower than average (inferred due to rates of means-tested benefits)
Heating systems	Gas or electric	Gas or electric	Intended sample 100% gas heating – but see text
Prices paid by customers	Estimated based on price caps	Actual, not including standing charges and government subsidies 2022/23	Actual, including standing charges and government subsidies 2022/23
External temperature	Sophisticated temperature correction included in comparisons	Data not temperature corrected	Data not temperature corrected

A number of key findings are highlighted below.

In response to price rises, households used 10-20% less gas. Figures differ between the SERL and Utilita samples, but both samples showed considerable reductions in gas use in winter 2022/23.

Different studies showed different response to price rises by fuel (price elasticity). SERL showed that gas elasticity was great than electricity elasticity, whereas Utilita reported the opposite. This is likely to be related to the different income characteristics of the samples. If this is the case, it illustrates the limitations of national price elasticity figures for understanding the effects of price rises on lower income households, and the need for more sophisticated policy responses to high prices.

There is a relationship between income and price response for gas and electricity. SERL showed evidence of differences in elasticity by financial well-being, in different directions for gas and electricity. Richer households were more elastic than poorer for electricity, poorer more elastic than richer for gas. EDOL data showed the same pattern for electricity. The Utilita study, which covers households that are poorer than the average, showed higher gas price elasticity and lower electricity price elasticity than the SERL Observatory average, and which therefore also suggests the same pattern of a relationship between income and price response for gas and electricity.

Some households switched from gas to electricity for heating. A proportion of households who have a gas supply were shown in both SERL and Utilita studies to be switching to electricity for heating. SERL showed this increased overall bills.

Poorer households undertook more heating reduction actions. The difference between percentage gas reduction in SERL and Utilita data indicates this, as does more detailed SERL research showing greater setpoint reductions by those reporting that they could not afford to heat their living room to a comfortable temperature.

High prices caused under-heating and negative health effects. SERL studies showed that the proportion of households reporting a setpoint lower than 18°C increased from 6.7% to 15.2%, and that difficulties in meeting heat costs are associated with lower wellbeing and life satisfaction. Utilita data showed that the length of disconnections from gas supplies rose.

Discussion

Challenges of meta-analyses

A key challenge for this paper is meaningfully bringing together conclusions from multiple, independent studies. This challenge is a function of drawing from studies informed by different literature and framed around specific research questions, using different samples and methodologies. Considerable space has been given to describing how each sample was selected and comparing characteristics with those of GB households, to enable readers to understand why the studies may differ. As more studies use smart meter data, developing good meta-analyses will become of increasing interest.

It will also be important to understand the extent to which smart meter findings are representative of the whole population for countries like the UK, where they are not yet ubiquitous. For example, there is initial evidence of differences between response to high prices by smart and non-smart PPM households (Utilita Energy 2023), with traditional PPM customers reducing their electricity use in winter 2022/23 by 20% compared with the 3% seen in smart PPM. More needs to be done on this issue. In addition, none of the studies here included households from Northern Ireland – whose energy governance and use differs from the rest of the UK – and this needs remedying.

The need for new methods

Longitudinal studies like the ones reported here are relatively novel in the field of research of energy in buildings and this novel data comes with challenges that require methodological improvements. Firstly, the studies reveal common challenges in analysis such as: dealing with missing data and correcting for the effects of weather. These studies have highlighted the reality of smart meter data, which despite being ‘smart’ suffers from considerable data quality issues. This leads to a methodological need to deal with missing data to reduce impact on sample sizes and statistical power, bias, etc. Second, while the studies shared similar goals in terms of analysis (e.g. estimating changes in energy use, price elasticities, etc.) they used different methods to achieve these. And third, the challenge of this paper in comparing results from different longitudinal studies where the samples are different. All of this points to a need for methodological improvements. However, while panel data analysis like these studies may be relatively novel in the field of energy in buildings, it is routine in other fields like epidemiology, and this points to a value in drawing on the lessons learned and methods from this field and the need for a comparable field of 'energy epidemiology' (Hamilton, Summerfield et al. 2017).

The need for longitudinal contextual data, not just energy data

To explain longitudinal energy data, we need longitudinal contextual data. While smart meter data enables collection of longitudinal energy data sets, longitudinal contextual data is still rare and remains difficult and costly to collect. This is something which the EDOL project hopes to make progress on by founding a longitudinal study collecting and making publicly available both types of data and also experimenting with new data collection methods, which are low cost and non-intrusive. For example, to understand detailed dynamics within households, diary instrumentation can be used (Grunewald and Diakonova 2018).

