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Retrofit Strategies for Alleviating Fuel Poverty and Improving Subjective Well-Being in the UK's Social Housing

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Abstract: This research delves into the intricate realm of social housing flat units within tower blocks in Leicester, as a microcosm that serves as a perfect reflection of the larger problem of fuel poverty among social housing systems within the UK. The multifaceted approach intertwines energy efficiency upgrades, indoor comfort, and resident satisfaction. Rooted in a comprehensive methodology, this research seeks to address pressing societal challenges within these architectural projects, from fuel poverty and well-being to environmental sustainability and social justice. Through surveys, interviews, audits, simulations, and detailed analyses of summer and winter thermal performance, this study navigates the complex interplay of factors that influence retrofit success. The findings underscore the transformative potential of comprehensive retrofit measures and the paramount importance of resident engagement while offering a potential holistic checklist for future projects. This research paves the way for future studies encompassing contextual diversity, interdisciplinary collaboration, and long-term impact assessment. As it advances, these findings guide the commitment to fostering positive change, enhancing lives, and contributing to a more sustainable and equitable future in social housing retrofit endeavours.

Keywords: social housing; retrofit strategies; fuel poverty; energy efficiency; thermal comfort; resident engagement; building performance simulation; social sustainability

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1. Introduction

Social housing, often a lifeline for vulnerable and marginalised communities, stands at the nexus of critical societal challenges [1]. As the world grapples with escalating fuel poverty, climate change, and the imperative for environmental sustainability [2], architects, researchers, and energy consultants find themselves on the front lines, seeking innovative solutions to mitigate these global crises. Within this landscape, the retrofitting of social housing emerges as a pivotal battleground [3]. Anchored in a multidimensional framework, this research seeks to transcend the boundaries of conventional retrofit approaches, aiming to address not only the thermal envelopes of buildings but also the lives of those who reside within them. In the spirit of the modern age and its emphasis on interdisciplinary collaboration, this study harnesses diverse aspects of architecture, engineering, psychology, sociology, and environmental science. Yet, at its core, this research is driven by an unwavering commitment to social justice, environmental stewardship, and the enhancement in subjective well-being. Fuel poverty, a pervasive issue in the United Kingdom, underscores the urgency of casting a long shadow over vulnerable households [4]. Therefore, the focal point of this research lies within Leicester, a microcosm of the larger urban landscape where the ramifications of inadequate housing conditions and energy inefficiency are acutely felt. Within this context, the researchers undertake the mission of understanding, analysing, and offering practical insights into the retrofitting of social housing units. The overarching goal is ambitious yet essential: to identify the most effective retrofitting approaches, underpinned by rigorous analysis, that will not only improve the energy performance of these flats but also enhance the well-being and livelihoods of their inhabitants. In this quest, the researchers navigate a landscape rich in data, ranging from the ecological principles embedded in the UK's retrofitting measures to international and domestic recommendations. This intellectual journey delves into the realms of thermal performance, heat gains and losses, HVAC systems, and insulation materials—a testament to the researchers' commitment to unearthing tangible solutions. It emphasises that these architectural solutions are not merely technical endeavours but rather a means to empower communities, safeguard the environment, and foster a more equitable and comfortable society for all.

2. Context and Background Knowledge

The literature review focuses on the persistent issue of fuel poverty in the United Kingdom, examining its detrimental effects on household welfare and life quality, which is characterised by the struggle to afford sufficient heating and energy services. Fuel poverty is attributed to factors like low wages, expensive utility bills, and energy-inefficient residences. To address this challenge, the review is structured into three main sections. Firstly, it discusses the concept of fuel poverty, its correlation with energy-efficient enhancements, and strategies for alleviation. The second section delves into subjective well-being, elucidating its connection to fuel poverty and energy-efficient interventions. The third section provides a holistic analysis of research on social and council housing, exploring how energy-efficient measures impact fuel poverty in these settings. Additionally, the review comprehensively analyses information on the area, encompassing its history, planning policies, and relevant statistical data. This multifaceted literature review sets the stage for a detailed examination of retrofitting strategies and their potential impact on energy efficiency and resident well-being.

2.1. Fuel Poverty

Establishing a common definition of fuel poverty can be challenging, as the concept has changed over time and varies by country. For instance, fuel poverty is defined as "the failure to pay for enough and adequate warmth at homes" [5]. They go on to say that it develops due to an overlap of both excessive heating expenses and low income. Notably, it sets itself apart from standard poverty. In England, the (LILEE) definition captures the notion, which evaluates houses with an energy-efficiency grade of D or lower, and whether the household's heating cost results in its members possessing an earnings surplus below the poverty line [6]. In the UK, fuel poverty is identified when household members spend more than ten percent of their total gross salary on essential fuel to maintain a decent comfort level [7]. This criterion is mirrored in Scotland and Wales, where the measure is based on Boardman's guidelines from 1991 [8,9]. Furthermore, the DCENR adopts a similar approach, addressing both fuel costs and the insufficiency of remaining living expenses [10]. In the United States, a historical perspective from 1986 emphasises the need for proper heating equipment and its effective functionality [11]. This diverse set of criteria and approaches underscores the complex and multifaceted nature of defining and addressing it across different regions. This highlights the emergence of an energy price crisis [2]. It is believed to be exacerbated by the post-pandemic economic recovery outpacing energy supplies and the global energy crisis. Ormandy delved into the relationship between fuel poverty and energy inequality, stressing that it extends beyond insufficient space heating to include non-heating energy consumption and services, impacting all energy sources [12]. To navigate these complexities, robust measuring techniques and indicators are essential to capture the influencing variables like energy costs, household income levels, and energy efficiency. Recognising the social, economic, and environmental components of fuel poverty, in addition to its financial implications, is crucial [7]. Therefore, broadening the scope of fuel poverty discourse and policy measures is imperative for a thorough comprehension of energy-related deprivation.

It goes beyond space heating, as emphasised by Simcock et al. [5], who stress the importance of considering non-heating energy uses and services in fuel poverty definitions and policies. The Multifaceted Energy Poverty Index (MEPI), for example, was proposed by Nussbaumer et al. [13] and addresses not only fuel costs but also the insufficiency of remaining living expenses to preserve a satisfactory life standard, acknowledging the multifaceted nature of fuel poverty, often referred to as energy poverty [13]. The need for comprehensive measurement techniques accounting for wider fuel poverty effects is also underscored by health implications related to housing conditions, such as lung troubles and cardiovascular issues [7]. Collaboration among government, energy providers, and community organisations is essential, prompting questions about ensuring fair access to affordable and sustainable energy services through cooperative efforts [7].

Income-based metrics, for example, are exemplified by the Low-Income-High-Costs (LIHC) Indicator, which compares a household's earnings to a ceiling set at sixty percent of the average wage after subtracting housing costs to determine relative fuel poverty, providing insights into household energy affordability [14]. Moving to metrics for energy efficiency, in the UK, SAP is a tool that provides an energy performance index for a specific property by considering elements like insulation, heating systems, and fuel prices. The SAP rating is used to pinpoint households susceptible to the threat of fuel poverty and to assess the likelihood of energy savings [15]. The BREDEM-12 algorithm determines how much it will cost to heat a dwelling [7]. According to this strategy, inefficient dwellings demand greater resources to heat, which raises energy costs and makes a household more susceptible to fuel poverty (Figure 1). Assessing living conditions is another metric used. One example is the Excess Cold Index (ECI), which gauges excessive cold in residential buildings, considering indoor and outdoor temperatures [14]. Additionally, a different indicator is based on subjective indicators, such as self-reports from large-scale social surveys like the European Union (EU) Survey on Income and Living Conditions (SILC), and offers a straightforward perspective on fuel poverty [7].

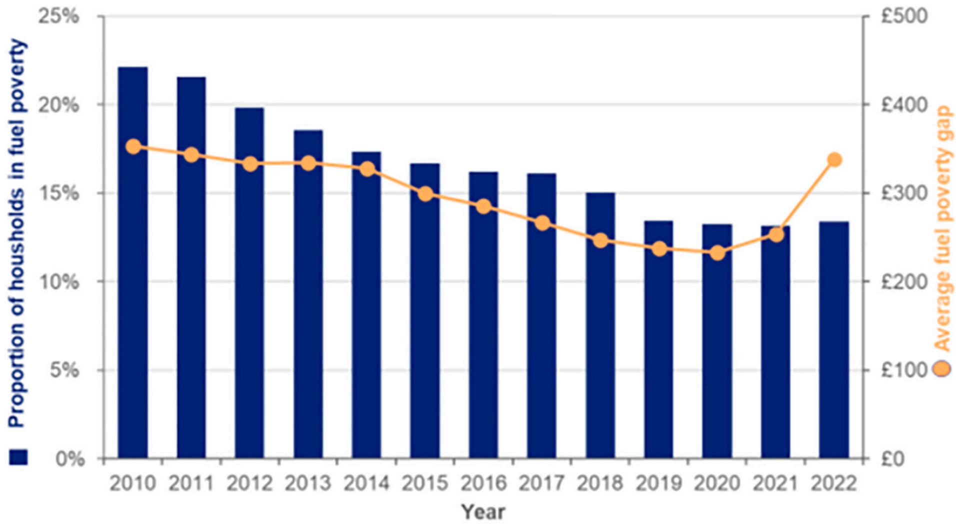


Figure 1. The proportion of fuel-poor households in England [16].

Area-based metrics, on the other hand, such as the Index of Multiple Deprivation (IMD), effectively identify areas with high poverty levels, involving income, work, wellness, and housing. They serve as vital instruments for policymakers [17]. Fuel poverty, which affects 15% of UK households [18], dispels the misconception that it is solely a rural issue. Globally, as highlighted by Xiao et al. [19], energy poverty challenges in Asian and African countries underscore the need for focused measures due to governance and economic issues. Understanding the geographical distribution also emphasises the need for efficient governmental and economic measures, particularly in underdeveloped areas. Focusing on disadvantaged regions and enacting appropriate policies can alleviate the consequences of fuel poverty and ensure equal access to energy services [20].

The concept of "energy injustice" is introduced to underscore landlords' responsibilities for maintaining energy-efficient properties and shifting the burden to tenants [12]. The fuel poverty phrase minimises the obligation of landlords to make sure their buildings are energy-efficient and places the burden on renters for failing to maintain a safe temperature in their residences. The only thing that the landlord is required to do for repairs is fix and restore. This wording does not include improving energy efficiency or fixing what was incorrect in the first place. Supporting this perspective, there is an acknowledgement that statutory definitions of fuel poverty in the UK partially recognise different energy users, yet public discourse predominantly centres on insufficient space heating [5]. It is emphasised that more research is needed on landlords' roles in alleviating fuel poverty and re-evaluating how they relate to the house itself. The underrepresentation of low-income families in fuel poverty initiatives is underscored, emphasising the importance of tailored strategies to address their needs and ensure their participation, reducing socioeconomic disparities using a social justice lens [21].

Questioning the responsibility placed on low-income renters for fuel poverty while being left out in the cold to deal with the repercussions, there is advocacy for a deeper understanding of the term "fuel poverty", asserting that the house itself is inherently the issue [5]. Targeted policies, considering local characteristics and issues, are proposed to combat fuel poverty effectively. Despite the widely acknowledged importance of energy-saving techniques such as insulation, a critical question arises regarding the persisting lack of proper insulation in fuel-poor houses. Policymakers have the opportunity to delve into this issue, understanding why certain houses remain insufficiently insulated despite known solutions. By addressing this at its core and aligning strategies with environmental concerns, policymakers can enhance dwelling energy efficiency [22]. There is a highlight of the requirement for landlords to obtain an energy performance certificate (EPC) before leasing a home with an EPC rating of F or G [5]. This concludes that fuel poverty is a complex issue demanding thorough examination and deliberate policy responses. Incorporating non-heating energy use and services in discussions and policies, recognising landlord obligations, and addressing socioeconomic inequities are all necessary for effectively tackling this issue.

- Factors contributing to fuel poverty:

Energy efficiency, energy prices, and household income collectively contribute to fuel poverty [23]. Understanding the substantial effects of high energy costs on fuel poverty to gain insights into households' coping strategies during energy price crises is necessary. In a groundbreaking study spanning 116 countries, particularly focusing on developing countries, Guan et al. [2] meticulously evaluated the direct and indirect effects of escalating energy costs on household spending, utilising an extensive spending database from the World Bank integrated with a globally multi-regional input–output database. Despite a considerable surge in home energy prices ranging from 62.6% to 112.9%, the resulting increase in household expenditures was relatively moderate, ranging from 2.7% to 4.8%. That is due the fact that this study considered different energy price scenarios, highlighting the varying contributions of direct and indirect costs. The breakdown shows that indirect energy costs increased considerably more than direct energy costs, with a notable rise in crude oil and petroleum products, coal and coal products, and natural gas prices [2].

The pervasive impact of energy poverty, stemming from the oil crisis of the 1970s, casts a shadow over various household activities [19]. Moreover, rising prices linked to high energy costs hinder residents' pursuit of personal development activities, making it challenging to elevate their socioeconomic status. Households grappling with this crisis exhibit resilience through diverse coping mechanisms. These include prudent energy consumption practices such as turning off lights and appliances, regulating heating and cooling, and adopting energy-efficient appliances [2]. Seeking financial aid from government programmes or charities helps alleviate the burden of energy bills. Resourceful households embrace alternative energy sources like solar panels or wind turbines to reduce their reliance on costly energy. [2]. In England, the government introduced a fuel poverty target aiming to enhance the energy-efficiency ratings of fuel-poor homes by 2030, striving for a minimum energy efficiency rating of Band C [23]. Moreover, the absence of cost-saving measures, coupled with increased energy requirements, particularly among individuals with disabilities, exacerbates the fuel poverty predicament [24].

Affordability poses a significant barrier for many households lacking funds for energy-saving measures or investments in alternative energy sources. Behavioural barriers, such as resistance to change and discomfort perceptions, impede the implementation of energy-efficient solutions [2]. Xiao et al.'s energy-ladder concept [19], highlighting the connection between energy types and socioeconomic status, underscores the impact of socioeconomic factors on fuel poverty and the need for targeted responses. Demographic variables, on the other hand, influence fuel poverty, with vulnerable groups including older individuals, single-parent households with dependent children, low-income families, children, young people, pregnant women, individuals with disabilities, those with pre-existing illnesses, and single unemployed individuals [23]. Moreover, the geographic location of homes shapes the fuel poverty experience, with detached buildings in rural areas, where solid fuel is commonly used for heating, experiencing a higher prevalence [22]. The demographic makeup of families, such as having children, retirees, or elderly members, further impacts poverty due to their preferences for warmer temperatures.

The inefficient energy performance of buildings stands out as a key driver of fuel poverty [25]. Healthy housing, as defined by the World Health Organisation [26], encompasses defence against the elements, excessive moisture, pollutants, mould, and pests. Residing in cold, unmaintained dwellings not only increases the likelihood of illness [23] but also induces stress due to discomfort and financial concerns, negatively impacting occupants' well-being [27] and making poor users resort to alternative heating methods, such as using ovens, due to heating system inadequacies, reflecting the dire state of the buildings.

Older constructions, which make up a sizable proportion of the housing stock built before 1965 in the United Kingdom, are not well maintained and are leading to fuel poverty [28]. These structures, characterised by outdated features and varying floor plans, contribute significantly to increased heating energy use [18]. Geographic variations in fuel poverty rates further emphasise the severity of the issue. When compared to England's 13.4% and the Southeast's 7.5%, East Sussex's 8.2% household fuel poverty rate stands out [23]. The importance of tailored interventions and region-specific policies is emphasised, given the geographical discrepancies in fuel poverty rates [24]. Tools like the Potential Fuel Poverty Index (PFPI) (Figure 2) prove instrumental in the initial stages of combating fuel poverty [21]. The PFPI enables the identification of homes at risk, facilitating targeted interventions by policymakers and stakeholders. This approach ensures more effective identification and support for families vulnerable to fuel poverty, aligning interventions with specific needs and circumstances.

