Energy Efficiency (2023) 16:62
https://doi.org/10.1007/s12053-023-10143-3

ORIGINAL ARTICLE

Domestic energy consumption: temporal unregulated electrical energy consumption in kitchens in Scottish affordable and social housing

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Received: 1 April 2022 / Accepted: 24 June 2023 / Published online: 14 July 2023

Abstract Housing contributes significantly to greenhouse gas emissions. It is also a social determinant of health. In Scotland, 25% of households in 2019 were in fuel poverty. Current (2023) energy price increases are likely to further increase this proportion, particularly among low-income families. Fuel affordability measures implemented by the Scottish and UK Governments generally focus on achieving thermal comfort, largely disregarding appliance energy usage, termed 'unregulated loads'. These include essential household items in kitchens such as the cooker, washing machines, fridges and freezers. The inability of occupants to afford to cook and store food and launder clothing can have broader health implications. This study reviews one year of energy consumption data collected from 17 newly constructed energy-efficient dwellings available for a combination of social rent and purchased through an affordable shared equity scheme in Scotland. The data are used to determine the proportion of total household energy consumption used in kitchen environments. Analysis indicated a vast range of 20–72% (41% mean) of total household electricity consumption was linked to the kitchen, excluding artificial lighting. In this study, energy efficiency ratings of the cookers, fridges, freezers and washing machines identified that those in social housing had the least energy-efficient kitchen appliances compared to those in purchased affordable homes. This suggests inequitable practices for kitchen appliance procurement in social homes compared with affordable homes. Overall, this study highlighted the need for larger-scale, in situ research to evaluate energy efficiency and consumption in kitchens to inform social landlords and policymakers to reduce disparities and to form a focus on fuel poverty calculations.

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Keywords Domestic kitchen · Energy · Poverty · Unregulated energy · Building performance evaluation · Kitchen appliances

Introduction

Fuel poverty is a well-recognised problem characterised by a household's inability to maintain an adequate thermal comfort standard at an affordable cost. Three main factors impact fuel poverty: the energy efficiency of homes, fuel prices and household incomes, with low-income households and houses occupied by vulnerable people being disproportionately affected (Boardman, 1991). In the United Kingdom (UK), households consume fuel for maintaining thermal comfort, generating hot water and operating electrical appliances to achieve a reasonable standard of living, comfort and well-being (Ellegård & Palm, 2011). Thirty years ago, Boardman identified that 60% of energy consumption in dwellings was used for space heating, with the remainder attributed to water heating, lighting and operation of electrical appliances. Since then, opportunities for reducing energy use and greenhouse gas emissions have been based on switching heating fuel from electricity to gas and encouraging the uptake of energy-efficient electrical appliances; the latter is considered more challenging for low-income homes (Boardman, 1993). Today, the building regulation process for home energy rating assesses the efficiency of heating, hot water and artificial lighting systems. All remaining household energy consumption—including from kitchens—is termed 'unregulated'. As a result, it is not directly considered in the fuel poverty assessment (The Scottish Government, 2016b).

A broad range of research concerning domestic energy consumption and fuel poverty has been conducted over the last three decades (Boardman, 1991; Bradshaw & Keung, 2022; Burlinson et al., 2021; Gupta et al., 2018; Hinson et al., 2022; Kearns et al., 2019; Marmot et al., 2022; Middlemiss et al., 2019; Teli et al., 2016; Walker & Day, 2012). While there is a recognition of low-income households being particularly vulnerable to fuel poverty, there appears to be limited research reviewing and quantifying unregulated energy consumption, particularly in social and affordable homes, which are typically occupied by those on lower incomes.

Household appliances tend to be clustered in kitchens and used for essential household activities, including cooking, refrigeration and laundry. While the energy efficiency of kitchen appliances is improving, very little appears to be known about measured energy consumption and energy efficiency ratings of kitchen appliances in the context of occupied social and affordable homes. Due to Scotland having the highest number of fuel-poor households in the UK (Hinson et al., 2022), this paper draws on energy consumption and appliance audit data collected during a previous building performance evaluation (BPE) study from occupied social and affordable homes in Scotland.

Previous literature

In the UK, a household is described as suffering from fuel poverty when it cannot maintain indoor temperatures at comfortable levels for less than 10% of the household income. When more than 20% of household income is spent, that household is described as suffering from *extreme* fuel poverty (The Scottish Government, 2021). Fuel poverty has been recognised in the UK since the late 1970s, with the first accepted definition developed in the 1990s (Boardman, 1991). Being unable to heat a home adequately can lead to several consequences, including low temperature, dampness and condensation, and mould growth. Through fuel poverty research, it is widely acknowledged that affected occupants suffer from a wide range of adverse impacts when living in these conditions and that this can exacerbate poverty, lead to social isolation and negatively impact mental and physical health (Chatterton et al., 2016; Liddell & Morris, 2010; Marmot et al., 2022; Walker & Day, 2012). It is also recognised that people living in rented accommodations and households in rural and remote areas are at a higher risk of fuel poverty (Energy Action Scotland, (n.d.); Hardy et al., 2019).

