Socio-Temporal Dynamics and Spatial Scales for Future Home Energy Transitions and Crisis Planning – UK insights.

Abstract

Planning for future equitable home energy transitions and electrification is dependent on multidimensional technical, social, temporal, and spatial insights. Despite growing calls to integrate social, spatial, and temporal insights, most studies have either overlooked these dimensions or examined them mostly from the perspective of social acceptance. The purpose of this paper is to discuss the role of social identities in shaping collective energy behaviours and temporal rhythms in the home and the consequences this may have on future electrification, flexible demand, energy transition and crisis planning. This research work draws on mixed methods using diverse data including surveys, photos, and interviews with residents in Glasgow and Bristol, UK. The research reveals that social identities shape energy use temporal rhythms – either in regular or irregular patterns over time. These socio-temporal rhythms have diverse consequences for demand flexibility and crisis planning to provide a responsive and dynamic evidence-based approach. This work offers a novel socio-temporal and spatial approach that could be used by local government, the housing sector, and energy providers in planning targeted collective responses to anticipated frequent energy crises and peak load events. There are also benefits to academics in offering a new conceptual lens by combining social practice, identity, and rhythm analysis for the study of energy transitions and crisis phenomena.

Keywords: energy demand, energy transitions, crisis, home, social identity, social dynamics

Highlights:

- Socio-temporal and spatial characterisation of collective energy management behaviours in the home.
- Energy management practices are shaped socio-temporally and spatially differently by diverse identity perceptions of the neighbourhood.
- Social identity dynamics in neighbourhoods drive regularity or irregularity of home energy management practices and rhythms.
- Planning for targeted collective responses to anticipated frequent energy crises and peak load events.

1.0 Introduction

Understanding socio-temporal dynamics is critical in planning for effective energy transitions and electrification, particularly in the domestic context and future crisis scenarios such as peak load demand management or energy scarcity [1, 2]. These dynamics may include social relations and identities within multiple spatial scales such as the home [3-5], neighbourhoods [6] towns and the wider context. They also include diverse temporalities of energy demand and use [7]. Whilst these dynamics have been found to accelerate energy transitions such as efficiency programmes for the retrofit [8], or in discussions on future collective governance approaches in the smart energy systems [9-11], they have so far not been characterised socio-temporally across multiple spatial scales. The spatial dimension, largely overlooked by the literature, is critical as energy transitions take place within temporally and spatially diverse contexts [12]. Moreover, daily rhythms and routines are shaped by individuals' energy use and management practices, as well as their social identities [1]. A successful energy transition, particularly when planning for future energy crisis events, will rely on a better understanding of the temporal and spatial characterisation of social dynamics within the home and beyond, from individuals to collectives. Without fully understanding the temporal and spatial

characterisation of these social dynamics, planning, or implementation of various energy transition routes such as demand flexibility will remain incomplete and likely unsustainable.

Understanding and integrating energy demand flexibility is critical in the development of smart energy systems, such as smart grids and smart energy management approaches [13], as they represent key transition pathways for transitioning to an electrified society fully reliant on renewable or low-carbon energy sources [14]. There have been growing calls to consider and implement social dynamics within the development of these systems [2, 15-21], there have been no accounts to date that explain or discuss what these may look like, how they may function in practice or what may influence their characterisation or functioning. Exceptions include causal considerations in the computational models [22, 23] or system dynamics modelling [24], whereby the complexity of social dynamics is underexamined. Social dynamics have also been considered in envisioning how smart grids may function in the future [25, 26], though mostly drawing on data from surveys with the general public on their attitudes and likely acceptance of such systems [27, 28] addressing issues at a surface level. Whilst these studies are helpful, there has been no research to date that considers the collective capabilities involved at multiple scales – the home and neighbourhood for instance. In addition, there have been very limited conceptual approaches to energy transitions that enable an analysis of complex socio-temporal and spatial characteristics [1].

The purpose of this paper is to provide new insights into temporal and spatial characterisation of social dynamics in future residential management of energy in crisis scenarios such as demand management and flexible energy use. The empirical evidence includes survey responses from 639 residents living in Glasgow and Bristol, 539 photographs of evening energy use routines provided by the participants and 34 semi-structured interviews conducted with the residents. The methods section discusses approaches to data collection and data analysis. In this research, the conceptual approach draws on Theories of Social Identity and Social Practice, as well as Rhythm-Analysis [1].

The following sections discuss the relevant literature on social dynamics, smart energy systems and the role of identities and rhythms. This is followed by a discussion of the methodological approach and findings from the study. The discussion and conclusion expand upon the implications and limitations of the work, as well as identify areas for future research directions.