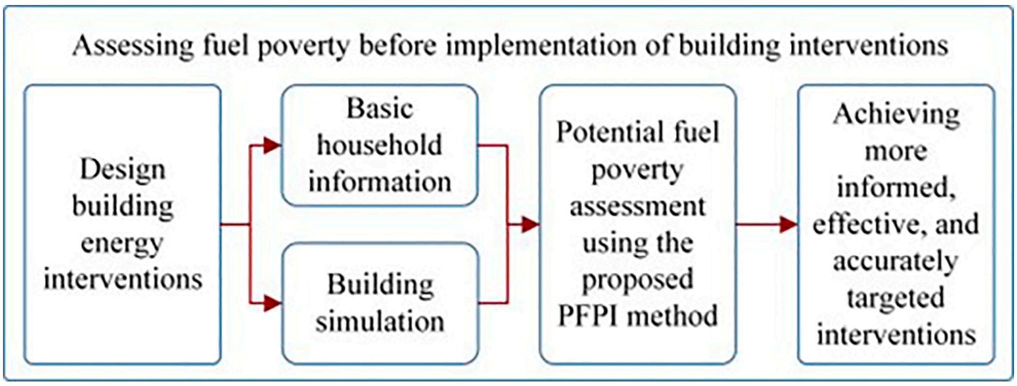


Figure 2. PFPI concept explained [21].

- Energy efficiency upgrades versus fuel poverty reduction:

A 2020 EU-wide survey revealed that approximately eight percent of EU citizens faced difficulties affording indoor thermal comfort, underscoring the widespread nature of the problem [4]. In the UK, housing units alone contribute 32% of the total energy consumption [21]. Efforts to address energy poverty in the building industry rely on energy retrofits and renovations, including insulation, double-glazing, and heating upgrades [3]. Targeted energy efficiency initiatives enhance health for those at risk of fuel poverty, improving overall well-being [29] while reducing energy usage and heating expenses. Upgrades to heating systems have been shown to reduce energy use by 10–30% and heating expenses by 10–20% [29]. Insulation may save heating expenses by 20–30% and energy usage by 15–30%, respectively [30]. In some circumstances, energy-efficient renovations might lower energy usage by as much as 50% [4]. Simulation research by Sawyer et al. [23] on 149 properties in areas of high fuel poverty revealed that inhabitants reported greater comfort, a reduced desire for extra blankets or layers of clothes, improved damp conditions, increased comfort, and improved health following energy efficiency measures. Such measures include solid wall, loft, and cavity wall insulation with central heating systems, boilers (57.7%), and new central heating systems (32.2%) [23]. Additionally, Poortinga et al.'s [31] study tracked indoor conditions for at least 28 consecutive days prior to and subsequent to the setting up of the Arbed project and demonstrated that energy efficiency improvements raised average interior air temperature readings. As a consequence, the majority of interior temperature readings fell within the "healthy" comfort range of 18 to 24 °C, contributing to a decrease in daily gas use of 37% [32,33].

A study was conducted on an energy-related living lab aimed at providing low-cost techniques to combat fuel poverty in energy-vulnerable homes. The experiment involved installing monitoring devices, checking heating systems, and offering energy-saving advice. Homes with monitoring technology reported improved energy-related behaviours and higher life quality (better thermal comfort, fewer moisture issues, and lower energy expenses), with notable improvements in burner energy efficiency resulting from a regular central heating system upkeep [34]. Another study conducted a randomised controlled study on households living in fuel poverty, evaluating the effects of various energy-saving practices on personal, societal, and economic levels. Adopters of practices like loft and cavity wall insulation and central heating upgrades demonstrated higher Standard Assessment Procedure (SAP) scores, reflecting positive impacts on daily activities [35]. McGinley et al. [36] investigated the retrofitting of detached dwellings in the same area, highlighting the benefits of exterior insulation, heating systems, and loft insulation. The results showed increased interior temperatures, decreased primary energy use, and improved thermal comfort [36].

In rural regions, challenges in implementing energy-efficiency upgrades stem from factors such as an ageing dwelling stock, insufficient insulation, and limited access to energy-efficient technology [37]. To anticipate the energy needs of structures post-energy interventions, advanced simulation tools using EnergyPlus DesignBuilder or IES-Virtual Environment are recommended [38]. Proper modelling and parameter setups should consider variables like climate, construction materials, occupancy circumstances, and heating and cooling systems [39], and laws and regulations play a crucial role in improving energy efficiency and alleviating fuel-poverty [1].

2.2. Subjective-Well-Being

In psychology, wellness and subjective well-being (SWB) play significant roles in understanding individuals' perceptions and interactions with their lives [40]. SWB encompasses emotional reactions, domain satisfaction, and overall life fulfilment, which are usually measured using self-reported utility metrics. Variables influencing SWB are categorised into seven broad groups, including earnings, individual traits, socially developed qualities, how people invest time, and mindsets and beliefs about themselves and others, alongside life, relationships, and the broader social, political, and economic environment [41]. Diverse perspectives exist on the definition of wellness, leading to conflicting views [36]. Happiness is viewed differently, with some emphasising its importance in an ideal life while others argue for a broader focus on human development, equity, relationships, and liberty [42]. SWB, promoting human flourishing, involves factors like joyful feelings, stimulating activities, satisfying relationships, and meaningfulness [43,44].

Despite cultural variations in the definition of happiness, studies indicate common characteristics influencing this concept [45]. The relationship between well-being and health is significant, showing that higher SWB levels are associated with improved health [46]. Unemployment negatively impacts SWB, irrespective of income levels [46]. At a macro level, environmental variables, such as climate factors, have a substantial impact on SWB, with global warming potentially affecting well-being worldwide [47]. Addressing these influencing factors can contribute to successful solutions that enhance well-being and happiness. Higher levels of life satisfaction are linked to lower future suicide and depressive attempt rates.

Well-being assessments encompass both affective and cognitive evaluations of emotions and feelings, forming a multifaceted appraisal of life. Well-being indicators are categorised into objective and subjective, with objective metrics relying on observable facts like economic and social statistics, while subjective metrics record individuals' sentiments and experiences [46]. Self-reported happiness and life satisfaction, measured by tools like the Satisfaction with Life Scale (SWLS) and the Positive and Negative Affect Schedule (PANAS), are frequently used in SWB studies [40,48]. Long-term moods, as opposed to fleeting emotions, receive more attention in SWB documentation, emphasising the importance of including measures of both positive and negative affect in studies [49]. Demographic characteristics and test results also show minor but significant associations [50,51]. Various measuring techniques, such as the Experience Sampling Method (ESM) and Ecological Momentary Assessment (EMA), aim to improve the validity and reliability of SWB evaluations by capturing frequent and quick responses in natural settings [46]. The Day Reconstruction Method (DRM) provides detailed accounts of daily experiences through participant diaries matching incidents from the previous day.

Methodological issues, including the global use of self-reported scales with good psychometric qualities but a susceptibility to insignificant life incidents, are acknowledged [52]. SWB measurements may be affected by language and cultural biases in cross-country comparisons, considering that they rely on questionnaires [46]. Contrary to the setpoint hypothesis, unfavourable changes in health have a lasting detrimental impact on happiness, and adaptations to declining health are often insufficient [45]. Individuals experiencing significant health changes may have lower levels of happiness compared to their reference group.

The relationship between indoor architectural design and well-being has gained prominence in the built environment, challenging historical priorities where architects focused on practical requirements [53]. Evidence suggests that long-term pleasure is more contingent on activities than physical conditions, prompting a paradigm shift to view built environments as dynamic entities supporting desired behaviours and inspiring joy and purpose [53]. In "The Architecture of Happiness", ref. [54] emphasises the significant impact of surroundings on pleasure and unhappiness, inspiring scholars from diverse architectural disciplines to delve into the core of mental health in architectural design [55]. Designers must consider both space's actual circumstances and individuals' subjective experiences, relying heavily on environmental psychology to understand their blend's impact on well-being. Objective well-being, on the other hand, denotes the contribution of external factors to life quality [56] and is a crucial concept in architecture related to well-being. This understanding urges architects to ensure interior settings meet requirements for fostering mental health effectively.

The primary research question emerges: Could residential environments empower users to thrive where they live? Healthcare facilities have historically dominated the interior design focus, but current trends extend to promoting well-being in daily contexts for everyone [57]. Architecture, interior architecture, and artefacts collectively shape environments that should be motivating, significant, and powerful for occupants [53]. Contemporary design languages emphasise collaboration, intentionally involving users and addressing their problems to create resonant spaces [53]. The positive design framework provides a viable strategy, considering users' needs and ambitions. Design, a crucial well-being component, aids individuals in achieving meaningful objectives and fostering personal growth [53,58].

In the UK, 44% of respondents reported feelings of misery, anxiety, or depression due to the poor condition of their accommodation, contributing to the urgent issue of the fuel crisis in housing [27]. Fuel poverty compounds financial strain, forcing individuals to choose between heating their homes and meeting their basic needs, leading to hunger and other health issues [7]. This situation induces anxiety and stress, negatively impacting mental health and overall well-being.

The poor state of accommodation in fuel poverty leads to insufficient heating and poor indoor air quality, causing respiratory disorders, cardiovascular illness, and mental health concerns [7]. Simcock et al. [5] highlight the significant financial burden on the NHS from cold-related diseases, emphasising the need for improving indoor comfort and energy efficiency [5]. Additionally, energy poverty is linked to higher winter death rates, particularly affecting vulnerable communities [59]. Research has linked energy poverty to higher winter death rates. Respiratory illnesses, such as asthma and bronchitis, prevail in those living in energy poverty, emphasising the negative health effects of insufficient heating and high energy costs [59]. In addition, other issues related to energy poverty, such as inadequate heating and indoor air pollution, are associated with cardiovascular disease and respiratory conditions [19]. Vulnerable groups, including the elderly and children, are at higher risk of hypothermia and "excess winter mortality" due to living conditions with inadequate fuel supply [7,60]. This challenging environment contributes to feelings of gloominess, nervousness, or depression among a significant percentage of inhabitants, adversely affecting both physical and mental health [27]. The recent surge in energy costs has further worsened households' psychological well-being, hindering their ability to develop coping methods [2]. Households struggle to implement behavioural changes to address increasing utility bills due to stress, worry, and a sense of powerlessness. Their limited ability to cope is exacerbated by a lack of awareness about energy-efficient practices and alternative energy sources [2]. According to Maslow's hierarchy of needs theory, addressing fundamental needs, such as adequate heat and energy, is a prerequisite for pursuing higher-level needs [61].

Addressing energy poverty is essential for encouraging education and individual growth. Xiao et al. [19] found that while 35.08% of respondents reported strong individual growth, spontaneous learning remained a secondary activity in residents' free time. Solving energy poverty becomes crucial for residents to pursue higher-level demands and engage in creative endeavours. However, coping with a prolonged crisis can lead to coping fatigue, limiting households' ability to maintain coping techniques over time. The stigma associated with being fuel-poor is another significant factor, with individuals avoiding guests due to dwelling shame, leading to loneliness and social isolation [23]. This shame not only deters people from seeking help for a better life but also exacerbates existing difficulties, contributing to social isolation, embarrassment, and tension among household members.

2.3. Social and Council Housing in the UK

Over a quarter of the total energy consumption within the UK is attributed to the domestic sector, with excessive energy use and subpar housing quality contributing to fuel poverty and impacting individuals' health and well-being, posing challenges for the UK in achieving the Sustainable Development Goals (SDGs) [39]. Despite progress in reducing fossil fuel production and increasing renewable energy, space heating remains a significant contributor to residential energy consumption, accounting for 63% and contributing to over 25% of the UK's overall energy usage and greenhouse gas emissions [62]. The social housing market in the UK, in particular, requires improvement in both quantity and quality, aiming for a substantial reduction in carbon emissions from energy consumption. Challenges persist, with over 10% of families in England waiting for social housing for at least five years and affordable property developments comprising less than 20% of the annual total [39]. Social-rented housing is facing multilayered deprivation in specific locations, prompting the need for government intervention [60]. Despite improvements, a considerable portion of social housing fails to meet the Decent Homes Criteria, with 13% falling short, according to HM Government (2021b) data [1]. Addressing these issues is crucial not only for reducing energy poverty but also for enhancing the overall well-being of communities.

Council housing has historically played a crucial role in lifting individuals out of poverty, fostering safe environments for growth, and contributing significantly to educational achievements, productivity, and overall economic prosperity [1]. Originating from philanthropic concerns in the 19th century, the Housing of the Working Classes Act of 1890 marked a significant step, leading to the construction of around 24,000 council houses in England by 1914 [63]. The formal introduction of "council housing" came with the Housing and Town Planning Act of 1919, defining it as housing owned and managed by local authorities [1]. Although many of these homes are now managed by housing associations, they are still commonly referred to as council housing. After World War I, the "homes fit for heroes" vision emerged, leading to the ambitious Housing and Town Planning Act of 1919, also known as the "Addison Act", with the aim of building 500,000 new houses within three years [63]. However, only 213,000 homes were completed [64]. Despite concerns about the relatively small-scale nature of housebuilding compared to other countries, such as the USA and Germany, the Building Research Station (BRS) was established in 1921 to modernise and industrialise the housebuilding process [1].

In 1930, the Greenwood Housing Act addressed slum clearance by providing government subsidies to local authorities, resulting in the clearing of numerous slums and the construction of approximately 700,000 new homes [64]. Emphasising affordable flats, the initiative aimed to rehouse those living in slums [65]. During the 1939–1945 hostilities, bombings rendered around 450,000 homes uninhabitable, leading to the erection of temporary structures [66]. To address the housing shortage, the government introduced "short-life" housing, including factory-prefabricated homes, or "pre-fabs" [66]. Non-traditional housing, comprising metal-framed, pre-cast concrete, in situ concrete, and timber-framed houses, became a solution, with around 1 million homes constructed. Initially a short-term measure, many of these homes were eligible for "Right-to-Buy" (RTB) by the 1970s, but design and construction defects emerged in the early 1980s. For long-term solutions, planned housing developments, which are led by local councils, gained prominence. The 1946 Housing Act and the 1949 Housing Act allowed councils to acquire homes for improvement or conversion with government assistance, eliminating the restriction of providing social housing exclusively for the working class [67]. This change aimed to encourage mixed housing estates across income groups, resulting in the construction of almost two million new council homes. Following the 1960s, the focus on slum clearance and new social housing shifted towards the construction of tower blocks, initially considered futuristic. However, by the 1970s, it became evident that these tower blocks were not always well received, particularly by families, and posed challenges in terms of management and maintenance [1]. Social mobility in the 1960s and 1970s played a role in pushing council tenants towards homeownership.

Instead of achieving a diverse mix of households in social housing estates, the phenomenon of "residualisation" occurred, with the least popular estates predominantly occupied by those who could not afford to live elsewhere [1]. Relocating people from private slums to council housing did not always offer the best solution, leading to housing associations being granted funding to acquire and rehabilitate private dwellings. This shift resulted in a decline in new council home construction to around 100,000 units per year in the 1970s, while housing association housebuilding increased significantly from 8300 units per year in 1973 to 24,000 units per year in 1977. The RTB scheme, introduced later, led to the transfer of approximately 1.8 million council homes into private ownership. RTB offered tenants purchase discounts based on tenancy duration and access to mortgages for eligible properties. Concurrently, the Priority Estates Project fund aimed to improve underprivileged public sector estates. Although RTB was initially popular, sales figures fluctuated over time, closely tied to prevailing economic conditions [1]. Flats' sales through RTB were slower compared to houses, presenting challenges for local authorities and owners of ex-council homes. Repair costs for older, former council houses, built before 1965, are higher, and flats generally incur greater maintenance expenses due to roofing, kitchens, communal areas, and the overall building environment, based on the DLUHC 2023 data. These factors contribute to the complexities faced by authorities and homeowners of previously council-owned properties.