In 2002, the Scottish Government set out a long-term plan to eradicate fuel poverty by November 2016 (The Scottish Government, 2016a). This missed target led to the adoption of an evidence-based and lived experience approach to informing the development of the Scottish Government's, 2019 Fuel Poverty Act. This legislation sets out the revised ambition to eradicate fuel poverty 'as far as possible' by 2040, with interim reduction targets to ensure no more than 15% and 10% of households are fuel-poor by 2030 and 2035, respectively (The Scottish Government, 2021). The new strategy expands the previously accepted fuel poverty definition to include a household's ability to maintain a temperature of 21 °C in the living room and 18 °C in other areas of the home at varying times relating to occupancy patterns of those rooms (The Scottish Government, 2019). When the act was established, around 25% of Scottish households were in fuel poverty compared with 13% in England, 12% in Wales and 18% in Northern Ireland (Hinson et al., 2022). However, UK fuel poverty estimates are predicted to increase to more than 50% of UK households in 2023 (Bradshaw & Keung, 2022). This is due to a number of factors, including the current energy and cost of living crisis and a lack of adequate, energy-efficient housing. These will, in turn, impact households' financial ability to purchase and run kitchen appliances (Marmot et al., 2022).

European energy rating labels were introduced in 1994 to improve the energy efficiency of electrical appliances, including kitchen appliances (European Commission, (n.d.). The legislation that enabled this was revised in March 2021 with the twin objectives of simplifying energy labelling and eradicating designed appliance obsolescence (The UK Government, 2021). During the same 1994–2021 period, consumer purchasing habits have changed, with households typically owning more electrical appliances and lower-income families owning less-efficient appliances (Bradshaw & Keung, 2022). With the trend developing for households to own larger appliances, these will likely consume an increasing proportion of total household energy use (Palmer & Cooper, 2013). Examples of this include the move towards tall larder-style 'American' fridges and some households owning a second freezer, both of which are in 24-h use. Recent research reviewing the energy consumption of refrigeration appliances aged 16 years or older indicated a 27% increase in energy consumption (Paul et al., 2022) compared to when new. It should be recognised that extending appliance life can have the unintended consequence of increasing energy use, which might financially hamper a low-income household in the long term.

Palmer and Cooper (2013) identify that household energy consumption for appliances increased by approximately 3% per year between 1970 and 2011. Their definition of appliances includes all household consumption excluding space and water heating, lighting and (perhaps counter-intuitively) the oven and hob. In their research, appliances were responsible for almost 14% of household energy consumption, with cooking at 3%. The report's authors reasoned that the apparently low figure for energy use for cooking did not consider the use of other kitchen 'cooking' appliances, including toasters, bread-making machines and microwave ovens. The proportion of all non-heating energy consumption was estimated at 38% of household consumption, similar to Boardman's (Boardman, 1993) earlier work. However, a drawback of this study was that the data was derived using computer algorithms, indicating an opportunity to explore measured data to corroborate or advance the existing knowledge of unregulated energy in a domestic setting. One in situ study of six social houses in England indicated that unregulated energy consumption ranged from 14 to 35% of household consumption (Gupta et al., 2018).

In Scotland, BPE undertaken on a social-rented home containing one occupant with additional care needs indicated that the kitchen energy consumption accounted for 57% of total electrical energy use in the house (ECD Architects, 2014). While the report did not explain whether the electrical consumption was uncharacteristic for this housing typology, it suggested that the lifestyle factors of the occupant involved relatively high levels of food preparation and laundry. It did not qualify whether these factors were related to increased care needs.

Other research implies that the type and range of appliances purchased by occupants determine energy use behaviour patterns in low-income households (Yohanis et al., 2008); however, there is little research into the energy efficiency of household appliances for different social groups (Simcock et al., 2016). It is widely reported that the current energy and cost of living crises are impacting the affordability of food (The Health Foundation, 2023), with increasing numbers of people relying on food banks. Yet there is little understanding of whether low-income households can afford the fuel needed to cook. Being able to afford to cook hot meals is an essential component of meeting household needs, however, recognition of this appears to have been overlooked in the review of minimum income standards (Davis et al. 2022).

In its human rights standards for living, the United Nations includes the right to adequate housing (OHCHR, 2014) and specifically 'energy for cooking, heating, lighting, food storage'. Its guidance on the right to adequate food is closely linked to this, which states, 'When a house lacks basic amenities, such as for cooking or storing food, the right to adequate food of its residents may be undermined. Also, when the cost of housing is too high, people may have to cut down on their food bill' (OHCHR, 2010). The inequalities of appliances, unregulated energy use, and not ensuring home and kitchen design consider these factors have potentially far-reaching unintended consequences and need further consideration and research.

Existing energy research at a household level tends to focus on large data sets using metered data from energy providers. In the UK, metadata analysis provides typical low, average and high UK household consumption benchmarks and indicates an association between higher energy consumption and owner-occupied homes (Chatterton et al., 2016). While these studies are useful, there is very little granular information at the individual household level to permit further investigation of circumstances affecting energy use. To help achieve net zero carbon homes, there is a pressing need to understand how energy use is apportioned in a house. Moreover, studies focusing on appliance-level data tend to analyse peak demands that mainly benefit the energy generators and suppliers (Murray et al., 2017) rather than the occupant. Kitchens can be a significant source of energy consumption due to the concentration of high energy-demand appliances in this part of a home.

Behaviour change

Studies have identified behaviour change and altering purchasing habits as a theoretical means to help households to consume less energy (Gaspar & Antunes, 2011). However, these interventions may be harder to realise in practice (Hagejärd et al., 2020), particularly in homes with lower incomes and lack the finances to replace or purchase essential kitchen appliances (Turn2us, 2020). Most households use kitchen appliances at times that suit their lifestyles. Energy-efficient upgrades of kitchen appliances simply may not be affordable for households (Hager & Morawicki, 2013) already in poverty. The affordability issue is further intensified for social housing tenants as they must typically provide their kitchen appliances when taking up a tenancy. This is in addition to purchasing other expensive items, including floor coverings (The Scottish Government, 2017). Such practice is in direct contrast to the mid-market, affordable and private rental sector, where appliances and floor finishes are usually provided as part of a tenancy. It highlights a high level of inequality between housing sectors that negatively impact those with lower incomes.