2.0 Literature review

The review of the literature discusses the key social, spatial, and temporal dimensions in the context of residential energy transitions, crisis planning and electrification research. The first section of this review discusses how energy demand and flexibility planning have been approached so far in the domestic context and the need for a greater understanding of future collective approaches and multiple dimensions of the home is highlighted. The following section discusses collective behaviours, viewed socially, temporally, and spatially in the context of smart energy systems and future crisis energy events. The next sections further explore these spatial and temporal dynamics in the context of social identities and rhythms.

2.1 Energy demand and flexibility in the home – residents' roles

In energy transition research and the planning for an electrified society reliant on renewable energy sources, considerable attention has been dedicated to understanding methods for achieving future energy demand management. Research and policy have predominantly focused on examining, mainly through simulated data-driven and automated responses, how residents respond to shifting their

domestic energy use activities through financial or other incentives. Analytical and engineering-driven methods dominate the literature on residential energy demand, drawing on smart meter and smart appliance data [5]. Such work reveals that only 15% of the studies involved empirical data from residents themselves. Additionally, in another study on energy demand approaches, it was found that a broader comprehension of the social drivers for specific energy use activities is crucial [29]. Although their focus was not specifically on the domestic sector, the argument was made that shifting some activities may impact unfavourably on others. Such work reveals that only 15% of the studies involved empirical data from residents themselves. Additionally, in another study on energy demand approaches, it was found that a broader comprehension of the social drivers for specific energy use activities is crucial [29]. Although their focus was not specifically on the domestic sector, the argument was made that shifting some activities may impact unfavourably on others.

While some approaches suggest temporally shifting energy use activities, others suggest solutions lie in adjusting a building's performance. An empirical approach has been proposed to quantify a building's potential for a flexible energy operation [30]. They present a metric based on which the measured temperature drops in a building under standard conditions after the heating is switched off, utilising smart meters and internal temperature data. The study derived results for 96% of 193 homes within a test dataset, indicating a mean temperature drop of 1.5 °C in 3 hours at 15 °C inside-outside temperature differential. Though this approach is helpful in considering the use of smart systems, the study does not consider how residents may respond to such temperature drops and how this may shape their overall energy use.

Whilst earlier work acknowledged that temporalities and daily energy rhythms may be diverse and shaped by both social and other needs, only in recent years have there been accelerated efforts to analyse this in much more fine-grained detail. A recent study explores how residents may integrate demand reduction approaches and adapt their energy use as part of a UK national demand flexibility programme [31]. The study argues that greater attention needs to be placed on non-financial motivations to adapt including a better understanding of residents' access to technology, as well as any prior experience of changing energy use in their home. In other studies, the influence of factors such as the duration of the flexibility event and the decrease have been highlighted in the set point temperature of spaces in homes [32]. They emphasise the role of occupant behaviour, suggesting how activities related to thermostat adjustment and clothing changes, significantly influence the flexibility of a neighbourhood. Certain activities, such as personal care and meal preparation, exhibit low flexibility potential due to their fixed temporal nature [33]. Energy use activities are categorised into various load types such as energy used for continuously running activities, constant load activities, activities with shifted demand, constant load activities with time/capacity constraints, and dependent activities [34]. Research has shown that work-related activities contribute to the formation of continuity of energy use practices, potentially influencing the timing and duration of activities like watching TV or engaging with electronic devices [35]. The importance of understanding these socially and spatially driven behavioural patterns for effective energy demand management and demand flexibility has been emphasised.

While existing research has acknowledged the temporalities and rhythms of energy use activities as discussed above, it has mostly discussed this at the scale of an individual household, without appreciating the social context and spatial scale of a neighbourhood. While scholars have increasingly recognised the importance of collective social dynamics and temporal dimensions in energy research and policy, empirical research, and theoretical advancement in characterising these dynamics across spatial scales are lacking. In this context, smart energy systems are seen to offer the potential to capture, interpret, and influence communal energy dynamics, providing a foundation for developing targeted and scalable interventions that go beyond individual households. The subsequent section discusses how smart systems research approaches social collective behaviours and characterises social dynamics.

2.2 Collective social dynamics in energy transitions and smart energy systems

Within the energy transitions literature, citizen engagement [9] and the emergence of concepts such as "energy community" [36], "energy citizenship" [37, 38], and "prosumer collectives" [39] is often seen as a means of empowering individuals and communities to shape their energy future [9]. Whilst there has been work on better understanding the social collective dimensions of the energy crisis and smart energy systems [40], literature in the area remains largely descriptive with very few academic studies offering evidence of the collective factors contributing to energy projects [20, 41]. For example, social parameters such as the social capital [20] or social relations [3, 42] have been recognised as a significant aspect of participation and the success of community energy initiatives [36, 43]. However, social capital has only been empirically explored by capturing descriptive perspectives of shareholders in the community initiatives [43, 44] or the intentions of the general public to participate in hypothetical initiatives [36].