The introduction of the "Decent Homes Standard" by the Labour Government in 2001 aimed to provide all social housing tenants with quality homes within a decade-long investment journey [1]. In 2018, 60% of social housing was managed by housing associations, with local authorities retaining around 1.6 million homes. Despite significant investments, about 13% of rented social homes were still considered "non-decent" in 2017 [1]. The housing industry has seen transformations in dwelling types, with a decline in semi-detached and detached houses by 67% since 1991 and terraced houses by 64%. Purpose-built flats decreased from 1.5 million to 702,000, raising concerns, particularly for larger families. Overcrowding became a serious issue, demanding government attention to safeguard health and well-being. The Decent Homes programme positively impacted home quality, reducing carbon emissions through energy efficiency and addressing health and safety hazards with the Housing Health and Safety Rating System (HHSRS). Quality social housing has led to quantifiable benefits such as improved public health, increased life expectancy, a reduced carbon footprint, enhanced educational attainment, and boosted incomes and asset values [1]. Beyond data, good housing impacts intangible aspects like well-being, community engagement, security, and life opportunities. Improved social sector homes have saved the NHS an estimated GBP 392 million, with potential annual savings of GBP 71 million [64]. While the journey to revolutionise modern social housing is commendable, there is more ground to cover. Focusing on creating living spaces that elevate lives, foster stronger communities, and inspire sustainable practices remains crucial for a thriving social housing landscape. The path may be challenging, but the promise of a brighter future makes the effort worthwhile. While 83% of social renters express satisfaction with their tenure, a significant portion of council tenants in poverty-stricken communities feel marginalised. Social-rented sector reports show 46% falling into the lowest income quintile, with associated health risks costing the NHS GBP 1.4 billion annually. In fact, fuel poverty affects 13% of UK households, with social tenants constituting 23.8% [67]. Over half of the social tenants (51%) are inactive, retired, in full-time education, or fulfilling caretaking responsibilities [67].

Addressing energy inefficiencies, the "Future Homes Standard", scheduled for 2025, aims for "zero-carbon-ready" new builds [39]. Meanwhile, the Passivhaus standard, known for impressive energy reductions and a healthy indoor environment, faces slow adoption in the UK's social housing sector [39]. This highlights how, in light of these challenges, green building measures like BREEAM, LEED, Green Mark, BEAM-Plus, and Green Star offer hope by encompassing various green criteria internationally [39]. Embracing the "Future Homes Standard" and innovative methodologies can lead to a greener, more inclusive future, promoting community well-being and resilience.

In essence, fuel poverty is a complex issue intricately linked to the housing sector, impacting people's well-being due to a combination of low income and high heating costs. The global characterisation of fuel varies among nations, measured through income-based, energy-efficiency-based, living-conditions-based, and area-based indices. Poorly maintained homes with insufficient heating systems contribute to tension, discomfort, and negative consequences for physical and emotional well-being. While the housing system, including social housing, has significantly improved lives, changes in policies and methods, such as the RTB Act and the construction of tower blocks, have brought both achievements and challenges, leading to issues like residualisation. Addressing fuel poverty requires more in-depth, long-term analyses of energy-efficiency upgrades' lasting impact, especially in affordable housing. Comparative studies and a design framework for retrofitting existing houses, especially the tower block flats, are lacking, along with investigations into innovative financing structures for feasible energy-efficiency upgrades in social housing. Therefore, the specific objectives of this paper are to:

- Assess the perspectives of residents who live in social housing/tower block flats in Leicester, focusing on energy efficiency and living conditions as they relate to changes in people's subjective well-being and fuel poverty.
- Explore retrofit strategies and determine the most effective approach to improve subjective well-being and alleviate fuel poverty among residents of social housing flats.
- Produce technical advice and generalisable knowledge about the relationship between fuel poverty and subjective well-being in social housing systems in the UK.

3. Methodology

This study adopts a microscale approach, focusing on a neighbourhood in Leicester, to gain localised insights into the relationships between retrofit policies, fuel alleviation, and residents' well-being. It is chosen due to its dense population, socioeconomic conditions, and notable prevalence of fuel poverty, making it a suitable case study reflecting the broader challenges in social housing. The diverse range of social accommodations in Leicester provides valuable information on various dwelling types, energy-saving practices, and residents' quality of life. It is anticipated that the research carried out in this area will shed light on the difficulties and prospective solutions associated with fuel poverty and energy efficiency improvements in the mentioned housing. The case study's investigation of Leicester's distinctive features (Table 1) seeks to further the knowledge of fuel poverty. The findings aim to offer focused insights for Leicester while having the potential for broader generalisation to similar communities facing analogous concerns.

Table 1. Statistical data to justify the selection of Highfields based on Census data 2021 [68].

Statistical Data			**Highfields North**	**Highfields South**
Demographic data	Age		64% aged 16–64 Median age—32	66.1%—aged 16–64 Median Age—31
	Sex		Female: 50.1% Male: 49.9%	Female: 49% Male: 51%
	Country of birth		Outside UK—56.8%	Outside UK—57.3%
Work data	Economic activity		Economic. Inactive—49.9%	Economic. Inactive—48.5%
Housing data	Flats Percentage		62.9%	23.4%
	Number of bedrooms		39.4% (2-bedroom flat)	36.7% (3-bedroom flat)
	Tenure of household	Council rented	36%	5.8%
		Social housing	12.5%	15.8%
		Total targeted Area	48.5%	21.6%

According to Leicester City Council data in 2019, the Index of Multiple Deprivation 2019 incorporates data from the seven areas, and it places Leicester as the 32nd-most deprived municipality in England [69], with 29.9% of residents residing in the 20% most deprived areas nationally for wider barriers to housing such as affordability and overcrowding. Highfields, on the other hand, is the most deprived local area for barriers to housing and services deprivation and shows very bad "indoors" living environment measures; the quality of housing includes whether households have central heating or meet the decent home standard.

The research question revolves around identifying the most effective retrofit approach for flats within social housing systems in Leicester to alleviate fuel poverty and enhance subjective well-being. The selection of the study area ensures representativeness and researcher access through collaborations with local organisations and government agencies.

The methodology consists of a mixed-methods approach (Figure 3). Employing a quantitative approach provides a systematic examination of energy consumption, heating expenses, household income, and well-being metrics. Methodical surveys and utility analyses form the basis for measuring fuel poverty and well-being indicators, offering empirical data and statistical insights. This quantitative foundation allows for the identification of trends, correlations, and potential causal relationships between fuel poverty and well-being in social housing. To complement this, this research incorporates energy simulations for a selected housing unit, utilising advanced modelling techniques to predict energy consumption patterns, assess potential efficiency measures, and estimate their impact on fuel costs and indoor environmental quality. Qualitative data collection involves in-depth interviews and discussions, offering participants the opportunity to openly share their lived experiences, perceptions, and challenges related to fuel poverty and well-being. This qualitative investigation adds depth, context, and a comprehensive understanding to the study of the interplay between energy-related challenges and dimensions of well-being by exploring underlying psychological dynamics, contextual subtleties, and personal narratives.

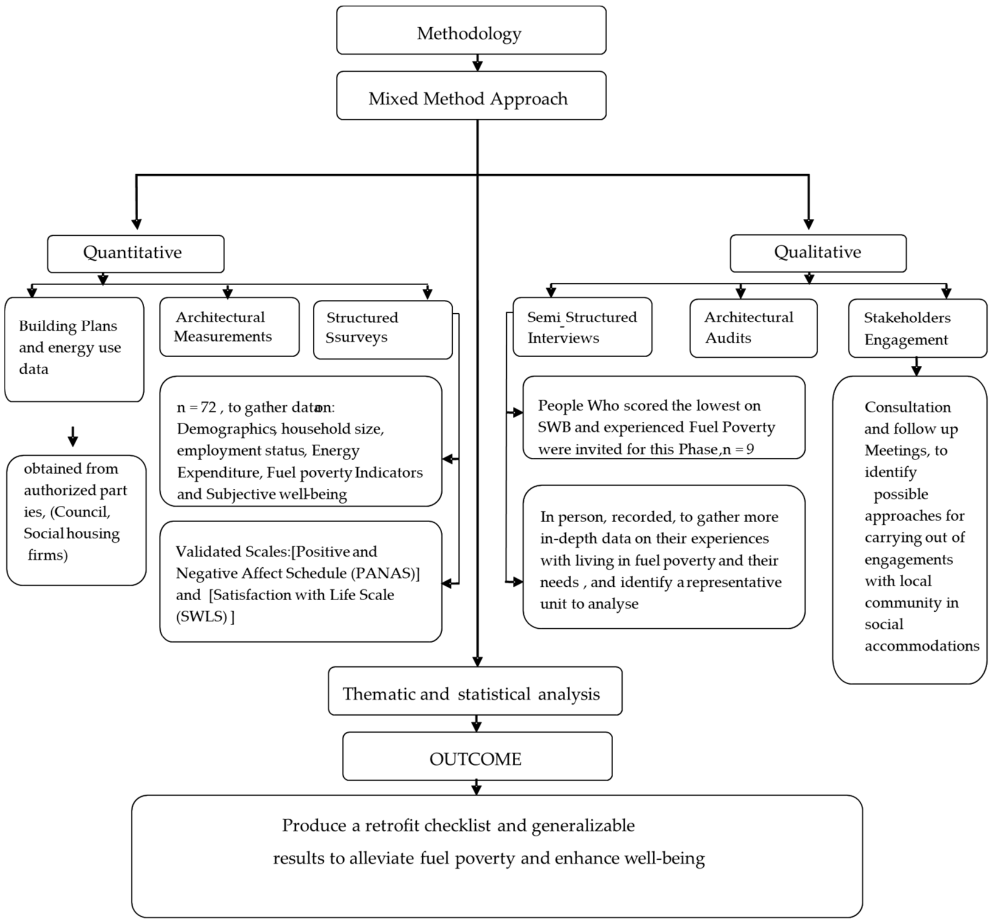


Figure 3. Methodology flow chart.

The research methods, which included surveys, interviews, stakeholder interaction, and site visits, were conducted with great care and attention to detail, strictly according to the laws that are currently in effect in the United Kingdom. Furthermore, these methods were subjected to thorough scrutiny and received formal approval from the De Montfort ethics committee, underscoring the commitment to upholding ethical standards and ensuring the integrity of the research endeavour.

4. Survey

This study implemented a random sampling approach in the area of Leicester, specifically targeting social housing flats susceptible to fuel poverty. The microscale investigation focused on a representative area of Highfields with a high concentration of council and social housing. The selection criteria considered dwelling type, tenure, income levels, and energy expenses. A sample size of approximately 136 households was the aim for the first phase as follows: in accordance with Census (2021) data [68], with a total of 6900 houses and a population of 23,400 in both South and North Highfields, a sample size was estimated using the following method:

- The desired level of confidence is stated as 90%, which is equivalent to having a Z-value of 1.645.
- The acceptable margin of error (E) is ±10%.
- Number of residents (n): 23,400.
- q equals 1 minus p = 0.5.

The sample size (n) was determined using the following formula:

$$n = (Z^2 \times p \times q)/E^2 \quad (1)$$

Since the population percentage (p) in this instance was unknown, a cautious value of 0.5 was used to maximise the sample size while still providing a reliable estimate of $n \approx 67.63$; the resulting sample size was roughly 68 households. However, because the population size was 6900 residences, it was hoped to increase the sample size to be more suitable in order to create a more representative sample. Given the practical limits, a sample size of 136 (about double the estimated value) was the aim during the first phase. For a breakdown of the total dwelling population within the study area and the research sample, refer to Table 2.

Table 2. Total dwellings population amongst the three phases of the study.

	Phase One	Phase Two	Phase Three
Name of the phase	Survey	Interviews	Energy Simulation
Number of dwellings	71	9	1
Selection process	Random sampling	Purposive sampling	Purposive sampling

The survey, consisting of twenty-nine closed-ended questions, aimed to collect quantitative data on energy use to measure fuel poverty and SWB and find a correlation between them. It covered demographic information, home energy use, energy-saving habits, fuel-poverty metrics, and SWB assessments using multiple-choice and Likert scale questions. The survey underwent pilot testing for clarity and efficacy. Data collection was conducted by a member of the research team, and key stakeholders, including local and community organisations (Table 3), were consulted during the engagement process. These comprised regional organisations actively involved in neighbourhood growth and social welfare programmes, housing associations operating the council housing, and local governments in charge of housing regulations and policies. The process involved in-person meetings to communicate this study's goals and seek their voluntary participation to help identify targeted users. Invitations were issued, emphasising the value of their contributions. Subsequent consultation and follow-up sessions were organised, fostering an open atmosphere for stakeholders to express their opinions and concerns. Efforts, including follow-up meetings, aimed to encourage increased participation in the survey. The survey occurred through face-to-face interviews and online participation. A total of 120 households approached, despite the effort of trying to reach double the sample size. It is believed that this was influenced by cultural and time constraints. Seventy-one were eligible and completed the survey in 10–20 min per participant, ensuring data confidentiality. Validated scales, including the Positive and Negative Affect Schedule (PANAS) and Satisfaction with Life

Scale (SWLS), enhanced the reliability of SWB assessments. Participants in this study were provided with a comprehensive participant information leaflet outlining this study's objectives, participation details, potential risks, and data privacy measures. The information was presented in simple language to ensure understanding, and participants provided written or online consent using a consent form. The ethical considerations were taken into account throughout the research process, in accordance with the guidelines set by the Ethics Committee. The data cleaning and preparation phase involved rigorous validation during data entry, including range checks and consistency assessments. Missing data were addressed through imputation and exclusion, ensuring dataset integrity. Data formatting and standardisation ensured uniformity, addressing inconsistencies in representations or labels for a coherent dataset ready for analysis.

Table 3. Identification of stakeholders.

Stakeholder Group	Description	Size	Role/Interest in the Study
Local government agency	Housing policies, community development	Large	Active engagement, data provision
Community support organisation	Supports integration of Somali community	Medium	Active involvement Insight Research process Active engagement
Community centre	Community hub fostering cultural exchange, programs	Medium	
Youth and community organisation	Empower youth cultural activities.	Medium	
Women's welfare centre	Supports women's welfare.	Small	
Community library	Info. Hub, community space promoting literacy and learning.	Small	
Equality advocacy organisation	Promoting racial equality, diversity, and justice	Medium	
Community centre	Social activities hub	Medium	
Religious and community centre	Religious services, community engagement	Large	

4.1. Survey Results

4.1.1. Demographics

Demographic data from the survey reveal a diverse representation among the respondents. The demographic breakdown is shown in (Table 4), which shows diagrams of the gender distribution. Age spans a wide range, with median ages for females, males, and those who chose not to disclose being approximately 36.44, 40.52, and 43.8 years, respectively, as well as household sizes. This comprehensive demographic overview (Table 5) provides essential context for interpreting survey results and drawing relevant conclusions in subsequent analysis.

Table 4. Demographic composition of the sample.