Tariff and bills

Since the onset of the 2020 coronavirus (COVID-19) pandemic, the general population has been spending more time at home, increasing household electrical consumption (Bahmanyar et al., 2020; Mitra et al., 2022; Rouleau & Gosselin, 2020). This pattern has been observed in many high-income countries, including the UK, and has resulted in increased poverty levels due to home working, homeschooling, furlough and redundancy (The Scottish Government, 2020). Poverty may be further increased by the UK's ongoing conversion to an all-electric future (Chatterton et al., 2016), caused by the drive to achieve net zero, particularly if electricity costs to the end consumer remain high. At the time of writing, there have been sharp increases in the unit cost of gas and electricity. Average UK direct-debit prices for one kilowatt-hour (kWh) of electricity (£0.34 per kWh) are over three times that for gas (£0.10 per kWh), and daily standing charges have increased to £0.46 and £0.28 for electricity and gas respectively (Ofgem, 2022).

'Economy 7' and 'Economy 10' tariffs offer lower electrical prices to encourage off-peak consumption at night, charging lower rates for electricity used for seven off-peak hours and ten off-peak hours for Economy 7 and 10, respectively. These were initially developed for consumers with high overnight electrical demand, for example, electric storage heaters. On these tariffs, unit costs for electrical consumption during peak hours are charged at a higher rate, resulting in considerable expense for occupants if that tariff is not used correctly (Hardy et al., 2019). To avoid high energy costs, those on Economy 7 and 10 have been encouraged through the media and online sources to use kitchen appliances such as washing machines and dishwashers during the tariff's off-peak periods, i.e., at night (Money Saving Expert, 2020). However, operating heat-generating appliances such as washing machines, tumble dryers and dishwashers at night or while sleeping is strongly discouraged due to the increased fire risk (Scottish Fire and Rescue Service, 2019).

Those living in social and affordable housing are more likely to be on higher energy tariffs due to more tenants having prepayment meters installed in their homes or tariffs that are not direct debit. While gas consumption for space heating usually accounts for the largest share of energy consumed in a household, its lower unit cost means that the comparably smaller proportion of unregulated electricity used by occupants can be of equal or greater financial cost to that of keeping warm. From this, it is clear that there is a pressing need for researchers and policymakers to understand household demand for unregulated loads in housing, particularly in kitchens.

As part of household budgeting, those moving into new homes often use the predicted energy use recorded on a home's Energy Performance Certificate (EPC) to estimate their likely monthly costs. However, EPCs do not include a prediction of unregulated energy use and therefore fail to give a complete picture of total potential energy use (The Scottish Government, 2016c). In an Innovate UK-funded BPE of 76 new low-energy homes across the UK, researchers evaluated predicted consumption against measured consumption of regulated energy (i.e., space heating, domestic hot water, lighting and ventilation). The previous study found that measured energy consumption was up to three times higher than the design prediction, as recorded on the EPC (Palmer et al., 2016). While only reviewing regulated consumption this finding strongly indicates that EPCs not only contain inaccurate data but that their figures are incomplete and do not consider unregulated consumption—this information is misleading for households and may contribute to their risk of falling into fuel poverty.

Kitchens

Domestic kitchens are essential for supporting a reasonable standard of living and are an integral part of a home for storage, food preparation, cooking and laundry practices. Establishing the energy consumption contribution of kitchens is essential if demand reduction is to effectively decrease consumers' energy costs to an affordable level and help achieve net zero (The Scottish Government, 2016a). One major issue is inconsistency in available consumption data. For example, statistical analysis for UK dwellings indicates 2.8% of household energy consumption is for cooking and 17.3% for lighting and appliances (Eurostat, 2018), similar to Palmer and Cooper's (Palmer & Cooper, 2013) estimate. However, a separate study using measured data identified that kitchen appliances such as fridge freezers, dishwashers, washer dryers and kettles are among the highest household energy-consuming appliances (Kelly & Knottenbelt, 2015). The Energy Saving Trust has kitchen appliances and cookers in its top five energy consumers (Energy Saving Trust, 2022), indicating the importance of clearly identifying their energy consumption in EPC calculations. Research by the charity Turn2us (2020) has illustrated that occupants in the social housing sector are more likely to purchase second-hand kitchen appliances or, because of their high capital and running costs, do without many kitchen appliances. Both scenarios can increase household expenditure and increase poverty (Turn2us, 2020), which impacts health through a lack of adequate nourishment (Harrison & Taren, 2018) or foodborne illness due to ineffective refrigeration (Byrd-Bredbenner et al., 2013).

Understanding whether households have kitchen appliances and how much they cost to run to meet household needs is vital for reducing poverty and improving health and equity. This study, therefore, aims to investigate the quantity of energy consumed at kitchen sockets and cookers in social and affordable homes across rented and owned tenures. It uses measured annual electricity consumption data and includes analysis of the energy efficiency ratings of each household's kitchen appliances (cooker, washing machine and refrigeration). The determination of fuel poverty is principally based on regulated consumption. As such, it is anticipated that this study will advance the understanding of unregulated energy consumption and the energy efficiency rating of kitchen appliances in a Scottish social and affordable housing context and identify further related areas for research. The findings will benefit those researching and working with energy-vulnerable households and highlight the need to expand domestic BPE assessments to include unregulated consumption measurement and inform fuel poverty campaign groups, social housing providers and policymakers.