Similarly social relations, despite their importance in the context of collective dimensions of energy transitions [3], have been explored to a limited extent. Within the individual scale of a home, studies have found that social relations can significantly impact decision-making. This includes the influence of family and friends on energy efficiency projects such as retrofitting motivations, the establishment of trust with tradespeople within the home, and the importance of residents' access to community networks in the decision-making process [8, 45, 46]. Within the scale of a neighbourhood, identities and emotions have been found to shape the dynamics of 'emotional energy communities,' particularly during energy transitions and access to electricity, highlighting that the emotional impact of gaining access to electricity in off-grid communities is marked by emotions such as joy, pride, and gratitude [47]. This emotional state is discussed to be fragile often turning into sadness, disappointment, and even guilt when the technology ceases to function or when communities return to living without electricity. The authors emphasise that these emotions influence social processes around energy, leading to the formation of emotional energy communities and fostering collective agency in addressing energy poverty. Nevertheless, work on emotional energy communities is focused on niche community initiatives, and remains largely descriptive, whilst the application of those insights in the larger population is not yet justifiable.

Some initial empirical insights related to the ties within a community through social network analyses in the context of community energy initiatives have been provided [48], highlighting the importance of social relations especially when it comes to community member relationships with the initiator of an energy initiative and their potential to impact policy design. Notably, there has been a lack of research that considers how social capital or social relations may operate across various spatial scales, such as within homes and neighbourhoods, or how complex socio-spatial characteristics influence energy transitions. Beyond the scale of the neighbourhood, regional spatial scales have been highlighted [49] to be enacting social dynamics shaped by various contextual factors, involving different forms of agency, and resulting in various types of outcomes which these outcomes encompass not only changes within the energy system but also broader impacts on the socio-economic fabric, infrastructure, and development of the regions involved.

Social parameters or non-technical parameters – as the terms are referred to within more technology-driven realms of the energy literature - have received some consideration in certain computational [22, 50] or system dynamics models [24]. Nevertheless, there have been no accounts that explain or discuss what social parameters may entail empirically, how they function, or what factors influence their characterisation or operation. Furthermore, the development of system models or computational tools depends on data availability and on parameters that can be rigid in terms of

introducing uncertainty and despite their significance, such tools have been criticised for their inadequacy to directly support real-time energy decision-making during energy crises or emergencies [51, 52].

In general, the above literature suggests that collective social dynamics such as social relations and social capital have been found to shape the effectiveness and sustainability of energy transition planning and implementation in the domestic sector. Most studies have highlighted how these social dynamics either within the individual scale of a home or in a collective scale of a neighbourhood and community impact the effectiveness and development of transition approaches such as retrofit or energy efficiency programmes. Whilst many studies have noted the importance of temporalities of energy use [29] as well as social identity in shaping these relations and shaping capital [3], their characterisation, especially in the context of collective responses to crisis events such as peak load demand shifts have yet to be explored. The following section discusses why social identity and temporal dimensions of energy use matter for an expanded understanding of collective social dynamics in energy transitions.

2.3 Why identities and rhythms matter

The complex interfaces between social identities, spatial scales and temporal rhythms of energy use have received limited attention thus far, particularly in the context of homes and neighbourhoods. Any type of resource consumption in the home including energy involves understanding complex associations between social identity and class [53]. Consumption practices serve not only as a means of constructing identity but also as an expression of social identity [54]. Social and spatial dynamics of consumption in suburbia are characterised as being shaped by social identity dimensions, specifically conformity and distinction [55]. In addition to manifesting across diverse spatial scales, social identity concepts have also been suggested to be particularly relevant in the context of collective transformations.

Social identity is proposed as a key concept that connects societal and individual aspects of transformation processes, such as those that may be expected and are anticipated in the energy transitions [56]. Social identities inform how networks arise between people who frequently choose to associate with others on account of such similarities while, conversely, often choosing to avoid interactions with those who are different from themselves. Identity is often understood as referring to group membership based on ascriptive characteristics; however, a broader view considers how the process of identifying with identity dynamics of neighbourhoods (class, party, gender, ethnicity, religion, etc.) could affect various societal outcomes [57]. The prevailing notions of fixed ethnic identities need to be challenged and suggest that fluidity and constraints in ethnic categorisations play a significant role in shaping individual and collective behaviours in domestic and multi-ethnic contexts [57].

Whilst the primary focus is not on energy, some studies have explored identities and rhythms in the context of water practices within households. Residents' notions of both conformity and distinction shape their social capital, as well as the temporal and spatial patterns of water consumption [58]. Although the study examines the use of water as a resource, insights from their research are relevant to the context of energy use, given that energy constitutes a significant societal consumption practice. Advocating for a more in-depth examination of social identity dimensions of consumption practices, a study argues that contrasting notions of social distinction and social conformity influence both temporal and spatial patterns of water use [58]. Additionally, the interconnectedness of social identity, everyday practices, and environmental awareness in the context of water use practices is highlighted [59] with a focus on the spatial scale of neighbourhoods. This highlights the importance of

the interconnectedness of social identity, home daily consumption practices and neighbourhoods. Consumption practices, such as those acted through energy use and demand are a product of interwoven social practices and temporal rhythms, highlighting the need to study practices in the context of rhythms [60].