Interpretation of findings

While it would be a mistake to over-interpret differences in findings between the studies, given the methodological & sampling differences already mentioned, it is noticeable that they do vary in the way findings are interpreted. For example, the Utilita study was designed to provide actionable advice on policy, and paid close attention to the policy context. Thus, part of that study’s explanation of why the price elasticity of electricity was less than gas is that subsidy payments in winter 2022/23 were made directly to electricity (not gas) PPMs. The SERL study did not have the same finding, but equally it did not consider the detail of how price subsidies were delivered, and indeed did not have access to actual prices paid by householders. The SERL team did specific additional studies to increase insight into why energy use changed, and in which types of households – whereas neither the EDOL nor Utilita studies had this form of evidence to draw on.

The Utilita study used its analysis to propose in detail how governments could better target support to those in greatest need, and the minimum level of support needed to prevent serious suffering is important for both winter 2023/24 and beyond. The SERL studies, while generating some policy insights, focused primarily on contributions to the scientific & social scientific literature (and indeed published first results via journal articles rather than via a report).

Implications for policy response to crises

Smart meter data analysis has been shown to provide valuable insights in the effects of crises. Smart meter data from longitudinal studies can offer much quicker analysis of household’s energy use than waiting for official government statistics. For example, the Utilita report published research in August 2023 which included data up to the end of March 2023, with policy analysis available in time to feed into policy-making for the coming winter. In addition to speed, these studies offer more detailed contextual understanding of what changes are happening in different populations and demographics, in respect of different energy sources, when and why – although methodologies still need further work. The longitudinal nature of the data offers more opportunities to analyse the difference compared with ‘non-crisis’ counterfactuals, based on secure baselines (e.g. SERL analysis). With longitudinal studies, policy makers have access to a more responsive, richer, and more evidence-based analysis than would otherwise be the case.

Conclusions

This paper has brought together three different studies using smart meter energy data from Great Britain to learn lessons from the energy price crisis of winter 2022/23. The studies differ in some important respects, including sampling strategy and calculation methods, and the need for methodological improvements both at an individual study level and to enable high quality meta-analyses has been identified.

These studies are proving to be valuable, yielding novel and valuable insights in times of crises. The results highlight diversities and complexities in responses to price changes. The evidence has shown how high prices put pressure on the most vulnerable households in different ways, how they have responded, and indeed how they have suffered – paying considerably more to receive less energy.

Large-scale observational studies are possible and happening now, enabled by smart meters. There is room for further improvement with new methods of energy observation, which give a more detailed understanding of energy service provision. These include new instruments to observe occupancy and heat provision at scale in longitudinal panels.

These studies have demonstrated that independent data collection, monitoring and evaluation, over the long-term, is an important role for academic research in the net zero transition. By investing in longitudinal studies, governments have the means to quickly understand future crises and to take the necessary action to avert serious social consequences. In the price crisis of 2022/23, the UK spent £50bn on supporting energy prices, most of which went to households who were not in fuel poverty, and many of whom did not need financial support (however welcome it may have been). In the next crisis, good use of longitudinal data should enable governments to make more targeted interventions, focusing help on those who need it most, at less cost to the public purse.

Acknowledgements

The authors' time in writing the paper was funded via EDOL (EP/X00967X/1). The SERL Observatory data are accessible to accredited UK researchers on independently approved projects via UK Data Service Study Number 8666 https://doi.org/10.5255/UKDA-SN-8666-6. The SERL Observatory includes European Centre for Medium-Range Weather Forecasts (ECMWF) ERA5 data. Neither the European Commission nor the European Centre for Medium-Range Weather Forecasts is responsible for any use that may be made of the Copernicus information or data it contains. The Utilita research was funded by a grant from Utilita Giving.

References

ACER (2023). Energy retail and consumer protection: 2023 market monitoring report. https://acer.europa.eu/sites/default/files/documents/Publications/2023_MMR_Energy_Retail_Consumer_Protection.pdf [accessed 29/1/24], European Union Agency for the Cooperation of Energy Regulators.

Boardman, B. (1991). Fuel poverty: from cold homes to affordable warmth. London, Belhaven Press.

Citizens Advice (2023). Kept in the dark: The urgent need for action on prepayment meters. www.citizensadvice.org.uk, Citizens Advice.

Cornwall Insight (2022). Energy prices to remain significantly above average up to 2030 and beyond. https://www.cornwall-insight.com/press/energy-prices-to-remain-significantly-above-average-up-to-2030-and-beyond/.

DESNZ (2023). Annual fuel poverty statistics in England, 2023 (2022 data). https://www.gov.uk/government/statistics/annual-fuel-poverty-statistics-report-2023#page=77, Department for Energy Security and Net Zero.

DESNZ (2023). Energy Bills Support Scheme GB: payments made by electricity suppliers to customers. https://www.gov.uk/government/publications/energy-bills-support-scheme-payments-made-by-electricity-suppliers-to-customers, Department for Energy Security and Net Zero.