Materials and methods

This study draws on secondary data collected during a BPE study of 17 new-build homes in Scotland that were included in an £8 million Innovate UK-funded BPE programme (Build Up, 2010) designed to assess the performance gap in 76 new homes across the UK. The data analysis consists of a quantitative assessment of annual electrical energy data against consumption drawn from the kitchen sockets and cooker, collected simultaneously from each house. Separating the consumption for kitchen and cooker allowed a comparison to be made against previous consumption data derived through algorithms (Palmer & Cooper, 2013). The energy consumption for the cooker is reviewed by the installed appliance energy ratings to explore whether the energy efficiency rating has an impact on annual consumption.

The houses in the study represent a range of housing typologies across five new-build social housing developments located in different regions in Scotland. While it is recognised that the sample is small, background knowledge of each household's electrical appliances, supported by significant qualitative data collection and ethnographic research, provides additional context to the study. The following briefly describes the households and how the electricity consumption measurements and appliance audit were conducted in the primary research.

Household information

A one-year synchronous data set from each of the 17 homes was analysed. Each family living in the homes had previously consented to participate in the BPE research and permitted the use of collected data for secondary research. Key characteristics of each house type are presented in Table 1. Seven of the 17 homes were houses of one and a half or two storeys, with the remaining dwellings comprising mixed-tenure flats. Five flats (IC2, ID1, ID2, GB1 and GB2) were owner-occupied and purchased under a government shared-equity affordable housing scheme. Three flats (GA1, GA2 and GA3) were located within a sheltered housing complex for elderly adults living independently. BB1 was situated in a development constructed for retired tenants, and LA2 was one house on a terrace of new homes for elderly and ambulant persons living with their caregivers.

Electricity consumption measurement

The BPE programme included continual field measurements of electrical consumption from the fiscal meter collected through an inline pulse counting electrical meter. Data were collected using 100 Amp current transformers installed around the live cable in the domestic fuse board for up to eight electrical sub-circuits. An example of the equipment in one of the dwellings is shown in Fig. 1.

Table 1 Participating household size and occupancy data

House ID	House type		Total floor area (m^2)	Occupants	
				Adult	Child
BB1	Flat	2 Bed	76	2	0
LA2	House	3 Bed	104	3	0
TA1	House	3 Bed	120	2	3
TA2	House	3 bed	120	2	1
TB1	House	2 Bed	120	1	1
IA1	House	4 Bed	110	2	4
IB1	House	3 Bed	90	2	2
IB2	House	3 Bed	90	2	2
IC2*	Flat	1 Bed	63	2	0
ID1*	Flat	2 Bed	76	2	0
ID2*	Flat	2 Bed	76	2	0
GA1	Flat	1 Bed	50	1	0
GA2	Flat	1 Bed	50	1	0
GA3	Flat	1 Bed	76	1	0
GB1*	Flat	2 Bed	66	1	0
GB2*	Flat	2 Bed	66	2	1
GB3	Flat	2 Bed	73	2	1

Monitoring equipment from Orsis was used to record total household electrical consumption, while T-Mac equipment was used to record electrical consumption by sub-circuit. Data were collected simultaneously in all homes at 5 min intervals and transmitted in real-time to the providers' online platform via General Packet Radio Service (GPRS). The data communication method was in its infancy at the time of the study, with limited equipment and suppliers available. Initial teething problems with the data transfer method included weak signals from the cellular communication networks, resulting in the loss of data from some households. Despite this, using a remote monitoring approach for long-term data collection had distinct benefits. Firstly, installing the apparatus within the domestic fuse board meant there were no visible wires, reducing the risk to the occupants and for accidental unplugging of the monitoring equipment. Secondly, data was downloaded from an online portal, reducing the frequency of home visits and the risk of occupant fatigue over the monitoring period. Other than patchy communications, the main drawback of this data collection method was the inability to collect fine-grain data for individual household appliances.

Fig. 1 Data monitoring equipment showing current transformers in the domestic fuse board (centre image) and data transfer equipment (top left) and inline electrical meter (top right). The photo was taken before closing both units

While field collection occurred over two years, varied project start dates and data loss through poor transmission dictated the analysis period. Sufficient synchronous data were collected for one year, from 1st July 2013 to 30th June 2014, for 17 households. The data collection period and small household sample were deemed acceptable as the data set remained large enough to allow a comparative study across homes and yield insights into electrical energy consumption in domestic kitchens—an under-researched area. The researchers consider the original data collection dates to remain valid and significant for review today. Due to the expense and relatively long-life span of appliances, it is unlikely that appliances and consumption patterns would have altered significantly since the original data collection occurred. Data were examined using Microsoft Excel 2019 to calculate and review annual electrical consumption trends.

Electrical appliance and equipment audit

The BPE programme mandated a detailed benchmarking exercise of energy use within each home, involving a physical audit of all household electrical appliances and equipment. Secondary data from this audit were used to inform the analysis, and occupants consented to the appliance audit at the start of the BPE programme. The audit consisted of manually recording the equipment type, make and model number, the declared electrical power (wattage), and details of any stated energy efficiency rating. The researchers also established the frequency of use of each item with the tenants. The recorded data was transcribed to a project-specific spreadsheet, DomEARM (DOMestic Energy Assessment and Reporting Methodology), developed by Arup Ltd and Oxford Brookes University (Gupta et al., 2019), to compare annual household energy consumption against current benchmarks. The energy efficiency ratings for the kitchen appliances (cooker, refrigeration and washing machine) were extracted from this dataset to inform this study.