Although temporal rhythms are assumed and loosely referred to in work in the context of social identities of water consumption, there has been no work to date in the context of energy that examined temporal rhythms and social identities of energy use [58]. There has been though work on combining insights from social practice theory and rhythms [61]. A prior study focuses on the temporal ordering and social practices brought about by the use of household energy technologies [62]. This study examines energy transitions through crisis moments such as infrastructure failures, including blackouts, and findings that they create moments in which the rhythms of everyday life and the relationship between humans and technological systems are renegotiated. The other study explores energy use rhythms, contending that these rhythms manifest as both circular (recurrent) and linear (sequential) forms [63]. They argue that these rhythms are observable in the overall patterns of 'times when' social practices are performed across society. In this study, their examination of rhythms extends across multiple scales, encompassing micro-level rhythms experienced by individuals and households to macro-level rhythms such as peak hours in energy demand and rush hours. However, the mere observations of rhythms provide limited insight into how such rhythms are formed and reproduced over time.

As discussed above, identities and rhythms have been shown to shape how consumption practices such as the use of water or energy emerge, evolve, are maintained, or renegotiated in neighbourhoods and homes. Though helpful, there has been limited empirical insight or theoretical advancement into the characterisation of rhythms across different types of homes and neighbourhoods. The following section discusses the theoretical framing for this paper and research methods drawn upon in the empirical settings.

3. Theoretical framing and methods

The conceptual starting point for the project draws on an inductive theoretical positioning combining Social Practice Theory (SPT), Social Identity Theory (SIT) and Rhythm Analysis [1]. The purpose of combining three conceptual perspectives was rooted in addressing the overlooked socio-temporal and spatial dimensions in energy transitions and crisis planning. As discussed in the review of literature in section 2 above, whilst it is well documented that combining social practice theories and rhythm analysis can help examine the socio-temporal dynamics, the significant social identity dimensions that may shape those dynamics are so far underexamined. By adopting the three conceptual frames [1], and argued for tangentially by other scholars [58, 60, 63] this research work seeks to contribute to a novel analysis of the interplay between social practices, social identity, and temporal rhythms in the context of home energy transitions and crisis planning.

3.1 Research methods

The methodological approach was reliant on a mixed methods experimental design [64]. This approach integrates qualitative and quantitative fieldwork with experimental design in an iterative manner, allowing for a dynamic understanding of the phenomenon being studied at different stages of the research.

3.1.1 Data collection

Data collection involved the use of diverse techniques including surveys, photographs, and semi-structured interviews as well as workshops. These were conducted in stages overlapping with thematic analysis (see Figure 1). Throughout the stages focus was placed on understanding the social identities, practices and rhythms involved in residents managing energy in their homes and how this reflected in the neighbourhood. Emphasis was placed on understanding how this may inform a collective approach to energy demand management in crisis events.

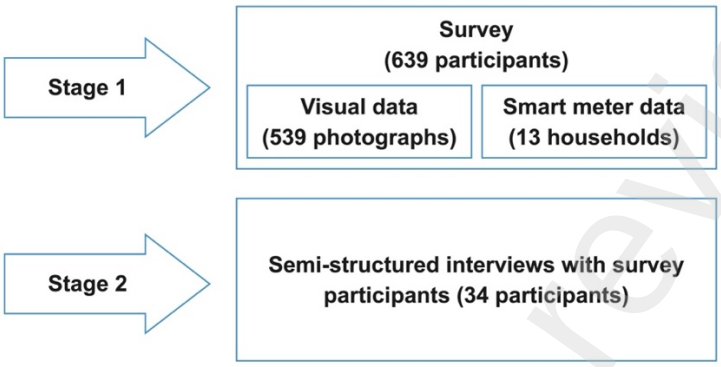

Figure 1: Two stages of data collection.

In Stage 1 an ethno-visual survey [1] was conducted online using Qualtrics. Bristol and Glasgow based participants were recruited through a call for participation published on social media (LinkedIn), local newspapers (Bristol Evening Post B24/7 and Bristol Green Capital News) and the University of Strathclyde Community. The recruitment criteria called for participants over the age of 18 living in Bristol or Glasgow, in full/part-time employment, unemployed or retired. The focus was on two different locations in the UK with distinct neighbourhood social and spatial characteristics but similarities in local energy policy (both Bristol City Council and Glasgow City Council had declared climate emergencies and had evolved decarbonisation plans including plans on energy demand). The survey garnered a total of 1,427 participants, with a final sample of 639 individuals after filtering incomplete responses. Participants were asked to convey their home spatial and social characteristics, their home energy management approaches, their neighbourhood and how they related to their neighbours, as well as their daily and weekly energy use and management routines (rhythms). Additionally, participants were asked to submit a photograph that conveyed an energy use activity in an evening routine. The evening routine was selected as it had been argued in the literature to be most inflexible to the peak load shifting [65].