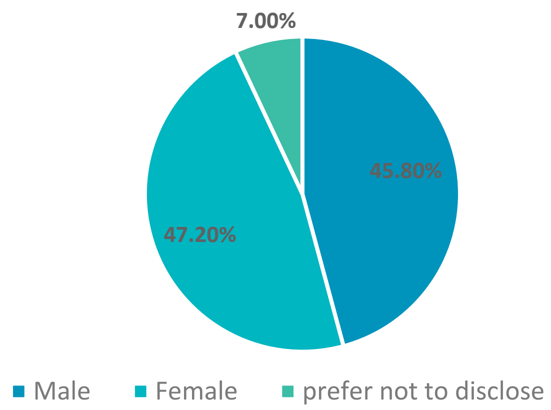
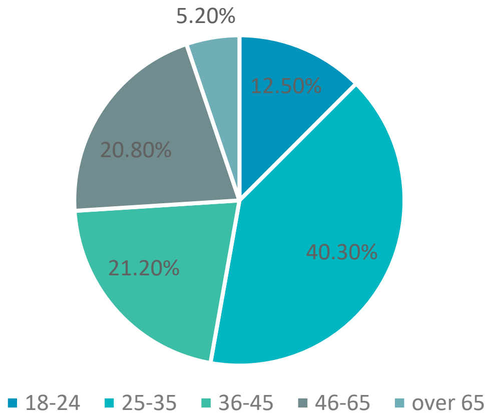
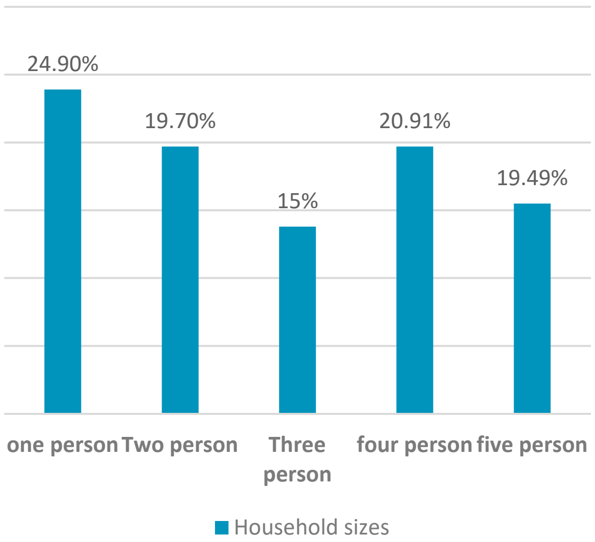
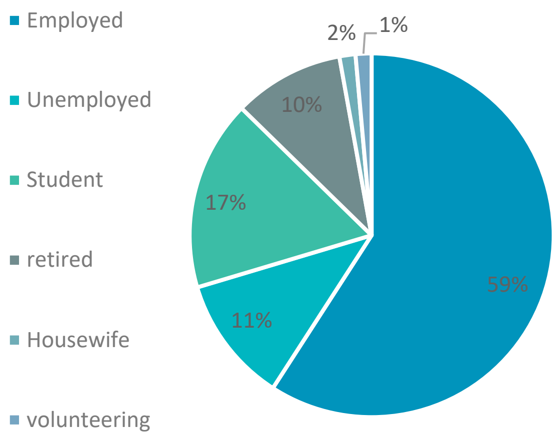
Gender Distribution	Age Distribution
	
Household size	**Employment Status**
	

Table 5. The diverse representation among the respondents.

Sum of Household (Flats) Size (Total Representative Sample)	225
Average	3.125
Minimum	1
Maximum	8

4.1.2. Household Income

The household income section provides an insightful overview of the respondents' financial situations. The majority of participants earn between GBP 1000 and 2000 monthly, with 40.3% falling into this category and 26.4% earning less than GBP 1000. According to the data, some people in this salary level spend a considerable amount of their income on energy bills, which may reflect a preference for high-energy equipment or larger living quarters. Further income ranges are explored, revealing interesting variations in energy consumption behaviours within different salary levels. Notably, the absence of participants in the GBP 4000 to 5000 income range prompts considerations about potential shifts in energy-consumption behaviours or sample composition. The median income is GBP 1500, and the average income is GBP 1750. The data also show that while respondents' reported salaries ranged from GBP 500 to 5000, a sizable fraction (80%) of them reported incomes of

GBP 2500 or less, highlighting a broad representation of income levels within the surveyed population. For a comprehensive overview, refer to Table 6 below:

Table 6. Income levels in household in study area.

Household Income Range (GBP)	Percentage	Respondents
Less than GBP 1000	26.4%	(19)
GBP 1000–2000	40.3%	(29)
GBP 2000–3000	23.6%	(17)
GBP 3000–4000	4.2%	(3)
More than GBP 5000	5.6%	(4)

4.1.3. Energy Expenditure

Energy Bills

Participants' average monthly energy bill expenditures were requested, giving an insight into how they manage their energy costs. Since the survey was conducted in 2022 during the cost-of-living crisis, it allowed for capturing the potential impact of rising energy prices on participants' expenses. It is worth noting that there was no access to actual billing data to verify these claims. The data provided by participants were based on their recall of the last year prior to this study. The findings reveal a variety of respondents' purchasing patterns (Figure 4). Only a small percentage (1.4%) projected monthly energy expenses of under GBP 50. A proportion of 8.3% of participants had an average budget of between GBP 50 and 100. While a sizable number (22.2%) budgeted between GBP 100 and 150 per month for energy costs, 20.8% of respondents said they spent between GBP 150 and 200. Meanwhile, the majority (47.2%) reported paying more than GBP 200 in energy bills per month, which, in light of the significant proportion of people with low incomes, is deemed excessive. Participants' reported energy use and household income show a strong correlation.

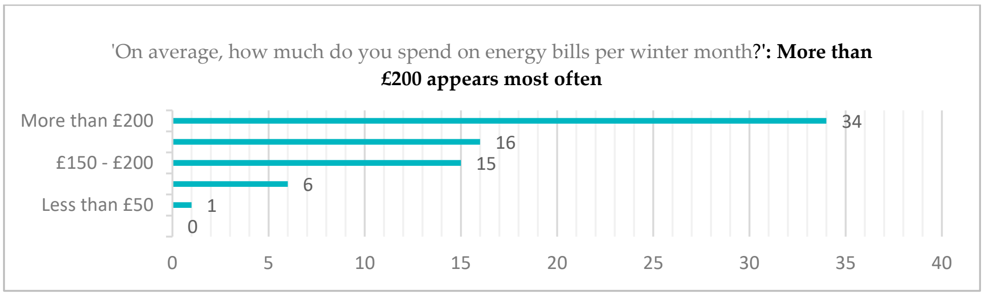


Figure 4. Spending on energy bills on a monthly basis (wintertime 2023).

Energy Source

Participants were also questioned about the energy sources they utilised at home. The findings include information on the prevalence of various energy sources, which may be related to fuel poverty factors. With 50.0% of respondents using them, Figure 5 shows how electricity emerged as the most popular energy source. A lower percentage (4.2%) of users said gas was their main energy source. It is interesting to note that 4.2% of respondents said they used electricity, gas, and renewable energy sources all at once. A proportion of 36.1% of respondents mixed gas and electricity, indicating a typical energy mix. No participant stated that they only used renewable energy. A small percentage of respondents (1.4%) combined gas and district heating. Similarly, 4.2% utilised both district heating and electricity. These results shed light on the dominant energy sources used by the sampled population, highlighting the dominance of electricity and the sporadic use of district heating and renewable energy.

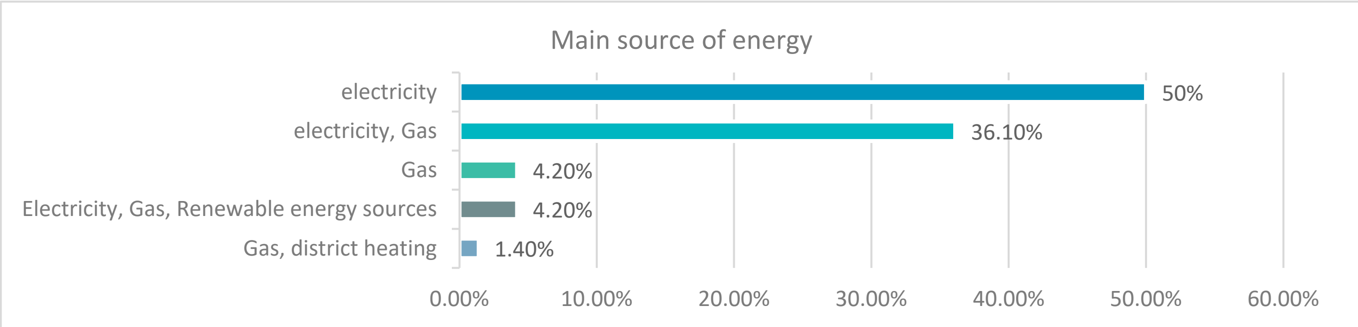


Figure 5. Main sources of energy in the surveyed sample.

Furthermore, only 25% of participants reported the presence of prepayment metres for energy use. Prepayment metres are frequently linked to better managed and tracked energy consumption, which may have an effect on budgeting and energy spending.

Frequency of Energy Supply Disruptions

The survey results indicate the following distribution of responses regarding the frequency of energy supply disruptions:

- A small percentage (6.9%) of participants reported experiencing energy supply disruptions "always".
- An even smaller portion (2.8%) indicated experiencing disruptions "very frequently".
- A portion of 11.1% of respondents reported facing disruptions "occasionally".
- A notable 20.8% of participants encountered disruptions "rarely".
- A substantial proportion (33.3%) reported experiencing disruptions "very rarely".
- A quarter of participants (25.0%) stated that they "never" experienced energy supply disruptions.

Examining the frequency of energy supply disruptions reveals a nuanced pattern in participants' experiences. The fact that a minority encounters disruptions "always" or "very frequently" indicates a specific segment of the population dealing with ongoing challenges in ensuring a dependable energy supply. Conversely, the substantial proportion reporting disruptions "never" implies a more stable energy situation for a considerable portion of respondents. The prevalence of responses in the "occasionally" and "rarely" categories indicates that intermittent disruptions are more widespread than frequent ones, with a significant number reporting infrequent challenges. Notably, the sizable group noting disruptions as "very rarely" highlights a considerable subset of participants seldom encountering issues with their energy supply. This analysis underscores the heterogeneity in respondents' experiences, emphasising both the commonality and rarity of energy disruptions within the surveyed population. Percentages on the difficulty in affording energy bills amongst the users in the sample is shown in Figure 6.

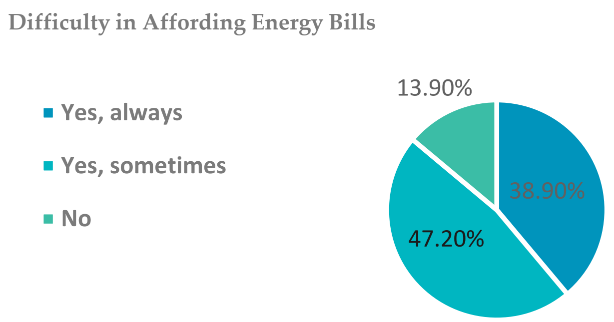


Figure 6. Rates of difficulty in affording energy bills associated with households dealing with fuel poverty.

4.1.4. Fuel Poverty Indicators

This section delved into indicators of fuel poverty, utilising the UK index, which categorises a household as fuel-poor if their energy costs surpass 10% of their income. The results reveal that a substantial majority of households, constituting 83.3% (60 households) (Figure 7), grapple with fuel poverty, indicating a significant financial burden. In contrast, 16.7% (16 respondents) fall into the non-fuel-poor category, displaying a more favourable energy expenditure-to-income ratio in these families. The stark connection between income and fuel poverty underscores the pivotal role of economic disparities in influencing energy access and affordability. Lower-income households bear a disproportionate burden of fuel poverty, necessitating targeted support and policies to ensure energy affordability across all income groups. This predicament poses challenges that may force these households to make difficult trade-offs between meeting basic needs and covering energy expenses.

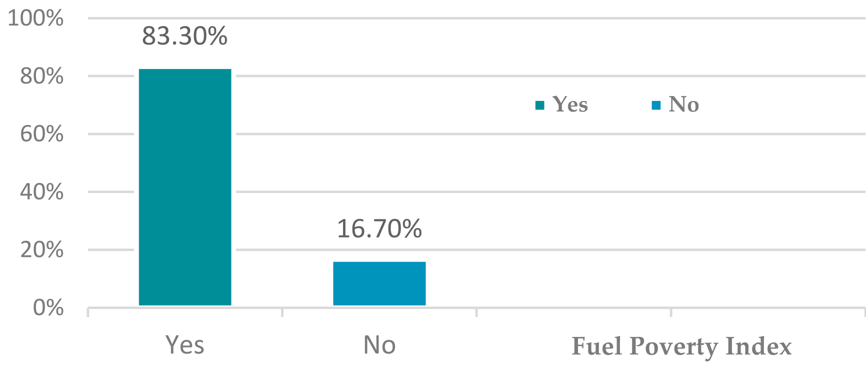


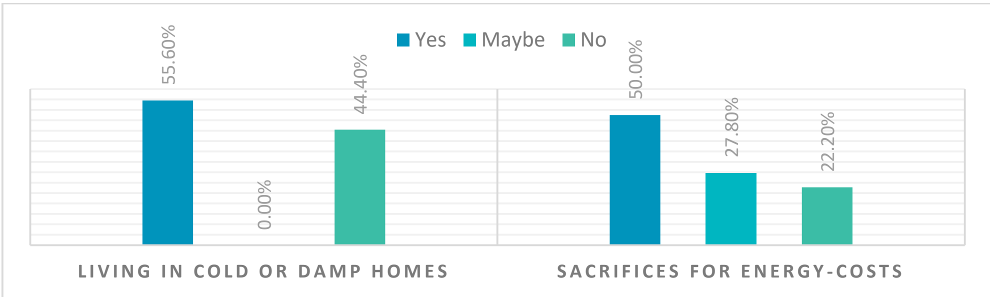
Figure 7. Fuel poverty index in sample area; calculated by authors using UK's fuel poverty.

An examination of the association between demographic factors like gender, for example, and fuel poverty reveals an almost equal distribution. These findings indicate that the frequency of fuel poverty within the sampled population does not appear to be influenced by such factors. However, it is the connection between household heating practices that yields significant insights. Specifically, 48.3% (22 users) of households relying solely on electricity for heating are in fuel poverty, indicating notable challenges with energy affordability, possibly due to the increased expenses associated with electric heating techniques. Gas and electricity combined represent the second-highest percentage at 37.9% (28 homes). Although slightly lower than households using only electricity, this still underscores the difficulty of managing energy expenses. The data reveal a nuanced relationship between heating methods and fuel poverty, suggesting that electric heating is linked to a higher likelihood of fuel poverty, likely due to the higher costs of electricity compared to other heating sources. Moreover, the significant proportion of households using both electricity and gas and experiencing fuel poverty implies that even combining heating sources may not fully alleviate the affordability challenge for these households.

Difficulty in Affording Energy Bills

The reflections of participants on their experiences with affordable energy bills in the previous year revealed significant challenges. Notably, 38.9% of respondents stated that they consistently had trouble paying their energy costs, while 47.2% reported occasional difficulties. In contrast, 13.9% indicated having no trouble paying their energy expenses. These findings underscore a prevalent financial hardship, with 87.3% of participants facing some difficulty paying energy bills. The substantial number of individuals and households grappling with the financial burden of energy costs aligns with the earlier analysis on fuel poverty and income disparities. It accentuates the need for comprehensive strategies addressing both energy consumption patterns and income disparities to alleviate the substantial impact of energy expenses on households, reinforcing the importance of developing effective and inclusive solutions.

Figure 8a shows that approximately 56% of respondents (40 participants) faced the challenges of living in cold or damp houses due to financial constraints, emphasising the critical role of energy affordability in ensuring safe and quality living conditions. This underscores concerns about potential health hazards and overall well-being. Furthermore, 50% of respondents (36 participants) had to make sacrifices in various aspects of their lives to cover the energy costs shown in Figure 8b, highlighting the significant financial hardship imposed by energy bills. This emphasises the intricate trade-offs individuals and families must navigate, underscoring the need for tailored assistance measures to alleviate the burden of energy expenditures without compromising well-being. The results also display a significant divide in seeking financial aid for energy costs, with 47.2% actively seeking assistance. This underlines the complexity of addressing energy-related financial strain. While nearly half are proactive, the substantial 52.8% not seeking help emphasises the need for improved outreach and education to ensure accessibility to resources. Bridging this gap requires comprehensive efforts for a more inclusive approach to managing energy-related expenses.