Results

This research set out to determine the household energy consumption in kitchen environments and assess the energy ratings of appliances in 17 occupied new-build social and affordable homes in Scotland. The following results present the unregulated electrical energy consumption associated with kitchens and an appliance audit for all homes.

Unregulated electrical energy consumption

The first part of the study aimed to understand the homes' total electrical energy consumption and compare it against the kitchen consumption. OFGEM has developed typical energy consumption benchmarks, referred to as Class 1, of 1800 kWh for low, 2900 kWh average and 4300 kWh for high consumption (Ofgem, 2020). Figure 2 plots, per household, the unregulated energy consumption of kitchens and cookers against each of the Class 1

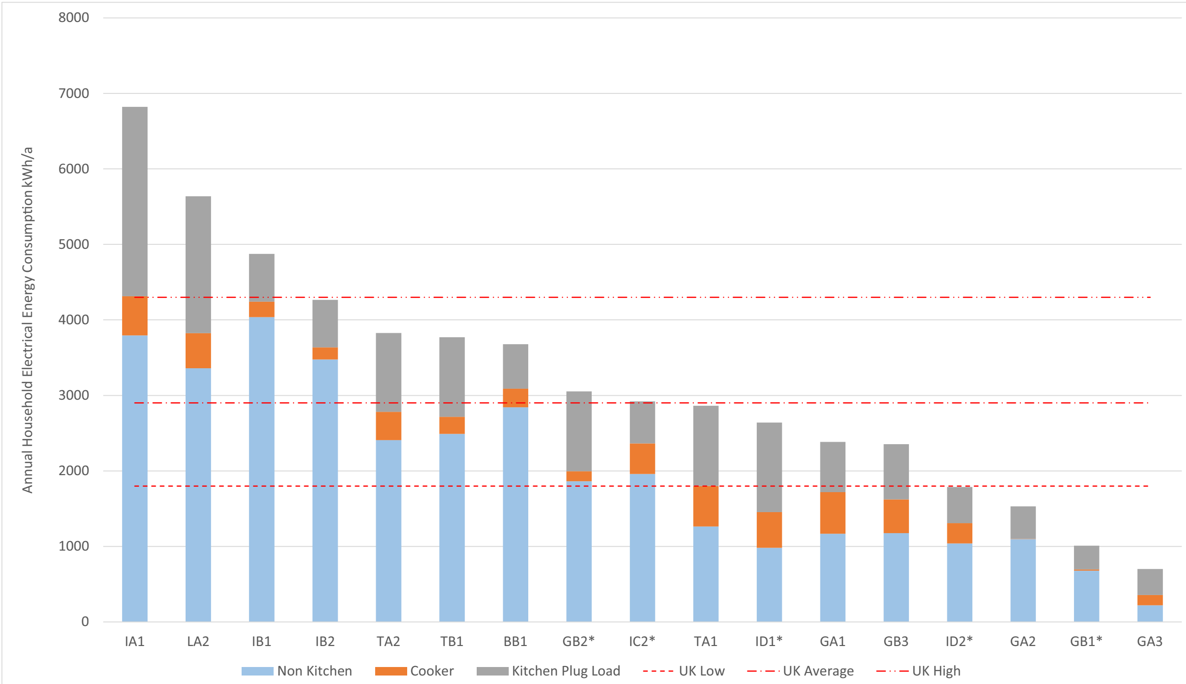

Fig. 2 Breakdown of absolute annual household electrical consumption against Ofgem's low, average and high UK consumption benchmarks Typical Domestic Consumption Values 2020 for Class 1

benchmarks. This chart shows a wide range of consumption levels across the homes, with three homes exceeding the highest benchmark rating. Electrical energy consumption in the owner-occupied dwellings, identifiable by an asterisk on the x-axis, was around or below the average benchmark with annual consumption of 3000 kWh/year or less.

The data review indicates no pattern between the unregulated consumption of kitchen plug sockets and cookers when comparing each household. Table 2 shows that kitchen consumption ranged from 20 to 72% of annual household electricity consumption, with a mean kitchen and cooking electrical consumption of 41%.

The homes' annual kitchen electrical energy consumption was reviewed against a series of metrics to understand better where trends exist.

Bedroom numbers Reviewing kitchen electrical energy consumption against the number of bedrooms in each home indicates a mean consumption of 641 kWh, 1106 kWh, 1385 kWh and 3035 kWh for dwellings with 1, 2, 3 and 4 bedrooms, respectively.

Occupancy Table 1 identifies household occupancy, while Table 3 sets out annual consumption relative to each occupant, per home, in kWh per person. This indicates that consumption in homes with 4 and 5 occupants is approximately 50% lower, per person, than in household groups of other sizes. It is difficult to conclude why there is this difference as the sample is small (two households with 4 persons and one household with 5 persons); however, the children in the 4 and 5-person homes were all of a similar age group, pre-teen and young teenagers. In contrast, children in the other households were younger.

Dwelling size The average floor area of the homes in the study is 82.9 m^2. The review by average dwelling floor area indicates that kitchen consumption is between 5.7 and 27.6 kWh/m^2, with a mean of 14.3 kWh/m^2, equating to 26–53% of total household electrical consumption. Ofgem figures (2020) for unregulated kitchen consumption per square metre are 21.7 kWh for low, 35 kWh for medium and 51.9 kWh for high electrical-using households, indicating the homes in the study are considered to have medium to low electrical use in their kitchens.