Following analysis of both survey responses and submitted photographs, Stage 2 involved the development of interview protocols based on initial survey analysis insights. Recruitment for the interviews occurred through a combination of a public engagement event and a social campaign associated with the project. A total of 34 interviews were conducted by phone and online. All the interviews were recorded, transcribed, and fully anonymised in accordance with Ethical approvals. These were then thematically analysed paying close attention to social identity, practice, and rhythm dynamics.

3.1.2 Data analysis

An iterative thematic inquiry (ITI) method was employed [66] building on the central role that themes already play in the analysis and reporting of mixed data. Iterative Thematic Inquiry builds on the conceptual approach taken to understand social dynamics through social identities, practices, and rhythms lens as above. The analysis was conducted in analytical phases as below (see Figure 2).

Phase 1	Phase 2	Phase 3	Phase 4
Categorising Survey Responses	**Visual Analysis**	**Interview Analysis**	**Holding Workshops**
Category 1 - Home Physical Properties **Category 2** - Home Social Properties **Category 3** - Managing Energy in the Home **Category 4** - Managing Energy in the Neighbourhood **Category 5** - Energy Use Home Rhythms	**1- Focus of the Photo** **2- Overall Compositions** **3- Activities that portrayed on the photo**	**Thematically drawing one established archetype themes established in Stages 1 & 2.**	**1- Workshop 1** Initial insights were shared with stakeholders working in both the energy and housing sectors.

Figure 2: The four phases of data analysis.

In phase 1, Survey responses were initially organised into analytical categories drawing upon SPT, SIT and rhythm analytical dimensions. These categories encompass 1) home physical properties, 2) home social properties, 3) managing energy in the home, 4) managing energy in the neighbourhood, and 5) energy use home rhythms.

Afterwards, the responses were grouped based on key parameters identified for peak load crisis scenarios [65]. within each category. These parameters included participants' social identity and community ties, their occupancy status at home during the daytime on weekdays (whether participants were mostly at home or away from home during the week), and the number of appliances they possessed - categorised under 10 and over 20. These were then further iteratively examined against all other categories via writing narrative memos [67] and in Miro[1], a virtual workspace platform, enabling the visualisation of all data in one place. The purpose of the narrative memo was to thematically reflect on key emerging thematic characteristics across analytical categories and to note observations in terms of:

- What characterises the 'neighbourhood' social identity of individuals in a sample subset, and how does this reflect in a home's spatial and social properties?
- How do different social identities shape (or not) home energy use/management practices?
- What are the actual rhythmic characteristics of a thematic group, and is this in any way shaped by social identity, energy management practices, or spatial context?

Initial similarities started to emerge between those who strongly identified with their neighbourhood and those who did not. We subsequently regrouped the initial groups into cluster archetypes based on the category parameters that distinguished the participants the most – especially, community ties and social acts. This process revealed four key cluster archetypes of participants.

In phase 2, visual analysis [68] was employed to understand how evening routines and rhythms were conveyed for each archetype and the rhythmic qualities they portrayed. Participants were requested to submit photos that, in their view, conveyed their typical evening routine. These photos were initially grouped under each archetype and then categorised based on:

- The focus of the photo (was it an object, person, or activity, it outdoor or indoor, whether it included a key focus or multiple sources of focus)
- The overall composition (whether it was composed in a particular way, whether it included people or not, whether it was full of colour or not, whether it was detailed or taken from afar)
- The activities they portrayed (for instance sleeping, dining, and working)

[1] https://miro.com/app/board/

Subsequently, the photos within the archetype were then regrouped into thematic frames. Within each thematic frame, observations were made regarding the aforementioned analytical dimensions: focus, composition, and activity. This analysis was then compared to how the evening routine was described in the survey.

In phase 3, following the survey and photo analysis, interview protocols were developed to deepen the understanding of social identity characterisations within each archetype. Particularly, dimensions such as social reach, engagement with neighbours and neighbourhood as well as energy management practices. Interviews were held online with 34 participants and recorded verbatim. These were then transcribed and analysed thematically, revealing two key energy managers – Proactive and Reactive – within which the four archetypes were grouped.

In phase 4, following the synthesis of all analytical work, initial insights on the Manager types and archetype groupings were shared in a workshop with invited expert stakeholders working in both the energy and housing sectors. This included a total of 8 participants who provided feedback, reflecting on the findings and implications for each sector. The discussion was documented through taking notes, observations, and graphic scribing techniques.