Espey, J. A. and M. Espey (2004). "Turning on the Lights: A Meta-Analysis of Residential Electricity Demand Elasticities." Journal of Agricultural and Applied Economics **36**(1): 65–81.

Few, J., M. Pullinger, E. McKenna, S. Elam, E. Webborn and T. Oreszczyn (2022). Smart Energy Research Lab: Energy use in GB domestic buildings 2021. www.serl.ac.uk, Smart Energy Research Lab, London, UK.

Grunewald, P. (2023). Energy use in crisis - lessons for net-zero? . BIEE, British Institute for Energy Economics. Oxford.

Grunewald, P. and M. Diakonova (2018). "The electricity footprint of household activities - implications for demand models." Energy and Buildings **174**: 635-641.

Hamilton, I., A. Summerfield, T. Oreszczyn and P. Ruyssevelt (2017). "Using epidemiological methods in energy and buildings research to achieve carbon emission targets." Energy and Buildings **154**: 188-197.

Hanmer, C. and E. Zapata-Webborn (2023). Settling for colder homes as energy prices rise: evidence from 4200 households in Great Britain BEHAVE 2023, the 7th European Conference on Behaviour Change and Energy Efficiency.

Huebner, G. M., C. Hanmer, E. Zapata-Webborn, M. Pullinger, E. J. McKenna, J. Few, S. Elam and T. Oreszczyn (2023). "Self-reported energy use behaviour changed significantly during the cost-of-living crisis in winter 2022/23: insights from cross-sectional and longitudinal surveys in Great Britain." Scientific Reports **13**(1): 21683.

Kambule, N., K. Yessoufou and N. Nwulu (2018). "A review and identification of persistent and emerging prepaid electricity meter trends." Energy for Sustainable Development **43**: 173-185.

Labandeira, X., J. M. Labeaga and X. López-Otero (2017). "A meta-analysis on the price elasticity of energy demand." Energy Policy **102**: 549-568.

NAO (2023). Energy bills support. https://www.nao.org.uk/reports/energy-bills-support-schemes/, National Audit Office.

NAO (2023). Update on the rollout of smart meters. https://www.nao.org.uk/wp-content/uploads/2023/06/update-on-the-rollout-of-smart-meters-summary.pdf, National Audit Office.

Ofgem (2023). Customers to pay less for energy bills from summer. https://www.ofgem.gov.uk/publications/customers-pay-less-energy-bills-summer, Ofgem.

Palmer, J., B. Boardman, N. Terry, T. Fawcett and U. Narayan (2023). Finding the fuel poor and framing better policy. https://www.eci.ox.ac.uk/article/finding-fuel-poor-and-framing-better-policy, Cambridge Architectural Research and University of Oxford.

Parag, Y., T. Fawcett, S. Hampton and N. Eyre (2023). "Energy saving in a hurry: A research agenda and guidelines to study European responses to the 2022–2023 energy crisis." Energy Research & Social Science **97**: 102999.

Telles Esteves, G. R., F. L. Cyrino Oliveira, C. H. Antunes and R. C. Souza (2016). "An overview of electricity prepayment experiences and the Brazilian new regulatory framework." Renewable and Sustainable Energy Reviews **54**: 704-722.

Urban Tide (2022). uZERO: Tackling the growing fuel poverty crisis with AI. https://urbantide.com/uzero.

Utilita Energy (2022). Suffering in Silence - Smart PAYG alleviating fuel poverty.

Utilita Energy (2023). Smart energy data for fuel poverty avoidance. https://drive.google.com/file/d/1jFcLPL7UhPF2jKehYr8KDhkhkaH90-2a/view, Utilita Energy.

Webborn, E., J. Few, E. McKenna, S. Elam, M. Pullinger, B. Anderson, D. Shipworth and T. Oreszczyn (2021). "The SERL Observatory Dataset: Longitudinal Smart Meter Electricity and Gas Data, Survey, EPC and Climate Data for over 13,000 Households in Great Britain." Energies **14**.

Zapata-Webborn, E., C. Hanmer, T. Oreszczyn, G. Huebner, E. McKenna, J. Few, S. Elam, M. Pullinger, C. Cheshire, D. Friel, H. Masters and A. Whittaker (2024). "Winter demand falls as fuel bills rise: Understanding the energy impacts of the cost-of-living crisis on British households." Energy and Buildings **305**: 113869.

Zapata-Webborn, E., E. McKenna, M. Pullinger, C. Cheshire, H. Masters, A. Whittaker, J. Few, S. Elam and T. Oreszczyn (2023). "The impact of COVID-19 on household energy consumption in England and Wales from April 2020 to March 2022." Energy and Buildings **297**: 113428.

Zhu, X., L. Li, K. Zhou, X. Zhang and S. Yang (2018). "A meta-analysis on the price elasticity and income elasticity of residential electricity demand." Journal of Cleaner Production **201**: 169-177.