Table 2 Annual kitchen electrical consumption expressed as a percentage of dwelling consumption

House ID	House type		Kitchen	
			Cooker (%)	Plug load (%)
BB1	Flat	2 Bed	15	29
LA2	House	3 Bed	8	32
TA1	House	3 Bed	19	23
TA2	House	3 bed	10	27
TB1	House	2 Bed	7	13
IA1	House	4 Bed	8	37
IB1	House	3 Bed	9	15
IB2	House	3 Bed	6	14
IC2*	Flat	1 Bed	7	22
ID1*	Flat	2 Bed	6	24
ID2*	Flat	2 Bed	13	59
GA1	Flat	1 Bed	17	23
GA2	Flat	1 Bed	1	21
GA3	Flat	1 Bed	0	61
GB1*	Flat	2 Bed	13	34
GB2*	Flat	2 Bed	4	35
GB3	Flat	2 Bed	20	50
Mean			10	31
SEM			1.41	3.54

Table 3 Annual kitchen electrical consumption kWh per occupant

Household occupancy	Min	Max	Mean
1 person	331	962	552
2 persons	374	799	520
3 persons	397	759	545
4 persons	198	320	259
5 persons	243	243	243
6 persons	506	506	506

Appliance review Table 4 presents the energy efficiency ratings from the kitchen appliance audit. The most notable finding is that almost all households have at least one 'A'-rated kitchen appliance. Some low-income families own some 'A'-rated appliances, but this was not the case for the two homes occupied by single elderly occupants in the sheltered accommodation.

Table 4 Appliance energy rating by the appliance for each household

House ID	Appliance energy rating			
	Cooker	Fridge freezer		Washing machine
BB1	B	A		A
LA2	A	A		A
TA1	B	A		A
TA2	B	B		A
TB1	C	B		A
IA1	C	A	A[1]	A
IB1	C	A		A
IB2	C	A		A+
IC2*	C	A		A
ID1*	A	A	A[1]	A
ID2*	A	A		A
GA1	B	B	C[1]	B
GA2	C	C		B
GA3	U[2]	U[2]		None
GB1*	A	A		A+
GB2*	A	A		A+
GB3	C	C		A

*Purchased property

[1]Separate under-counter freezer

[2]Energy ratings unknown

The refrigeration units (fridge and freezer) were all free-standing, mostly upright combination units containing a fridge and a separate freezer. Three homes had additional freezers. Of these, IA1 was a high occupancy household, and the sole occupant of GA1 indicated that cooking was a hobby and that they regularly catered for high numbers for a lunch and dinner club in their development.

Washing machines were all free-standing, front-loading and installed under the kitchen worktops. One of the residents in the sheltered housing complex (GA3) did not have a washing machine but, when home, used the separate laundry facility provided elsewhere in the development. Despite this communal facility, other occupants in the same development indicated they preferred to wash and dry clothing at home. This was due to the difficulty of carrying laundry to and from there, and that uneven external ground and being unsteady on their feet prevented access to the drying green—and reaching the drying lines—in the communal garden area. Some occupants also noted that the unpredictability of Scottish weather often precludes the desire for external clothes drying, particularly when they cannot be quickly retrieved when it is raining.

Energy rating labels indicated 87% of washing machines and 65% of refrigeration units were ‘A+’ or ‘A’-rated. Other than one ‘C’-rated separate freezer, the only appliances with ‘C’ energy ratings were the cookers, 41%. In this sample of homes, a relationship was identified between cooker energy rating and tenure. It was of note that the owner-occupied houses had built-in cookers, whereas the occupants in the rented housing installed free-standing cookers. Only one cooker in the rented accommodation was ‘A’-rated compared with most owner-occupied housing having built-in ‘A’-rated cookers. The building contractor installed a ‘C’-rated cooker in one owner-occupied home.

The annual energy consumption analysis by cooker energy rating in Fig. 3 indicates that yearly consumption is lowest in households with ‘A’-rated cooking appliances. In contrast, the ‘B’-rated cooking appliances had the highest consumption: the reason for this is unknown but can be assumed to be related to meals being cooked more than once a day in the homes with B-rated cookers due to household size, accounting for shift working patterns and includes the occupant frequently catering for high numbers of meals in the sheltered housing complex. The latter could have affected the results. Recognising that consumption is time-based and linked to usage, it is evident that households with ‘A’-rated appliances have a lower consumption, except for the outlier—(LA2)—where an ambulant occupant lives with caregivers.

Discussion

Understanding household electrical energy consumption is essential in addressing the current and significantly increasing costs for household energy and the broader goal of eradicating fuel poverty in Scotland. This research sets out the proportion of total household electrical energy that is consumed in kitchens for cold storing food, laundry and cooking in a selection of Scotland’s new social and affordable homes. While electrical energy is consumed in all parts of a home, the focus was on the kitchen environment due to the high number of electrical appliances and equipment considered essential for maintaining adequate living conditions.