4.0 Findings

The findings suggest that energy management practices are shaped socio-temporally and spatially differently by diverse perceptions of neighbourhood social identities. Participants conveyed different ways of identifying with their neighbourhoods shaped mostly by perceptions of social status, similarity of housing spatial aesthetic, and social strength (knowing and engaging with neighbours). These different identities were characterised by either regularity or irregularity of energy management practices within the home and neighbourhood. Two kinds of managers emerged characterised by four archetypes – Proactive Energy Managers (Archetypes 1 and 2) and Reactive Energy Managers (Archetypes 3 and 4).

The two archetypes in each manager type are differentiated mostly by their social identities and the ways these shape energy management practices. Archetype 1 participants are characterised very strongly by a high social identity, conveying a strong sense of knowing and relating to a high number of neighbours. This strength of identity with neighbours and neighbourhood is slightly weaker for Archetype 2 who convey knowing slightly fewer neighbours and not interacting in the same way with neighbours. There are also variations in the extent of taking individual responsibility over shared for managing energy in the home, as well as the extent of willingness to shift activities in peak load or similar energy demand scenarios. These differences in social identity and practice also manifest in the rhythms of energy management as discussed below. Similarly for Reactive managers, Archetype 3 signify slightly lower social identities than 2 and Archetype 4 signify lower than 3.

4.1 Proactive Energy Managers

For 197 number of participants (31% of the total sample), living in neighbourhoods where houses ‘looked’ similar to theirs, neighbours conveyed similar ‘lifestyles, habits and behaviours’, sense of identity was seen to be very high (over 75%). For Proactive Energy Managers, managing energy is conveyed to be highly proactive, frequent, and regular as well as consistent. These participants are motivated by either the need to minimise energy use or protect the ‘environment’. Their energy management rhythms are regular and mostly reliant on taking individual responsibility for checking, monitoring, and adjusting energy use at home. These proactive energy managers fell into two

groupings - either highly generous in their willingness to shift their energy use activities to benefit others (Archetype 1) or aware of the benefits of shifting and somewhat willing to shift their use of energy if incentivised to do so (Archetype 2). Proactive energy managers were also characterised by the need to manage energy by *balancing against other needs as well as protecting the environment and minimising use.* Further detail for each analytical category emerging theme is illustrated in Tables 1 and 2 below.

Table 1: Categories 1 and 2 – Proactive managers group (Archetypes 1 and 2).

Archetypes			Arch.1	Arch.2
Sample/Number			107	90
Category 1: Home physical properties	Type of home	Bungalow	28%	20%
		Detached	11%	12%
		Flat	17%	10%
		Maisonette	30%	35%
		Semi-detached	12%	14%
		Terraced	2%	9%
	Tenancy type	Lodger	6%	1%
		Live with family/friends	10%	13%
		Owner	69%	81%
		Tenant	15%	5%
Category 2: Home social properties	Gender	Female	44%	50%
		Male	56%	49%
		Prefer not to answer	0%	1%
	Participants' age	18 to 24	9%	9%
		25 to 34	57%	49%
		35 to 44	21%	30%
		45 to 54	7%	2%
		55 to 64	3%	8%
		65 or over	3%	2%
	Employment status	Full time	88%	77%
		Part time	5.6%	5%
		Retired	5.6%	7%
		Self-employed	0%	4%
		Student	1%	1%
		Unemployed	0%	6%
	Intensity of identifying with neighbourhood	100% intensity	100%	90%
		75% intensity	0%	10%
		50% intensity	0%	0%
		25% intensity	0%	0%
		0% intensity	0%	0%
	Importance placed on neighbourhood issues	100% matter	100%	5%
		75% matter	0%	69%
		50% matter	0%	23%
		25% matter	0%	2%
		0% matter	0%	1%

Physical properties (category 1) of homes did not differ for Proactive Managers – in both groups, there was a prevalence of bungalow and maisonette homes and owner-occupied tenancies. In terms of

social properties (category 2), there was similarly little differentiation with most being in full-time employment (82%) and predominantly in age groups 25 to 34. The archetypes differentiated mostly in the intensity of identifying with their neighbourhood with Archetype 1 presenting a 100% identity and Archetype 2 presenting a 90% identity with their neighbourhood.

Table 2: Categories 3, 4 and 5 – Proactive managers group (Archetypes 1 and 2).