(**a**) (**b**)

Figure 8. (**a**) Count of people living in cold or damp homes, (**b**) sacrifices for energy costs among survey responses.

4.1.5. Subjective Well-Being Scale

In the last section, participants' subjective well-being was assessed across various dimensions using a Likert scale. Questions on life satisfaction, daily happiness, and overall life quality received average scores of around 6.3, 6.3, and 6.14, respectively, indicating a general trend towards fair well-being. This shows that participants' assessments of their emotional health have been trending in the same direction. Stress or anxiety related to living arrangements and energy expenditures had a median score of 7, reflecting a fair amount of stress. An array of experiences is represented by the distribution of answers (Figure 9).

While the majority of participants reported having considerable amounts of stress or anxiety (scores between 6 and 9), this suggests that a sizable segment of the population being questioned experiences stress or anxiety periodically or frequently. Respondents perceived a notable influence of housing conditions on their health, with an average score of 7.04. The absence of scores in the lower range suggests that participants generally recognise the influence of housing on their well-being. Evaluating accommodations meeting basic needs yielded an average score of 6.03. While quite a few participants believe their accommodations match these criteria, a significant percentage of respondents expressed worries about meeting basic living standards. Satisfaction with physical health, sleep quality, and daily living activities averaged around 6.5, 6.25, and 7.08, respectively. While most participants reported satisfaction, major trends (Table 7) and disparities in experiences highlight the need for holistic strategies addressing both energy-related and health dimensions to enhance overall well-being.

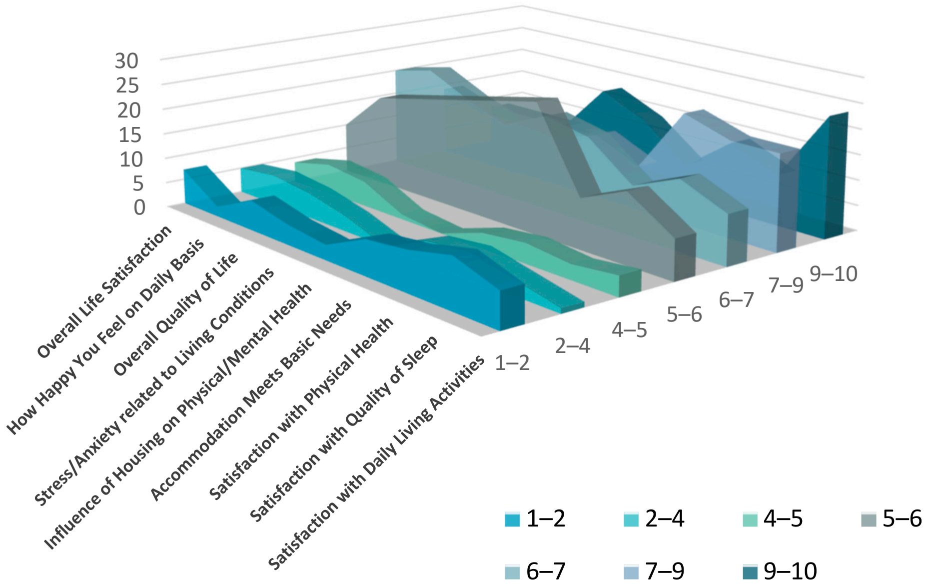


Figure 9. Major SWB correlation and distribution of results.

Table 7. Major trends and observations.

Central Tendency	Across all well-being questions, the median score consistently falls around six. This suggests that participants generally express moderate levels of well-being across various dimensions.
Moderate Satisfaction	The distribution often shows a concentration of responses in the 6–7 range, indicating moderate satisfaction. This trend is particularly noticeable in questions related to overall life satisfaction, daily happiness, and overall life quality.
Positive Extremes	In several questions, such as "Satisfaction with Daily Living Activities" and "Satisfaction with Physical Health", a relatively high number of participants indicate extreme levels of satisfaction (9–10). This suggests that many respondents perceive elevated levels of well-being in these specific areas.
Energy-Related Challenges	For questions regarding stress or anxiety related to living conditions and energy costs, as well as health influences from housing, the distribution extends across the entire scale. This indicates a wide range of experiences, suggesting that energy-related challenges can have varied impacts on participants' well-being.
Sleep Quality Variability	The question "Satisfaction with Quality of Sleep" shows a relatively even distribution across the scale, indicating a mix of responses. Participants' perceptions of sleep quality vary, with no single dominant trend.
Accommodation Adequacy	Responses to the question "Accommodation Meets Basic Needs" show a higher concentration in the 5–6 range, suggesting that participants' perceptions of their accommodations meeting basic needs are low to moderate overall.
Negative Extremes	In some cases, a small number of participants express extreme dissatisfaction (1–2 range). This is most notable in the questions about sleep quality, satisfaction with daily living activities, and satisfaction with physical health.
Overall Variation	The distribution patterns across all questions indicate that participants' well-being experiences vary widely. This underscores the diverse nature of well-being perceptions within the surveyed population.

In the absence of a predefined threshold for classifying low SWB, a simplified approach to categorising the well-being scores is used as follows:

- Low SWB: scores below 5 (1–4) are categorised as low well-being, constituting around 20.8% (15) of participants.
- Moderate SWB: scores between 5 and 7 are categorised as moderate well-being, constituting around 54.2% (39) of participants.

- High SWB: scores above 7 (8–10) are categorised as high well-being, constituting around 25% (18) of participants.

This extensive dataset, which included responses from seventy-two households, revealed that a percentage of respondents had scores that were suggestive of substantially lower levels of SWB. After identifying this subgroup, an affirmative step was taken to extend invitations for follow-up interviews. This proactive approach sought to delve deeper into the nuanced experiences and perspectives of these participants, providing an opportunity to glean valuable insights into the factors influencing their well-being assessments.

5. Interviews

For the interviews, a purposive sampling technique was employed, focusing on the respondents who scored extremely low on subjective well-being or had severe struggles with fuel poverty. The aim was to capture diverse experiences and viewpoints. Out of seventy-one survey respondents, twenty-two were invited based on their answers, fifteen expressed interest, and ten were interviewed, resulting in a 50% response rate. The interviews, administered by a member of the research team, were conducted in person in a conducive venue, fostering a comfortable environment and allowing participants to share their stories confidentially. Study kits, including an information sheet and consent form, were provided in person. A semi-structured interview schedule facilitated flexible responses, and audio recordings, along with field notes, were used to document non-verbal cues, background information, and researcher thoughts. Participants were assured of privacy and anonymity throughout this study. Participant comfort and well-being were prioritised, adhering to ethical standards for participant engagement. NVivo 1.6.1 software was employed for organising and analysing qualitative data systematically through the effective coding of interview transcripts. Pre-established codes were applied during the coding process, aiding in the identification and classification of themes and patterns. The visualisation of connections between codes and themes enhanced the interpretation of the results. It facilitated rigorous analysis by comparing codes from multiple interviews, improving overall validity.

In the course of analysing the interviews, each interview was assigned a unique code to ensure the anonymity of the subjects, as explained in Table 8. Each quotation is referred to by Ref 1, Ref 2, etc., in each theme.

Table 8. Unique codes assigned to each individual interviewed.

Interview 1	Interview 2	Interview 3	Interview 4	Interview 5	Interview 6	Interview 7	Interview 8	Interview 9
AA1	AB2	AC3	AD4	AE5	AF6	AG7	AH8	AI9

Interviewee 10 formally communicated their decision to withdraw from this study during the research process.

- Theme One: Factors Contributing to Low SWB Scores:

The first prominent theme extracted from the interview centres around the impact of high heating bills and discomfort on participants' SWB. Participants shared challenges related to staying warm during winter, emphasising the difficulties arising from insufficient heating (AA1, Ref 1). A vivid illustration of financial strain is provided by AA1 (Ref 2), recounting an instance where they had to huddle in one room with blankets due to soaring heating costs, highlighting the trade-off between warmth and affordability.

"**I work 9 to 5 as an accountant, and I do like to take care of my physical health, so I love to play football. But balancing a fulltime job with this passion can be exhausting. By the time I get home, I'm drained both physically and mentally. The lack of comfortable and well-ventilated spaces in my flat makes relaxation and recovery difficult (AE5,REF1)**" AB2 (Ref 1) expressed frustration with seemingly ineffective heating, reinforcing the notion that inadequate heating and associated expenses significantly contribute to lower SWB. Moreover, various references from different interviews underscore the financial stress induced by energy costs, revealing a direct correlation between financial concerns and the ability to enjoy one's living space. This theme illuminates the intricate relationship between heating expenditures, financial strain, and overall well-being, particularly for individuals on limited budgets, such as students.

- Theme Two: Issues (Support):

"It's a constant battle!!" (AB2,REF2)

A significant theme identified in interviews, voiced by 6 out of 9 participants, revolves around the challenges individuals face when seeking support to address housing-related issues. This theme unfolds through three key categories: struggles in seeking support, equality, and gaps in its impact. AC3 (Ref 1) emphasises the limitations of available support systems, highlighting their temporary relief but their inability to address underlying design issues, contributing to high energy costs in the long term. A common struggle is articulated by AC3 (Ref 2), pointing out the limited availability of support and the vulnerability of individuals left without adequate assistance when resources are quickly exhausted. The potential impact of support in the form of housing improvements is reflected in the words of AF6 (Ref 1), envisioning enhancements to insulation, ventilation, and temperature regulation for a more consistent and comfortable living environment.

A consistent pattern in the interviews underscores the profound impact of inadequate support on well-being. AI9 (Ref 2) reflects on the lack of support for mental health and disability, highlighting the distressing consequences of seeking support in vain, including the emotional toll and the potential threat of losing housing. This theme emphasises the critical need for more effective and sustainable support systems to address housing-related challenges and their impact on individual well-being.

"I asked my landlords (council). I cried. I talked to them… Why should I change it? I am a resident and I pay rent." (AF6,REF1)

- Theme Three/Four: Issues (Ventilation/Windows):

In examining the combined thematic analysis, the interplay between "ventilation" and "windows" within the context of flat conditions becomes apparent, contributing to 12.82% coverage of the identified issues. AA1 (Ref 1) vividly describes the struggle to maintain warmth during winters, attributing the challenge to the infiltration of cold air through windows and walls. This emphasises the collaborative impact of inadequate windows and ventilation on temperature control.

AB2 (Ref 1) recalls a specific winter experience where cold air permeated through the gaps around windows and doors, highlighting the interconnected role of windows and ventilation in influencing indoor temperature. AF6 (Ref 1) adds a unique perspective, discussing the detrimental effects of wooden windows during winter, further illustrating the connection between window conditions and ventilation, affecting both comfort and structural integrity.

"I do think that there is a lack of insulation which is a major concern, and single-pane windows do little to retain warmth." (AC3,REF1)

AH8 (Ref 1) discusses the trade-off between warmth and ventilation, noting the constant struggle residents face in balancing closed windows for warmth and the influx of air. This sentiment is echoed by six other interviewees, emphasising the recurring nature of this challenge in flat-living conditions. Additionally, AB2 (Ref 3) reflects on the design of windows, noting their small size and positioning, limiting sunlight penetration, and influencing occupants' perceptions of their living space. This observation introduces a connection to the broader theme of daylight, expanding the discussion beyond temperature regulation.

- Theme Five: Issues (Natural Lighting):

A repeating trend that highlights the value of having access to natural light in determining people's overall life quality was observed by analysing the interview data. AB2 (Ref 1) straightforwardly notes, “Natural light is scarce”, emphasising the importance of this resource. AD4 (Ref 1) emphasises the connection between lighting and mood, expressing how limited natural light on cloudy days affects mood and productivity. This underscores the emotional and functional impact of variations in natural light. AE5 (Ref 1) draws a connection between poor lighting and mental health, highlighting the negative influence of returning home to a dimly lit and inadequately ventilated flat on overall mental well-being. The associated financial strain amplifies the challenges faced by the individual.

> ***“The living room gets a bit of light, but the bedrooms are quite dark. It’s tough to maintain a cheerful atmosphere when even the simplest things like sunlight are a luxury.” (AA1,REF1)***

AE5 (Ref 1) made a connection between poor lighting and mental health, commenting that “after a long day at work and intense football sessions, coming home to an inadequately ventilated and dimly lit flat doesn’t contribute positively to my overall mental health. The rising costs add to the financial strain you can imagine”. On the other hand, AE5 (Ref 2) acknowledges the current lighting situation, expressing a desire for a more well-lit space. This reflects a longing for an environment with improved access to natural light, suggesting that individuals recognise the positive effects of well-lit spaces on their well-being.

- Theme Six/Seven: Issues (Thermal Comfort; Hot/Cold):

Among nine participants, seven expressed challenges with extreme cold in winter, highlighting difficulties in maintaining a comfortable indoor temperature. This points to broader issues related to insulation, heating systems, and building design. Conversely, four participants raised concerns about overheating in the summer, indicating an inadequate design for temperature management and potential health risks. The prevalence of these concerns emphasises the need for improved ventilation, shading, and cooling solutions in social housing. This user analysis underscores the urgency of addressing year-round temperature regulation issues in these living spaces. Refer to Table 9 for a detailed overview.

Table 9. Patterns around excess cold or overheating observations in social housing flats in study area.

Participant	Quote	Thermal Comfort	Coverage (%)		Patterns and Observations
AA1	“During winters, the cold air seeps through the windows and walls, making it feel like an icebox. It’s a constant battle to keep everyone warm.”	Extreme Cold	6.28%	8.37%	Inadequate insulation leads to cold air infiltration, requiring constant efforts to maintain warmth.
	“My young children’s room gets extremely cold, even with extra blankets.”		2.09%		Even additional blankets are insufficient to counter extreme cold in specific areas.
	“Summer are no better, as the lack of proper ventilation turns the place into an oven.”	Extreme Hot	5.78%	8.96%	Inadequate ventilation leads to extreme heat in the living space during summer.
	“And during summer heatwaves, the living room becomes unbearable. It’s like we’re at the mercy of the weather.”		3.18%		Extreme heat during heatwaves affects the living room’s comfort, highlighting vulnerability to weather conditions.
AB2	“Thermal comfort is a daily challenge.	Extreme Cold	1.10%	3.04%	Consistently challenging thermal conditions are faced daily.
	“My bedroom is a temperature battleground. In winter, it’s freezing.”		1.94%		Bedrooms experience extreme cold in winter, suggesting inadequate heating.
	“But in summer, it becomes less worse, and sleep is somehow better. But still, It’s a constant struggle for comfort.”	Extreme Hot	3.30%		Summer nights may be slightly more comfortable for sleep but still pose a challenge for overall comfort.
AC3	“It’s an everyday struggle to keep a comfortable temperature.”	Extreme Cold	1.85%		Maintaining a comfortable temperature is an ongoing challenge.