The results indicate that kitchen energy consumption is a significant proportion of households’ total electrical consumption, up to 72%. This figure exceeds the monitored unregulated household demand in the study in England (Gupta et al., 2018) and the estimations by Boardman and Palmer and Cooper (Boardman, 1993; Palmer & Cooper, 2013). Palmer and Cooper estimated 3% of household

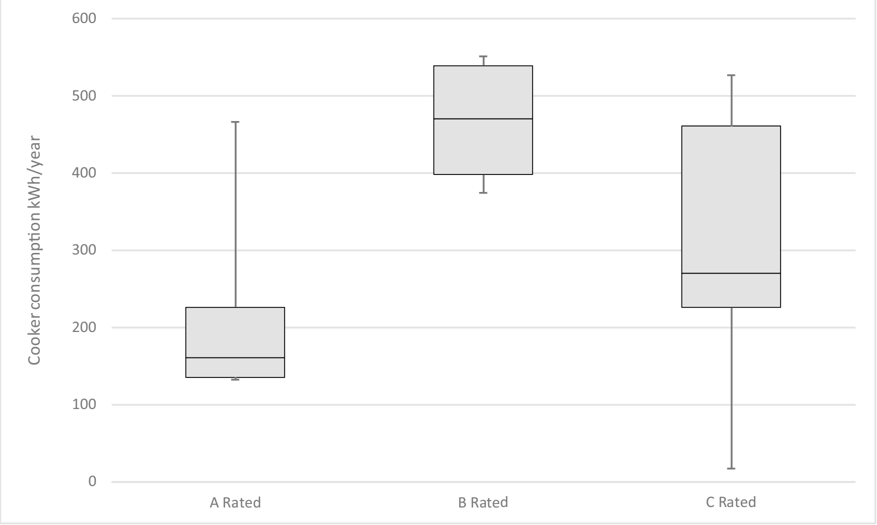

Fig. 3 Cooker consumption kWh by energy-efficiency rating

consumption was attributed to cooking using an oven and hob, compared with up to 10% in this study. The difference may be related to tenure or occupancy patterns in this cohort due to shift working patterns and families preparing meals at different times. These results display that unregulated consumption can form a significant proportion of household expenditure, yet it is excluded from household energy consumption predictions for Building Regulation compliance.

It is legally required to generate and provide an EPC when designing, renting and selling dwellings. They offer a standardised approach for energy efficiency rating and identify likely running costs (both energy and financial) for heating, hot water and lighting a home. Except for 'regulated' lighting and electricity for fans and pumps, all other household electrical consumption—including from typical kitchen appliances—is deemed 'unregulated' and excluded from this calculation.

In two respects, it is understandable that this is excluded: firstly, because households in the UK generally have historically lower energy demand for electricity than for gas for space and water heating, and, secondly, because electrical demand varies significantly relative to factors such as income, occupancy levels and usage patterns. However, as the unit cost of electricity is around three times that of gas (The UK Government, 2023), household energy bills for unregulated electrical energy can be comparable with the gas used for heating and hot water. The EPC uses standardised data to determine a home's energy efficiency. More accurate and realistic electrical consumption data is required to be included in the EPC calculation to offer a more reliable estimate for total household energy costs.

This study found that tenants were required to bring their appliances in all rented dwellings, all had free-standing cookers, and only one rented household had an 'A'-rated cooker. In contrast, the owner-occupied housing was supplied with built-in ovens and hobs. With low-income families tending to have less energy-efficient appliances (Simcock et al., 2016), it can be reasonably assumed that tenants brought their cookers to the new homes, which may be old, inefficient and poorly maintained. The requirement to provide your cooker raises questions over equity among tenure, as better energy-rated appliances are generally more expensive than poorer-rated ones. While not linked to energy consumption, there is a potential hygiene issue with free-standing cookers related to the accumulation of food, dust and grease between the sides of the cooker and adjacent cabinets (Foster & Poston, 2022)—another example impacting social housing occupants that are caused by inequitable practices for supplying ovens and hobs.

The second finding concerns kitchen appliances pre-installed by the building contractor in the owner-occupied property IC1. Here, the contractor installed 'C'-rated ovens and separate electric hot plate hobs. While only one house is in the sample informing this study, all houses in this development were installed with the same cooking appliances. It is likely these will likely remain in the dwellings long-term, and their relatively poor energy efficiency will impact running costs for many years until they are replaced. While this impacts the household individually, other impacts relate to the draw from the National Grid if poorly rated cooking appliances are installed development wide. Legislation should stipulate only 'A'-rated kitchen appliances to be installed in dwellings by building contractors/developers. Overall, the study did not provide evidence that the owner-occupiers in this cohort had a higher electrical energy consumption than those in the rented homes, as illustrated in Fig. 2. While this finding conflicts with the findings of Chatterton et al. (2016) for energy consumption in privately owned households, the current data set reviews a smaller number of homes, making direct comparison of the results difficult. A possible explanation for this disparity could be that the owner-occupied homes included in this study were 'affordable' homes purchased under a government shared-equality scheme. These were all flatted dwellings with their size and layout identical to the rented properties in the same developments. It could be possible that the homes examined in previous research were located on private developments rather than dwellings in the social and affordable sector housing sector. This could imply better socioeconomic stability in the owner occupancy tenure that Chatterton et al. studied in 2016.

Social housing is required to meet diverse needs. Some of the rented homes in this cohort housed elderly occupants with different vulnerabilities. The results indicated two participants living independently in sheltered housing had exceptionally low kitchen energy consumption. In one of these homes, GA3, there was no consumption, and in GA2, there was 1% consumption. Since the cookers were rarely operated, it could be questioned how these occupants receive adequate nourishment and hot meals or whether they rely on a delivered 'meals-on-wheels' service—questioning their 'independence' and care needs. Qualitative exchanges with these occupants identified that one occupant was frequently hospitalised due to ill health, and the other was immobile and relied on home helpers for food and other care needs.