Archetypes			Arch.1	Arch.2
Sample/Number			107	90
Category 3: Managing energy in the home (balancing against other needs/minimising use/protecting environment)	Individual responsibility for managing energy	Individual	81%	76%
		Collective	19%	34%
	Individual responsibility in adjusting comfort	Individual	78%	71%
		Collective	22%	29%
		Nobody does	0%	2%
	Frequency of adjustments made on energy use	Daily	50%	50%
		Weekly	1%	6%
		Monthly	9%	14%
		Seasonally	29%	19%
		Occasionally	11%	10%
		Never	0%	0%
	Adjusting heating in home	Partial home heated	59%	37%
		A few hours home heated	28%	33%
		Whole home heated	13%	30%
	Importance placed on saving energy	Very important	85%	64%
		Less important	15%	36%
	Satisfaction with energy efficiency in their home	Very satisfied	58%	38%
		Less satisfied	42%	74%
	Use energy in off-peak hours		47%	39%
Category 4: Managing energy in the neighbourhood (high conformity, high social reach, high social strength willing shifters)	Engaging with neighbours	Very common	80%	43%
		Less common	20%	57%
	Number of neighbours that participants were friendly with	11 or more	38%	22%
		7 to 10	35%	38%
		4 to 6	22%	22%
		1 to 3	5%	18%
		0	0%	0%
	Frequency of engaging with neighbours	Daily	30%	22%
		Weekly	37%	36%
		Monthly	17%	30%
		Yearly	14%	12%
		Never	2%	0%
	Meeting points	Home	68%	53%
		Garden	59%	54%
		Public	100%	100%
Category 5: Regularity in management rhythms	Conveyed managing energy in a regular manner – daily and weekly rhythms			

In terms of managing energy in the home (category 3), participants in both Archetypes conveyed a need to *balance needs* and *minimise use,* as well as protect the environment. In addition, proactive managers conveyed regularity and consistency in monitoring, adjusting, and checking energy use. Archetype 1 takes individual responsibility for managing energy in their home (81%) and adjusting comfort in their home (78%) while Archetype 2 takes slightly less individual responsibility for managing energy in their home (76%) and adjusting comfort in their home (71%). Both archetypes conveyed adjusting comfort daily on a regular basis. In Archetype 1, almost 59% adjust comfort in half of their home with only part of their home being heated. There is a heightened level of *manual and checking* information on energy use via bills, smart meters, thermostats, lighting, and appliances but less involvement in switching providers (25%) or using energy management devices (6.5%). They perceive themselves as very high-value *savers* (85%) with 58% satisfied with their home energy efficiency. To *save* energy they tend to invest in actions that are *regular and frequent* with 78% switching appliances off standby. Saving similar to taking responsibility is seen as an individual rather than a shared task.

In Archetype 2, 37% adjust comfort in half of their home with only part of their home being heated. They perceive themselves as high-value savers (64%) with 37.8% satisfied with their home energy efficiency -somewhat less than Archetype 1. For most participants in both archetypes, managing energy was seen to be about balancing needs. For many participants, this was about "*maintaining energy use below a threshold of around 7.5kW.h."* (Participant 006) or shortening the use of water or cooking "*The shower needs to be really short…cooking needs to be really short…if you can do everything except for using electricity in the house you do it; but that means you're always thinking about it, always counting."* (Participant 023)

Balancing needs was closely related to minimising use to minimum levels of comfort or reducing through saving as much as possible.

> *"So, I said like a minimum threshold level of comfort, which is like I say, to keep in the winter flat at least 18 or 19 degrees when I'm working from home. But beyond that, then I try and minimise everything, so you know, turn off plugs that I'm not using, turn off lights that I'm not using, using the washing machine on a low temperature. So, the minimum comfort is the room temperature and everything else is minimised for cost."* (Participant 009)

While Participant 009 discusses minimising use as a way of reducing temperatures and financial cost saving, others viewed minimising through investing in efficiency.

> *"Uh, well, we try to reduce as much as possible. When we bought the house, the previous owners and then not have any savings lamps. So, all the old-fashioned appliances. So, I changed all of them. Umm, I think I have one or two of the old styles and it is saying my most are LED. Now even the spotlights, I have spotlights are all LED*." (Participant 029)

Most Proactive managers were interested in seeing their energy use on a frequent basis via smart meters and/or billing.

> *"Once a week, I log into my account to review my energy usage data. Since my meter sends readings on a daily basis, I can see what has been happening over the course of the week. By reviewing this information regularly, I can identify any patterns or trends in my energy usage and make adjustments as needed to reduce waste and promote sustainability."* (Participant 002)

> *"I like being able to see where our energy is being used. We've found it helpful on occasion, for example, when one of the kids has turned on the radiators and we can see the spike in electricity usage."* (Participant 006)

In terms of identifying with their neighbourhood and future capacities to manage energy in neighbourhoods (category 4), they conveyed a deep sense of belonging, mostly seeing their own home like others and neighbours from a similar background or social status. All the samples in Archetype 1 identified over 75% with their neighbourhood and conveyed knowing between 7-11 neighbours seeing them often and on a regular basis mostly in each other's gardens or homes. When asked to describe their neighbourhood, they would often describe their neighbours' homes as similar to theirs and their neighbours as similar to them either in terms of 'being from the same place' or 'having similar jobs or interests'.