Table 9. *Cont.*

Participant	Quote	Thermal Comfort	Coverage (%)		Patterns and Observations
AD4	"The common areas can be chilly, while my room becomes like a Sweating Buckets during hot spells, creating a stark difference in comfort levels."	Extreme Cold	4.43%		Uneven temperature distribution results in discomfort between common areas and individual rooms.
	"It gets stiflingly hot during summer, making it hard to concentrate, while other parts of the flat remain much colder."	Extreme Hot	3.30%	15.24%	Extreme heat impacts concentration during summer, with temperature disparities within the flat.
	"The common areas can be chilly, while my room becomes like a Sweating Buckets during hot spells, creating a stark difference in comfort levels."		4.43%		Discomfort is intensified by temperature differences between common areas and individual rooms during heatwaves.
	"There's a stark contrast in thermal comfort across the flat. My room is almost unbearably hot during summer and little cold in winter. Sometimes I do think this is because I'm on Higher floors, because my other friends in lower levels feel Okay."		7.51%		Significant thermal comfort disparities are experienced across the flat, potentially influenced by floor level.
AE5	"A struggle, especially during extreme weather. Coming back sweaty from football practice to a stifling uncomfortably cold flat adds to the exhaustion."	Extreme Cold	4.27%		Extreme cold exacerbates physical discomfort after physical activity.
AH8	"The house is colder from inside. The temperature is always almost 3–4 degrees less than what it outside.	Extreme Cold	3.90%	9.58%	Poor construction may contribute to reduced indoor temperatures compared to outdoor conditions.
	"It is actually normal, not too extra hot inside no, if it's like 27 degrees outside, it will Be 20 degrees inside the house. So, I like it."	Extreme Hot	2.75%		Comparatively moderate indoor temperatures during hot weather are appreciated.
	"My other friends live in student accommodation. With a new construction. In there, it's way too hot. Yeah, even in winter."		2.39%		Newer constructions may exhibit excessive indoor heat even during winter.
AI9	"I can, sometimes I can put the heating on but then I have to make sure that all heat radiated on certain levels to heat one room, I struggle just to balance. Other rooms are freezing in there. So, we rarely sit in my living room, it's just a wasted area."	Extreme Cold	3.24%		Difficulty in evenly distributing heat throughout the residence leads to specific rooms being excessively cold, and not using the spaces properly.

- Theme Eight: Issues (Building Envelope):

Participants expressed concerns about the building envelope, citing problems like poor insulation, chilly air infiltration, and the impact of building quality on temperature regulation. Single-pane windows and the lack of insulation contributed to thermal discomfort, emphasising the role of insulation in maintaining comfort. Building materials' quality affected cold air retention, leading to temperature disparities. Mould growth due to poor maintenance added to the discomfort and cleaning costs. Fireplaces without proper sealing cause air infiltration and discomfort. Safety concerns, including window shaking, highlighted the impact of building deficiencies on both comfort and safety.

- Theme Nine: Issues (Microclimates):

Participants voiced frustration over the lack of control and distinct microclimates within their living spaces (AD4-Ref 1). Concerns included stark comfort-level differences between areas, making shared spaces chilly while specific rooms became excessively hot (AD4-Ref 2). Finding a balance and addressing inconsistent room conditions proved challenging, according to AD4 in Ref 3. The complexity of managing microclimates to accommodate individual comfort needs was also highlighted (AI9-Ref 1).

> ***"In each room, everything is completely different. Every room has their own, like my daughter's room is extremely cold or extremely hot. She just stays in mine with me adter I heat it so we can sleep. Sometimes we go on walks, because we don't know what else to do and we wear extra clothes. But she's also autistic and it's hard to convince her to. She doesn't want too much clothing; she's got a thing about nor putting her feet under the covers. She's always complaining.. I don't know what to do!" (AI9,REF1)***

The coping strategies observed highlight the resilience of individuals in social housing facing harsh weather. Lifestyle changes, energy-saving measures, and community support underscore the need for practical solutions to address fuel poverty and poor well-being. Urgent improvements in social housing, including insulation, ventilation, and heating options, are emphasised.

The next phase included a decision that was made to zero in on a specific individual's condition in order to apply the findings. Based on the insightful information from the interviews, the flat that exhibited the highest percentage of issues was chosen to represent the sample. By creating a computer-based model that mimics energy usage and comfort based on their experiences, this aided in developing realistic strategies for raising living standards in social housing. The objective was to determine the optimal retrofitting strategy to alleviate fuel poverty and SWB in social housing flats by using up-to-date software and real-life examples and finding better methods to manage energy and well-being.

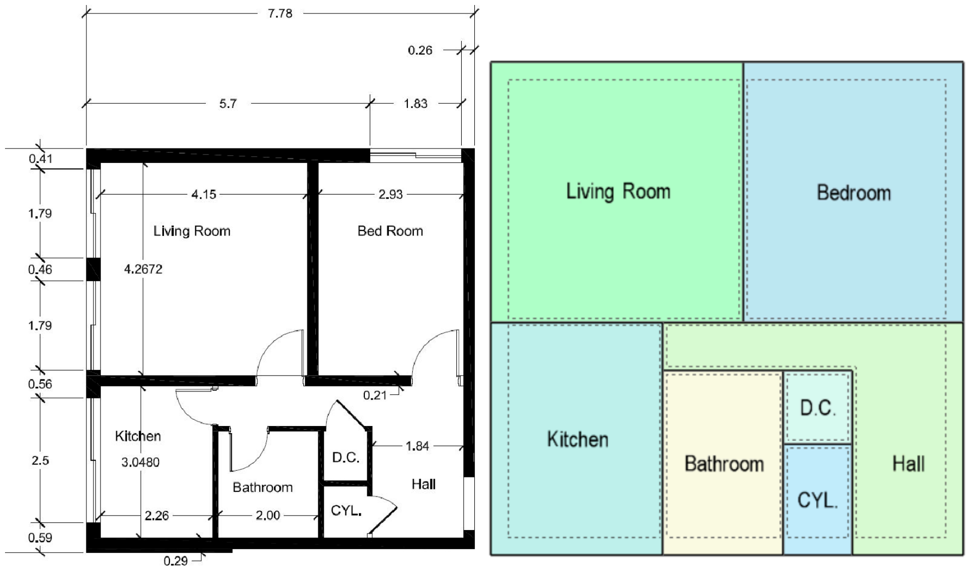
6. Unit Selection Process Based on the Interviews

The unit for simulation was selected meticulously, considering its representation of key issues in fuel poverty and well-being among the group of nine. A comprehensive architectural audit and access to blueprints were secured with the owner's permission, providing valuable insights into the unit's physical qualities (Table 6) and potential areas for improvement. The chosen flat is part of a 21-floor tower block with distinct characteristics on each level. The tower's structure includes a podium on the first five floors, followed by four two-bedroom flats per floor from the second to fifth floors. From the sixth to the sixteenth floor, each level has four one-bedroom flats, and beyond the sixteenth level, there are two one-bedroom flats per floor.

Situated on the ninth floor, the chosen flat is uniquely configured with one bedroom, a living room, a kitchen, a bathroom, and a separate cylinder room. Positioned on the left-hand side of the tower, this flat offers an opportunity to study its energy performance and comfort compared to other parts of the tower block. To fully understand the chosen unit, a site visit was conducted, including a comprehensive architectural audit. This detailed procedure involved precise measurements of each room, an evaluation of spatial organisation, and a thorough visual assessment. The audit went beyond dimensions and aesthetics, exploring the functionality of living spaces to grasp the user's perspective on subjective well-being. The site visit provided an immersive experience, allowing for first-hand exploration of the unit's surroundings, contexts, and the tower block environment. This engagement facilitated a deeper understanding of the unit's context and its place within the larger housing structure. Observing neighbouring flats, comprehending spatial dynamics, and envisioning occupants' everyday routines further enriched insights into the challenges and potential solutions for the unit.

7. Existing Unit Thermal and Energy Assessment

A thorough 3D simulation and analysis were conducted to assess the energy performance of the selected unit (Figure 10), utilising advanced simulation tools like EnergyPlus DesignBuilder v7.0.2.6 and SAP 10.2. The existing energy consumption patterns of the unit were replicated and scrutinised using these modelling tools. The simulations incorporated various energy-related factors, including thermal comfort, ventilation, and fabric considerations. By incorporating these variables into the simulation, a comprehensive understanding of the unit's energy usage profile was achieved.



(**a**) (**b**)

Figure 10. Flat's floor plans: (**a**) floor plans (produced by the author; derived from [70]), (**b**) DesignBuilder model, showing zones activities.

The DesignBuilder location is configured for the Midlands, the original flat location. Similarly, the simulation utilises a weather dataset for the East Midlands, England, to ensure precise simulation results. The template details are classified for residential use, and the construction template is tailored to match the original council building materials for different components, including walls, floors, ceilings, roofs, doors, and windows (Table 10). The specifics of occupancy are determined based on the schedule that the residents provided following the interviews. The programme for the corresponding heating spaces also includes the HVAC (gas heating) schedule for the simulation.

Table 10. Chosen unit characteristics, construction specifications of the selected unit based on the data provided by the record office.

Element	**Existing Layers**		**Total Thickness (m)**	**R Value ($m^2 \cdot K/W$)**
	Material	**Thickness (m)**		
External Walls	Aerated Concrete Slab XPS Extruded Polystyrene Plasterboard	0.2508 0.0254 0.0100	0.286	2.525
Internal Walls	Asbestos cement sheet-Plastic-faced XPS Extruded Polystyrene Timber Framing Chipboard	0.0064 0.0191 0.0826 0.0127	0.1208	1.469
Flooring	Clay Tiles Tile Bedding Concrete-Reinforced structural slab	0.0508 0.0508 0.200	0.3016	0.393
Roof	Asbestos Tiles Roofing (bitumen with inert fill) Roofing felt Roof screed Concrete roofing slab, Aerated	0.0254 0.0254 0.0254 0.0254 0.1778	0.2794	1.552

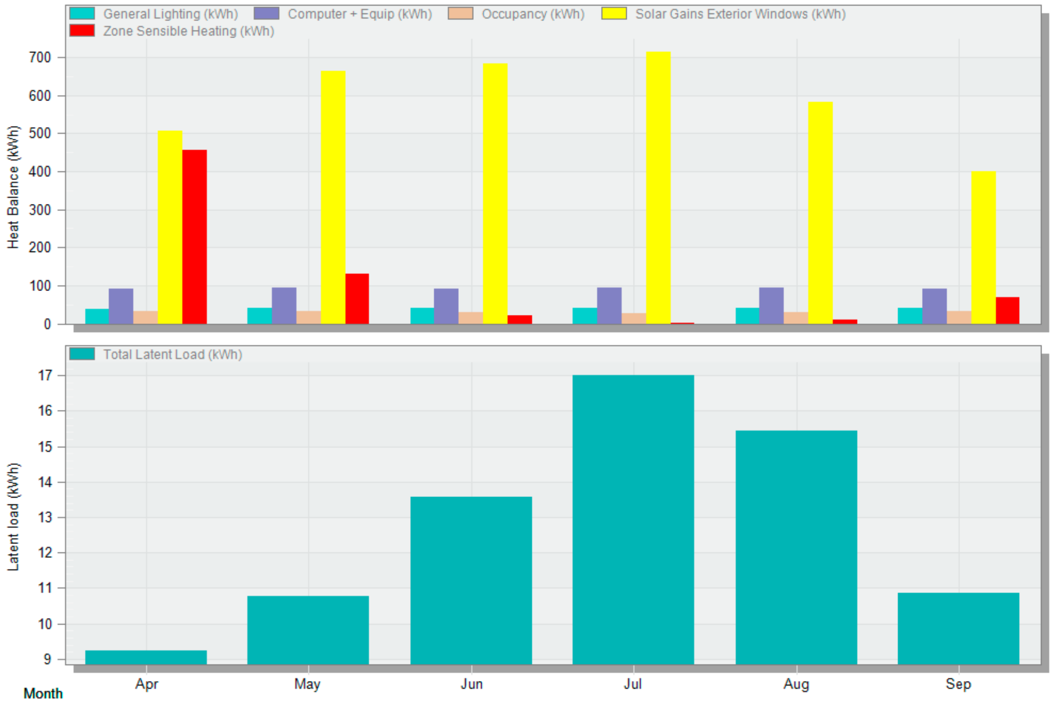
7.1. Thermal Analysis

7.1.1. Thermal Analysis—Summer

The flat's internal temperature steadily increases from 15.87 °C in April to 22.34 °C in June, indicating a warming trend. Radiant and operative temperatures follow a similar pattern, reflecting consistent thermal experiences. External temperatures positively correlate with internal temperatures, suggesting an external climatic influence. Despite warmer external temperatures, the operative temperature remains stable, indicating effective summer thermal regulation. Discomfort hours peak in April and May, gradually decreasing until August. The building manages summer thermal conditions well, but fluctuations and discomfort in transitional months highlight challenges. The building demonstrates functionality in managing summer conditions (Figure 11) but faces challenges in transitional months. Despite the generally consistent operative temperature, disparities in comfort levels within different areas of the flat are evident, with the bedroom on the northern elevation being cooler than the western-facing kitchen. This aligns with user perspectives derived from interviews. Proper ventilation is crucial for redistributing cooler air and improving overall comfort. Quantifiable contributions from lighting, equipment, occupancy, solar gains, zone-sensible heating, and latent load provide insights into heat sources and their implications for thermal comfort during the summer (Figure 12).

Month	Apr	May	Jun	Jul	Aug	Sep
Air Temperature (°C)	15.87	17.31	20.04	22.34	21.10	17.72
Radiant Temperature (°C)	15.38	17.42	20.43	22.86	21.46	17.78
Operative Temperature (°C)	15.63	17.37	20.24	22.60	21.28	17.75
Outside Dry-Bulb Temperature (°C)	7.45	11.03	14.23	17.17	16.27	13.15
Relative Humidity (%)	44.24	49.50	51.32	54.90	54.47	60.73
Discomfort hrs (all clothing) (hrs)	404.81	376.91	248.58	97.93	183.76	368.88

Figure 11. Thermal comfort levels in the summer, existing flat.



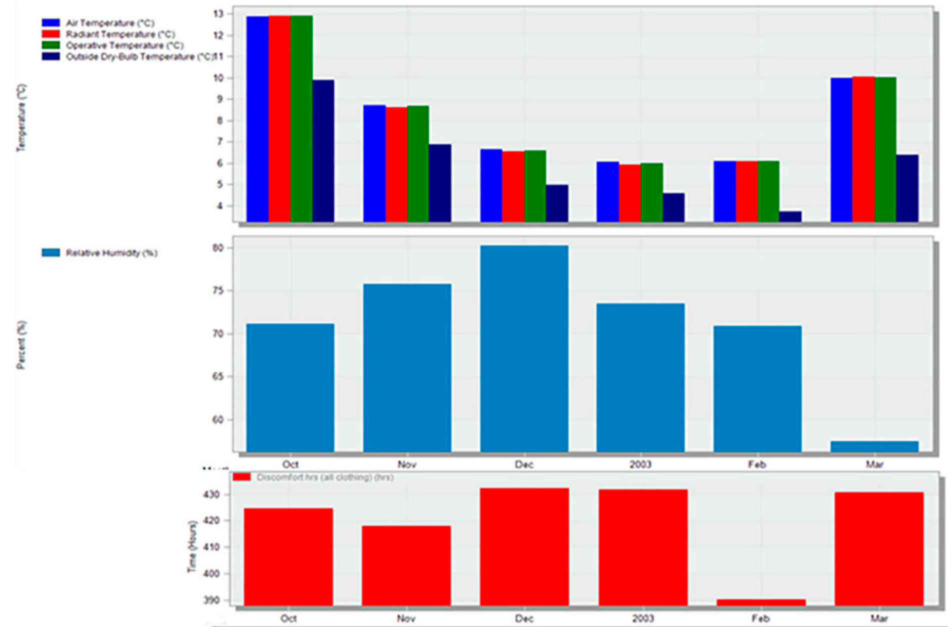
Month	Apr	May	Jun	Jul	Aug	Sep
General Lighting (kWh)	38.74	41.22	39.89	41.22	41.22	39.89
Computer + Equip (kWh)	90.27	93.28	90.27	93.28	93.28	90.27
Occupancy (kWh)	33.08	32.84	28.86	26.61	28.25	31.47
Solar Gains Exterior Windows (kWh)	507.94	665.09	684.12	714.21	583.81	401.46
Zone Sensible Heating (kWh)	457.32	130.51	20.71	0.27	9.12	69.43
Total Latent Load (kWh)	9.25	10.76	13.57	16.99	15.45	10.86

Figure 12. Heat gain in summer, existing flat.