In contrast, the household with a vulnerable occupant living full-time with caregivers had exceptionally high kitchen energy consumption. In this case, this household demographic may be disproportionately impacted by high energy costs to meet basic welfare needs, such as increased laundry and having hot meals prepared at different times. For these households, identifying energy demand reductions and the reality of behaviour change or replacement with higher efficiency appliances, as Gaspar and Antunes (2011) suggested, may not be feasible due to unpredictable needs and a potential lack of capital to change appliances with those with lower energy demand. Changing appliances based on energy rating may also create electrical waste.

Occupants of the sheltered flats in Glasgow had self-organised a lunch and dinner club with meals consumed in the residents' communal area. Despite the complex having a fully equipped kitchen beside the common room, the catering was primarily undertaken in one occupant's domestic kitchen (GA1) using a 'B' rated cooker. The catering for these social events impacted home cooking energy consumption, which was 17% of the household total. Despite the occupant complaining about the high electrical costs of the home, the decision to cook from home was due to several reasons. One was familiarity with the cooking equipment in the home and a lack of confidence to use a different kitchen. However, there were also practical issues; the occupant found it easier to wheel a trolley with two or three pans of hot food to the serving point than taking all the raw ingredients and cooking utensils to the communal kitchen. The occupant expressed concerns over potential distractions while cooking and worried about returning home to collect any forgotten items and leaving cooking food unattended.

While energy demand reductions at the household level are a tangible way for households to save money on energy and increase disposable income, this study has shown that there is complexity and sensitivity in a social housing context. Further studies are needed that qualitatively analyse occupants' lifestyle, kitchen use and eating and laundry habits to determine the impact of unregulated energy consumption, particularly in sheltered properties and homes with vulnerable residents.

Unregulated energy consumption is not considered when undertaking fuel poverty calculations, and the high kitchen energy consumption found in this study gives an indication that the actual number of households experiencing this situation may be considerably higher than official figures show. As the thermal performance of homes in Scotland is improved, for example, by insulating and draught-proofing, heating energy consumption is reduced. Without similar action on unregulated energy use, this cost will make up an increasing proportion of total household expenditure. As a result, more focused studies are required to assess unregulated consumption in a range of housing typologies throughout Scotland. The outcomes could strongly encourage policymakers to legislate for essential household appliances to be supplied with social and affordable homes and incorporate appliance energy ratings in the EPC calculations for assessing fuel poverty.

Further research is needed to review the viability of social landlords to procure high-quality and energy-efficient kitchen appliances for their new homes, regardless of tenure. Ownership and maintenance responsibility will need to be overcome for this provision to be implemented. The benefits include every household having efficient kitchen appliances that could reduce household costs involved with food preparation, cold storage and laundry. Furthermore, built-in ovens and hobs could improve kitchen hygiene. The complexities of households require research at the household level to holistically consider lifestyles and the dietary, societal and health impacts of living without or operating older appliances. This work could be in conjunction with occupant participation to learn appropriate and realistic techniques to optimise energy use in their household situations.

Conclusion

This research examined electrical energy consumption in the kitchens of 17 new social housing dwellings in Scotland to understand its proportion of the total household energy consumed over one year. While the overall household electricity consumption in this cohort was lower than the UK average, few studies have centred around the assessment of household kitchen energy consumption in social housing. The study highlighted unequal practices where cooking appliances were installed in the kitchens of new homes purchased under the affordable homes scheme, while there were no cooking appliances in the homes intended for social rent. An implication of this is the possibility of greater energy consumption linked to kitchen appliances in social homes compared with houses for sale in the affordable sector. The findings indicated that the kitchens consumed 41% (mean) of household electricity; however, the range of household consumption varied significantly between 20 and 72%. This study was unusual in that it used measured data rather than modelled data, the latter having been found to underestimate how unregulated household electrical energy consumption is apportioned in a home. The additional review of appliance energy ratings for refrigeration, washing machines and cookers indicates that washing machines and refrigeration were mainly 'A'-rated, with cookers being the least energy efficient. Owned affordable homes had a higher proportion of 'A'-rated cookers, at 80%, compared with 8% of social homes having 'A'-rated cookers.

Although this research was conducted with data from a small sample of social homes, it raises important issues that warrant further research, particularly as the current societal issue of rapidly increasing fuel prices and cost of living is disproportionately impacting low-income households. Instead of placing the onus on the tenants to cut back on the use of kitchen appliances, and to operate them through the night or replace them to increase efficiency, there is a necessity to tackle this from the top down with updated policies that stipulate white goods fitted before occupancy must be 'A'-rated and equitable practices adopted for residents in social homes. Families in this sector can least afford to purchase the most energy-efficient cookers. This research has significant implications for the human right to adequate housing, food and energy (OHCHR, 2010; OHCHR, 2014).

Acknowledgements The primary research was funded by the Innovate UK (formerly Technology Strategy Board) BPE programme which included data collection for energy consumption and survey of domestic appliances. The authors would like to thank the primary research team at MEARU who conducted BPE research, the support from the local authority, housing associations and the individual participating households and the helpful comments made by the anonymous peer reviewers.

Author contributions All authors contributed to the study conception and design of the manuscript. Material preparation, data collection and analysis were performed by Janice Foster and Anna Poston. The first manuscript draft was prepared by Janice Foster. Peer review edits/corrections were made by 1st review Janice Foster and Anna Poston and 2nd review Janice Foster. Both authors read and approved the final manuscript.

Data availability The datasets analysed during the current study are available from the corresponding author on reasonable request.

Declarations

This material is the author's own work, properly credits the meaningful contributions of authors and the manuscript has not been previously published. All participants gave informed consent for participation in the BPE programme. The authors declare no competing interests.

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