- During summer, observed wall gains (e.g., Hall: 40 kWh/m^2) indicate heat behaviour within the building's envelope (Figure 12). High negative values suggest the hall may become warmer as heat moves outwards, while lower negative values in areas like the bedroom and toilet imply better summer orientation or less exposure to external heat (e.g., kitchen: −22.5 kWh/m^2). Due to the fact that all rooms share the same envelope of insulation, there are additional factors that can influence the perceived thermal behaviour, like internal heat sources, ventilation and airflow, thermal mass, and infiltration.
- General lighting heat gains remain stable at an average of 40 kWh per month, contributing to a consistent thermal load.
- Equipment heat gains show a steady average of around 92 kWh per month, reflecting predictable energy consumption.
- Occupancy-related heat gains decrease, suggesting a potential shift in occupancy patterns impacting temperature regulation.
- Solar gains peak in July at 714 kWh, with fluctuations attributed to varying solar exposure and shading conditions.
- Zone-sensible heating exhibits irregular patterns, transitioning from heating to potential cooling needs, indicating adaptive thermal strategies.
- Peak latent load in July indicates a need for increased dehumidification. June and August show higher energy consumption. Managing latent load is crucial for indoor comfort.

7.1.2. Thermal Analysis—Winter

The recorded air, radiant, and operative temperatures consistently decline with outside temperatures (Figure 13). Operative temperatures fall below the recommended comfort range, indicating challenges in heat retention. The radiant temperature is slightly lower than the operative temperature (by around 5 °C in the best months and around 11 °C in the coldest months), which is overly concerning. A lower radiant temperature could potentially indicate challenges in retaining heat. The data also show fluctuating relative humidity levels, ranging from 70.89% to 80.27%, raising more concerns about indoor air quality and moisture content throughout the months. Managing humidity is crucial for comfort and energy efficiency, as high levels may lead to increased heating. The corresponding discomfort hours (around 430 h) correlate with declining relative humidity and a lower operative temperature. The disparity in comfort levels within the flat, notable during summer, is notably absent in winter (Figure 13), with most spaces falling within the range of 7 °C to 8 °C, indicating a common struggle to combat cold discomfort. This consistent low temperature across areas suggests challenges in both heat retention and the efficiency of heating systems, influenced by heat loss to the colder external environment. Unlike the varied discomfort observed in summer, winter discomfort is more uniform, primarily impacted by lower outside temperatures.

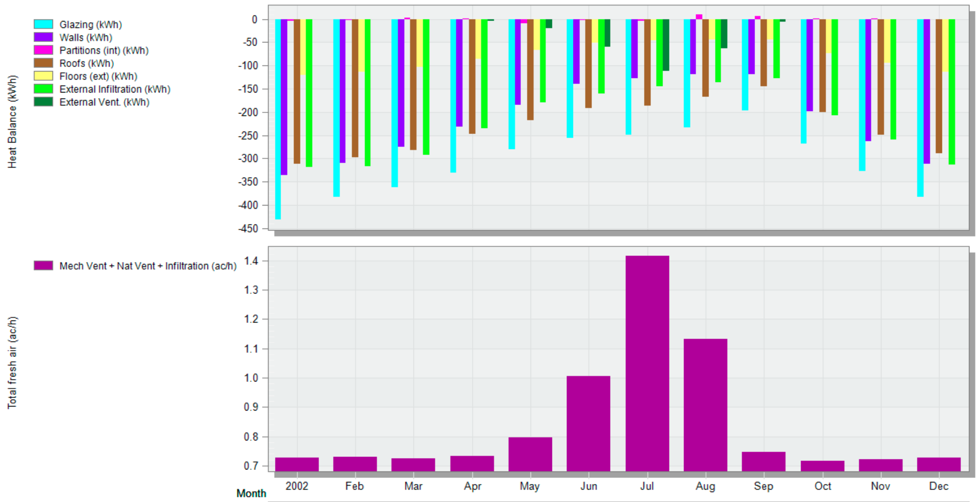


	Oct	Nov	Dec	2003	Feb	Mar
Air Temperature (°C)	12.88	8.71	6.65	6.06	6.11	9.97
Radiant Temperature (°C)	12.92	8.62	6.54	5.94	6.08	10.07
Operative Temperature (°C)	12.90	8.67	6.60	6.00	6.09	10.02
Outside Dry-Bulb Temperature (°C)	9.88	6.89	4.99	4.59	3.72	6.37
Relative Humidity (%)	71.10	75.72	80.27	73.51	70.89	57.41
Discomfort hrs (all clothing) (hrs)	424.67	418.03	432.45	431.88	390.05	430.86

Figure 13. Thermal comfort in winter, existing flat.

7.2. Fabric and Ventilation

Glazing, particularly windows, exhibits substantial heat loss, peaking at −431 kWh in January, emphasising the need for upgrading to more insulating options like double or triple glazing. Roofs contribute significantly to heat loss, ranging from −311 kWh in January to −145 kWh in September; improving insulation and considering reflective materials can enhance energy efficiency. Walls show considerable heat loss, varying from −335 kWh in January to −119 kWh in August and September. Floors have the least impact, recording values from −120 kWh to −45 kWh. The hierarchy underscores the importance of targeted interventions (Figure 14).

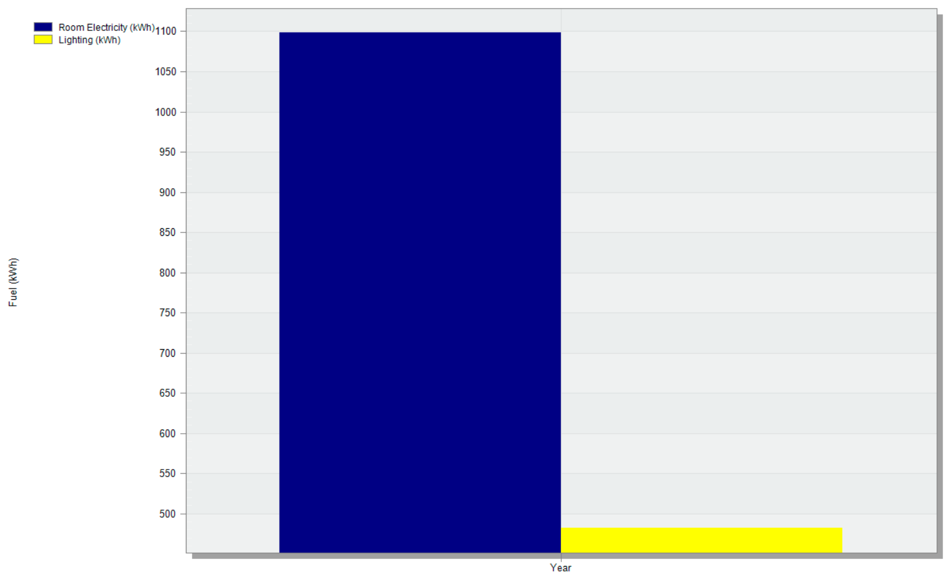


Month	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Glazing (kWh)	-430.95	-382.19	-362.57	-330.09	-280.37	-255.23	-249.61	-233.75	-196.83	-268.94	-326.99	-382.17
Walls (kWh)	-335.51	-310.38	-275.58	-232.39	-184.42	-139.55	-127.00	-118.60	-119.42	-199.34	-262.61	-312.30
Partitions (int) (kWh)	-3.48	-2.58	3.49	0.25	-9.02	-2.97	-4.84	9.30	6.65	0.28	0.14	-0.15
Roofs (kWh)	-311.02	-297.49	-282.48	-247.72	-217.98	-192.30	-186.60	-166.86	-145.41	-201.15	-249.69	-289.22
Floors (ext) (kWh)	-120.14	-113.25	-103.05	-86.40	-67.50	-50.98	-46.40	-44.81	-44.61	-73.56	-95.18	-113.43
External Infiltration (kWh)	-319.21	-316.26	-291.63	-234.48	-179.90	-160.52	-145.69	-136.98	-126.96	-207.43	-258.76	-313.65
External Vent. (kWh)	0.00	0.00	-0.25	-4.73	-20.46	-60.18	-112.51	-63.02	-6.49	0.00	0.00	0.00
Mech Vent + Nat Vent + Infiltration (ac/h)	0.73	0.73	0.73	0.73	0.80	1.01	1.41	1.13	0.75	0.72	0.72	0.73

Figure 14. Annual fabric analysis, existing flat.

7.3. Annual Energy Consumption

The flat's annual fuel consumption shown in Figure 15 of 1581 kWh/m^2 exceeds the typical average for UK residential buildings (120 kWh/m^2). This significant difference suggests higher-than-normal energy usage. When compared to CIBSE targets, the flat's energy performance is a cause for concern, indicating inefficiencies in both space heating and overall energy utilisation. This misalignment may contribute to fuel poverty, impacting residents' well-being by causing discomfort and financial stress. To address this issue, implementing retrofit measures such as improved insulation, efficient heating systems, and the integration of renewable energy sources is essential to meeting recommended energy targets. This comprehensive approach aligns with both energy efficiency goals and the well-being of occupants.



	Year
Room Electricity (kWh)	1098.30
Lighting (kWh)	482.48

Figure 15. Total fuel consumption in a year, existing flat.

7.4. Energy Ratings and SAP

7.4.1. Energy Rating and Performance

The current potential energy efficiency (Figure 16), with the G-rating, indicates that the flat's existing conditions have substantial room for improvement in terms of energy efficiency. This signifies that the flat is among the least energy-efficient dwellings. This calls for replacing single-glazed windows, upgrading the insulation in the walls, roof, and floor to improve thermal performance, and switching from inefficient electric room heaters to a system with thermostatic controls to maximise comfort and energy efficiency. Also, improving the hot water system, adding supplementary heating choices, and incorporating renewable energy sources can further enhance energy efficiency, reduce fuel poverty, and promote residents' well-being. The quantity of energy needed to satisfy the demands of the flat is 309 kWh/m^2. The primary energy, which is 483 kWh/m^2, represents the entire energy consumption after taking into account distribution and conversion losses. Estimated carbon dioxide emissions are 2.6 tonnes, with CO_2 emissions per square metre being 47 kg/m^2. These numbers demonstrate how the apartment's energy use significantly contributes to carbon emissions and environmental harm.

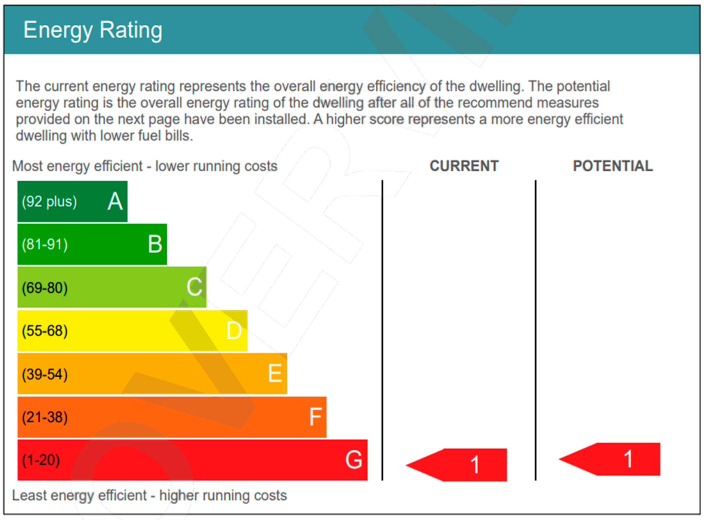


Figure 16. SAP EPC rating of existing flat.

7.4.2. Costs and Fuel Poverty

Considering the total heating costs of GBP 3626 (Table 11), which is significantly higher than the fuel poverty threshold of GBP 1200, it can be concluded that the flat is experiencing an extreme fuel poverty of approximately 30.22%. This indicates that the current energy expenditures for heating are excessive relative to the user's income, highlighting the urgent need for energy efficiency interventions to alleviate fuel poverty. Additionally, it confirms both literature concerns and both the survey and interview findings and insights.

Table 11. Energy cost, existing flat.

Energy type	Cost
Space Heating	GBP 3241
Water Heating	GBP 334
Lighting	GBP 51
Total	GBP 3626

8. Testing Retrofitting Approaches

This section's goal is to tailor a retrofit approach to this category of buildings and their social and environmental settings, by adjusting the selected metrics to take into consideration both possibilities and constraints in the building's dimensions, form, activity, and occupancy. Retrofitting just one parameter might have unforeseen results. By evaluating a wide range of retrofit approaches and employing analysis and building physics to discover an optimal blend, it is possible to give affordable staged solutions that can get around project restrictions like time limits, budgets, or keeping the building in operation.

All of the recommended retrofit solutions were thoroughly studied in order to discover the best option that works with the structure, ventilation, and thermal design of the building in order to enhance occupant satisfaction.

8.1. Selection of Retrofit Measures

A meticulous process was used to choose retrofit measures that are not only in line with CIBSE data and international or UK recommendations but are also tailored to the particular qualities and existing conditions of the flats in the efforts of finding the optimised retrofit approaches for the social housing units in the Leicester area. This selection procedure followed a number of fundamental guidelines that guaranteed an exhaustive assessment of the measures:

- "Fabric First" approach:

The "fabric first" strategy, which prioritises airtightness and insulation, was the most important factor in choosing retrofit procedures. This strategy acknowledges the critical value of strengthening the building's envelope to cut heat loss and boost energy effectiveness. It sought to lay a solid basis for further energy-saving solutions by concentrating on the structure of the building.

- Tailoring to existing conditions:

Given the wide range of factors observed in the housing system's residences, refit measures were made to meet the unique needs and specifications of the chosen unit. With this customized method, the refit maximises efficiency for the particular case while taking into consideration variances in size, structural components, and usage patterns.

- Engagement of residents:

The involvement of residents in the early stages of the retrofit project played a pivotal role. Engaging with residents not only facilitated a better understanding of their specific needs but also allowed for the effective management of their expectations. This collaborative approach ensured that the retrofit measures would enhance their living conditions and well-being. Following this selection process, two distinct retrofit approaches (Tables 12 and 13) were identified for comprehensive testing using DesignBuilder v7.0.2.6 and SAP 10.2 software.

Table 12. Retrofit No. 1 approach.

Retrofit No. 1	This Approach Comprises the Following Components:
1	Phenolic internal wall insulation bonded to 18 mm OSB.
2	Phenolic insulation applied to the solid ground floor.
3	A combination of insulation types employed for the roof.
4	Installation of Passivhaus-certified windows.
5	Utilisation of a mechanical ventilation with heat recovery (MVHR) system.
6	Updating the heating system to Air source heat pump (ASHP).
7	Integration of solar PV panels.

Table 13. Retrofit No. 2 approach.

Retrofit No. 2	This Approach Comprises the Following Components:
1	Application of aerogel-laminated chipboard to the ground floor.
2	Implementation of aerogel-laminated chipboards to internal walls.
3	Installation of blown loft insulation.
4	Fitting of insulated external doors and a secondary glazing system.
5	Integration of a mechanical ventilation with heat recovery (MVHR) system.
6	Adoption of an Air source heat pump in conjunction with solar PV technology.

8.2. Results and Identification of the Best Retrofit Measure

Overall Results Obtained from Retrofit Testing

To comprehensively assess the performance of each retrofit measure and their impact on key parameters, including thermal comfort, heat gains, energy efficiency, fuel breakdowns, EPC rating, and initial and operating costs, bills were evaluated:

Even though the financial and economic components of Retrofit No. 2 (Table 13) showed substantial improvements, significantly lower energy bills have been recorded. Retrofit No. 2 is a financially viable choice that adheres to the ideals of accessibility and sustainability. It is crucial to bear in mind nonetheless that, despite that, Retrofit No. 2 did not quite reach the intended degree of interior comfort in accordance with CIBSE and global standards. The improvement in thermal comfort and ventilation was not as significant as anticipated, and it was noted that there were still difficulties with temperature varia-tions, cold conditions in the winter, and overheating experiences in the summer.

Retrofit No. 1 (Table 12), which exhibited the best overall performance among the two retrofit measures, was chosen as the optimal choice, and it is detailed as follows (Tables 14–18):

Table 14. New external wall.

External Wall Layers		Total Thickness (m)	R-Value ($m^2 \cdot K/W$)
Material	Thickness (m)		
Aerated concrete slab Phenolic foam OSB layer	0.2508 0.1500 0.0180	0.4188	5.659

Table 15. New internal wall layers.

Material	Thickness (m)	Total Thickness (m)	R-Value ($m^2 \cdot K/W$)
Asbestos-related materials—Asbestos cement Phenolic foam Pvl wood Plywood	0.0064 0.1000 0.0750 0.0127	0.19	3.428

Table 16. New floor/roof.

Floor/Roof Layers		Total Thickness (m)	R-Value (m2·K/W)
Material	Thickness (m)		
Concrete, reinforced (with 1% steel) Polyethylene boards Phenolic foam Cork tiles	0.2000 0.0200 0.1000 0.0508	0.37	3.84

Table 17. New window installation.

Passivhaus Windows	
Triple-Glazed windows offer a comprehensive a choice of materials	
U-Value (W/m2·K)	0.620
Light transmission	0.696
Total solar transmission	0.604

Table 18. PV calculations.

Renewables PV
The amount of PV cells was calculated and resulted in 4 photovoltaics oriented south with a 30-degree elevation and a modest overshading with 0.8 as an overshading factor.

The decision on external wall layers (Table 14), to remove the XPS (extruded polystyrene) insulation layer and replace it with phenolic insulation, depended on various factors:

- Higher thermal performance: phenolic insulation often has better thermal performance compared to XPS, meaning it can provide higher levels of insulation and energy efficiency.
- Space saving: phenolic insulation is generally thinner than XPS for the same insulation value, which could be advantageous if space is limited.
- Environmental considerations: phenolic insulation is known for its lower environmental impact compared to XPS.

Table 15 shows that the choice of whether to keep the timber framing and chipboard depends on their condition and the structural integrity of the existing building. Keeping them can lead to cost savings, allowing for enhanced insulation and better structural stability when implementing an MVHR. When replacing the chipboard, we focused on finding a material that enhances insulation, is soundproof, and can be integrated with the MVHR system. Plywood will accommodate the placement of ducts while maintaining a proper airflow distribution.

The layer of a polyethylene vapour barrier can be placed over the phenolic foam insulation. This barrier acts as a shield, preventing ground moisture from penetrating the assembly (Table 16), while also changing finishes with insulating properties, like cork tiles, which can contribute to thermal comfort and add an extra layer of insulation.

Air source heat pumps (ASHPs) can work effectively in high-rise buildings in designated mechanical rooms. The system will reuse existing central heating radiators as part of the distribution system with mechanical ventilation with heat recovery (MVHR), which will offer significant benefits in terms of energy efficiency, indoor air quality, and overall comfort. The installation of new windows (Table 17) and renewables like PVC (Table 18) is crucial to maintain energy consumption.

8.3. Results and Improvements

The transition from rating 1 G to 82 B (Figure 17) indicates a significant leap in performance, resulting in reduced energy consumption, lower energy bills for residents, and a reduced environmental footprint. This transformation aligns with a reduction in energy expenses from GBP 3626 per year to just GBP 386 per year. Fuel poverty was approximately 30.22%, indicating a significant burden on the household's income to cover energy costs of only 3.22%, which leaves the flat out of fuel poverty definitions.

Figure 17. New EPC rating post-retrofit solution.

The data provided demonstrate that Retrofit No. 1 was remarkably successful in improving the indoor environment (Table 19). Notably, it achieved a substantial enhancement in both energy efficiency and thermal comfort. The operative and radiant temperatures within the flats were significantly improved, ensuring a more comfortable living environment throughout the year. Additionally, relative humidity levels remained within the comfort range. The retrofit measures effectively addressed heat loss through glazing, roofs, and walls, resulting in reduced energy consumption and lower annual energy costs.

Table 19. Comparison of pre/post-simulation values.

	Winter	Summer
Operative Temperature	19.47 °C	21.12 °C
Radiant Temperature (°C)	18.91	21.08
Relative Humidity	38.41%	48.70%
Post-Retrofit Interventions Results		
	Before	**After**
Glazing (kWh)	−431	−73
Roofs (kWh)	−311	−187
Walls (kWh)	−335	−254
Estimated energy costs (GBP/Year)	3626	368

Despite an increase in the initial construction cost of the flat, the long-term economic benefits, including substantial savings in energy bills, make Retrofit No. 1 a cost-effective and sustainable choice. Furthermore, the reduction in fuel consumption aligns with sustainability goals and addresses fuel poverty concerns among residents. Overall, the data underscore the success of Retrofit No. 1 in achieving its objectives of enhancing subjective well-being, environmental sustainability, and social justice within the context of social housing architecture.

Following the retrofit interventions, a notable improvement in temperature consistency within the flat, especially during winter, has been observed. The disparity in temperatures among different spaces is now minimal, with variations no greater than 0.6 °C. This alignment with CIBSE recommendations signifies that the indoor environment has become much more comfortable and conducive to well-being. However, in the summer season, while temperature disparities have reduced significantly, it is noteworthy that the kitchen area still registers a 1.25 °C higher temperature than other spaces. This indicates a potential area for further enhancement, like improved ventilation and shading.

9. Lessons and Recommendations

In the pursuit of addressing pressing challenges such as fuel poverty, enhancing well-being, promoting sustainability, and fostering social justice within our communities, social housing retrofit projects play a pivotal role. As architects, designers, housing companies, and stakeholders in these projects, the significance of meticulous planning and execution to achieve all collective goals is appreciated.

It has unearthed invaluable architectural insights that will be instrumental in this collective pursuit. Among the lessons learned, the critical importance of harmonising retrofit measures with the existing architectural fabric was emphasised. The selection of appropriate insulation materials and high-performance glazing to enhance thermal performance while preserving architectural aesthetics is paramount. Furthermore, the integration of energy-efficient HVAC systems, such as those aligned with Passivhaus standards, contributes not only to energy savings but also to an improved indoor environment. Additionally, it highlights the judicious use of renewable energy sources, such as solar PV panels, to minimise the environmental impact and operational costs. These architectural aspects, coupled with a deep understanding of local building codes and regulations, form the bedrock of best practices. By seamlessly integrating architectural considerations with energy efficiency, the results helped create a comprehensive social housing retrofit checklist that will serve as a valuable resource for future projects.

"The SOCIAL-FIT": The Complete Guide to Transformative Social Housing Retrofit Checklist represents a significant outcome of our research, offering a comprehensive roadmap for stakeholders engaged in social housing retrofit projects. This checklist spans the entire lifecycle of a retrofit initiative, from the initial planning and preparation phase to post-implementation monitoring and evaluation. It is meticulously designed to guide stakeholders in achieving dual objectives: alleviating fuel poverty among residents and enhancing their overall well-being, all while fostering environmental sustainability.

Within this checklist, each action step underscores the importance of a customised, resident-centric approach. The checklist ensures that retrofit measures not only prioritise energy efficiency but also adhere to economic sustainability and compliance with local regulations. It covers aspects ranging from initial audits and resident engagement to compliance assessments, energy efficiency measures, economic feasibility analysis, and ongoing monitoring. Furthermore, it emphasises the continuous monitoring of project performance and the collection of relevant data for analysis and optimisation.

10. Conclusion and Limitations

10.1. Summary of Research Findings

In this concluding section, the culmination of this research is brought together, which sought to address fuel poverty and highlight the challenges of subjective well-being and its relation to the housing condition in social housing to promote environmental sustainability and uphold principles of social justice within the realm of retrofit projects, by testing in-depth the intricacies of retrofit approaches, engaging with residents, evaluating energy efficiency measures, and analysing the impact on indoor comfort using surveys, interviews, audits, and simulations. The amalgamation of qualitative and quantitative data has provided a holistic view of the challenges and opportunities within the chosen research context to produce SOCIAL-FIT, The Complete Guide to Transformative Social Housing Retrofit, which will be an invaluable asset for future projects.

- Fuel poverty and SWB:

The investigation into the intersection of fuel poverty and subjective well-being has unearthed significant insights. A majority of households (83.3%) grapple with the unrelenting economic strain, with 87.3% reporting some level of difficulty in paying energy expenses. The economic landscape is marked by disparities, as 47.2% of participants pay over GBP 200 in energy bills, leading to personal sacrifices in various facets of life for 50% of respondents.

Amidst this challenging environment, residents exhibit a diverse range of well-being experiences. On one end of the spectrum, many respondents report elevated levels of satisfaction in specific aspects of daily life and physical health. Conversely, the distribution of responses regarding stress, anxiety, mental health, and physical health indicates the wide-ranging impacts of energy-related challenges on well-being.

An analysis further elucidated the intricate connections between fuel poverty and well-being. A moderately positive correlation (R = 0.42) between stress, anxiety, mental health, and fuel poverty was identified, highlighting the intertwined nature of these aspects. In contrast, a strong negative correlation (R = 0.64) underscores the profound influence of fuel poverty on physical health, quality of sleep, and daily performance.

In the well-being categorisation, it was found that 20.8% of participants reported low SWB (scores below 5), while 54.2% indicated moderate SWB (scores between 5 and 7). These findings underscore the complexity of well-being challenges within the context of fuel poverty, emphasising the urgency of addressing this multifaceted issue as it permeates the lives of social housing residents.

- Energy efficiency:

This research confirms the profound impact of comprehensive retrofit measures on energy efficiency. By prioritising insulation and airtightness ("fabric-first") and integrating Passivhaus-certified windows, solar PV panels, and mechanical ventilation with heat recovery (MVHR) systems, we observed remarkable reductions in energy consumption. Specifically, energy costs plummeted from an estimated 3626 GBP/year to a mere 386 GBP/year, representing a remarkable 89% decrease. Fuel totals saw an equally impressive drop, declining from 1581 kWh to 550 kWh, signifying not only substantial economic savings but also significant progress towards environmental sustainability.

- Indoor comfort:

The implementation of the selected retrofit measures led to a palpable enhancement in indoor comfort. Operative temperatures, critical for well-being, showed significant improvements. During winter, temperatures increased from as low as 6 °C to a comfortable 19.27 °C, while summer temperatures remained within an optimal range at 21.12 °C. Radiant temperatures similarly exhibited favourable changes, with winter temperatures reaching 18.54 °C and summer temperatures maintaining comfort at 21.08 °C. Resident satisfaction:

The findings underscore the importance of early resident engagement in retrofit projects. Through surveys and interviews, invaluable insights were gleaned into resident preferences and needs. Residents expressed heightened requirements for improved thermal comfort and reduced energy bills resulting from the retrofit measures. However, it is recognised that challenges remain in managing expectations and minimising disruptions during the retrofit process. Despite these challenges, resident engagement has proven to be a vital tool for aligning retrofit measures with their well-being aspirations.

10.2. Achievements and Significance

In addition to the specific findings detailed above, the research underscores the overarching achievement of the main objectives, as it demonstrated that comprehensive retrofit measures, thoughtfully designed and implemented, can concurrently address fuel poverty, enhance well-being, promote environmental sustainability, and uphold principles of social justice.

This holistic approach has the potential to not only transform communities but also serve as a model for sustainable and equitable social housing initiatives, using the checklist as a starting point.

10.3. Limitations and Challenges

This study's primary focus on the social housing community of Highfields in Leicester serves as both a strength and a limitation. While it provides valuable insights, applying the findings directly to diverse socio-economic and cultural contexts may present challenges. The limitations emphasise the necessity of considering regional variations in social housing dynamics when interpreting and generalising the results.

Despite efforts to overcome language barriers by securing translators, the unique characteristics of the user base posed challenges. The inherent differences in language and culture among residents may have limited accessibility for certain individuals, potentially influencing data representativeness and community engagement.

Given the complexity of the fuel poverty issue, this study recognises the importance of delving into various aspects, including the roles of major stakeholders in social housing, industry regulation, monitoring efforts, and the affordability of suggested measures. This paper acknowledges these complexities and strategically incorporates an in-depth analysis of these aspects into future work recommendations.

While the initial analysis may not have extensively covered all aspects related to dwelling types and ownership patterns, it serves as a crucial starting point within the specified context. The absence of direct verification with actual billing records is acknowledged as a limitation. Future research endeavours are encouraged to explore ways to access utility billing data directly to enhance the accuracy and reliability of energy expenditure information.

10.4. Future Research Directions

This study unveils compelling avenues for future research in the area of social housing retrofit projects. Primarily, there is a pressing need for comparative studies that scrutinise units within different levels, as distinct observations emerged between high and ground floors. In addition, delving into the intricacies behind temperature variations within the same unit warrants investigation. Expanding these research horizons beyond Leicester to establish a broader baseline and encompass diverse communities within the UK will enrich our understanding of the suggested effective retrofit strategies. Furthermore, conducting long-term impact assessments to measure the enduring effects of retrofit initiatives is crucial. This could involve tracking energy efficiency, well-being outcomes, and environmental sustainability over extended periods. Contextual diversity remains an imperative focus, considering how socio-economic and cultural contexts influence retrofit success. Exploring the intricate psychological and sociological dimensions of well-being post interventions offers a nuanced perspective. Additionally, assessing the checklist's viability and effectiveness in the context of other projects can refine its utility as a practical tool for future endeavours, exploring innovative financing models and strategies for funding such projects by investigating public–private partnerships, community investment initiatives, and new financial instruments that can accelerate the adoption of these measures. Altogether, these research directions promise to significantly contribute to the ongoing evolution of sustainable, equitable, and well-being-oriented social housing retrofit projects.

Further, the research findings encompass a multifaceted approach to social housing retrofit projects, utilising a comprehensive methodology to tackle pressing societal challenges. The amalgamation of energy efficiency, indoor comfort, and resident satisfaction portrays a compelling image of the potential for transformative change. Moving forward, guided by these findings and an unwavering commitment, the aim is to foster positive change, enhance lives, and contribute to a more sustainable and equitable future.

Future efforts may consider incorporating participant feedback and sharing findings as part of the research communication strategy.

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Abbreviations

ASHP	Air source heat pump
BREDEM	Building Research Establishment's Domestic Energy Model
BREEAM	Building Research Establishment Environmental Assessment Method
BRS	The Building Research Station
DCENR	Department of Communications Energy and Natural Resources
DRM	The Day Reconstruction Method
ECI	The Excess Cold Index
EMA	Ecological Momentary Assessment
EPC	Energy Performance Certificate
ESM	The Experience Sampling Method
HHSRS	The Housing Health and Safety Rating System
IMD	The Index of Multiple Deprivation
LEED	Leadership in Energy and Environmental Design

LIHC	The Low-Income-High-Costs Indicator
LILEE	The Low-Income Low Energy Efficiency
MEPI	The Multifaceted Energy Poverty Index
NGO	Non-Governmental Organization
PANAS	The Positive and Negative Affect Schedule
PFPI	The Potential Fuel Poverty Index
RTB	Right to Buy
SAP	The Standard Assessment Procedure
SWB	Subjective well-being
SWLS	The Satisfaction with Life Scale
UK CNEA	UK Charity-National-Energy-Action

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