> *"Most of the houses are completely detached. A lot of greenery. People are a little bit different from the previous place that we are. We moved our more confirmed. And educated, I would say so. That is, that isn't how I would describe the neighbourhood and then perhaps they. Umm, the description of the bands in the City Council can I explain it that it's slightly of the move Umm, I would say. Umm and nice postcode to be in and it's. It's a really nice neighbourhood and it's. It's, uh people around that area are really educated and perhaps that's one of the main reasons that have been moved to the area and we like it. We love it."* (Participant 010)

> *"Okay, most people in the area are homeowners and not renters, as far as we know. There are probably around 20 families who own their houses in the area."* (Participant 006)

Proactive managers across both archetypes conveyed managing energy in a highly regular manner – weekly and daily rhythms (category 5). This regularity was also apparent in the ways their evening routines were conveyed in photographs. Most photos submitted by Proactive Managers conveyed one point of focus such as the moon, or table lamp- mostly in a dark or shaded background- with a night-time feel (see Figure 3). The photos were mostly night-time outdoor photos- that portrayed stillness, moonlight, void of people or other activity and largely showed trees or night-time skies. There is a sense of circadian rhythm, stillness, and peacefulness. These photos strongly focus on a particular feature, which is the moon and a spotlight in the sky.

Figure 3: Example of photos uploaded by Proactive Managers conveying their evening.

They also conveyed a willingness to shift an evening energy use activity (such as cooking or laundry) to benefit the environment or others. Participant 022 discusses how a lack of understanding or knowledge on the benefits of peak load may not deter them from shifting an activity if this were to be better for the country or world.

"I'm not really that knowledgeable about off-peak energy. I mean I think obviously you have to have the type of energy account that is saving you money and then be important. But because I'm not in that situation… But if it means that it's better for anything to do with the country or the world, or, you know as a whole, then I think yes, we should all be doing it, but I'm not exactly sure of the link to that." (Participant 022)

This willingness to shift an activity was portrayed to be a commitment that could be made on a regular basis, fitting around regular and consistent energy use activities in an ongoing manner.

4.2 Reactive Energy Managers

On the other hand, a large percentage of the overall sample (69%), did not identify as strongly with the neighbourhood, perceived themselves to be of a different social status to neighbours and can be described largely as Reactive Energy Managers made up of two groupings (archetypes 3 and 4). Reactive managers prioritised comfort over energy use and adjusted use based on perceived errors in monitoring. Reactive managers were not engaged in checking or adjusting on a regular basis and were reluctant to shift their use of energy even if incentivised to do so as illustrated in Tables 3 and 4 below.

Table 3: Categories 1 and 2 – Reactive energy managers group (Archetypes 3 and 4).

Archetypes			Arch.3	Arch.4
Sample/Number			125	317
Category 1: Home physical properties	Type of home	Bungalow	42%	33%
		Detached	12%	16%
		Flat	14%	19%
		Maisonette	18%	19%
		Semi-detached	12%	12%
		Terraced	2%	1%
	Tenancy type	Lodger	1%	7%
		Live with family/friends	18%	17%
		Owner	62%	55%
		Tenant	19%	21%
Category 2: Home social properties	Gender	Female	45%	42%
		Male	55%	57%
		Prefer not to answer	0%	1%
	Participants' age	18 to 24	16%	19%
		25 to 34	53%	59%
		35 to 44	23%	16%
		45 to 54	5%	2%
		55 to 64	1%	3%
		65 or over	2%	1%
	Employment status	Full time	78%	80%
		Part time	6%	9%
		Retired	4%	2%
		Self-employed	3%	3%
		Student	5%	3%
		Unemployed	4%	3%
	Intensity of identifying with neighbourhood	100% intensity	0%	0%
		75% intensity	74%	56%

		50% intensity	20%	34%
		25% intensity	5%	8%
		0% intensity	1%	2%
	Importance placed on neighbourhood issues	100% matter	46%	1%
		75% matter	30%	56%
		50% matter	18%	35%
		25% matter	5%	6%
		0% matter	1%	1%

Physical properties (category 1) of homes did not differ for Reactive Managers – in both groups, there was a prevalence of bungalow and maisonette homes and owner-occupied tenancies, though there is a greater percentage of flats and tenanted properties in contrast to Proactive managers. In terms of social properties (category 2), there was similarly little differentiation with most being in full-time employment (79%) and predominantly in age groups 25 to 34. The archetypes, however, don't strongly identify themselves with their neighbourhood.

Table 4: Categories 3, 4 and 5 – Reactive energy managers group (Archetypes 3 and 4).

Archetypes			Arch.3	Arch.4
Sample/Number			125	317
Category 3: Managing energy in the home (balancing against other needs/minimising use/protecting environment)	Individual responsibility for managing energy	Individual	65%	52%
		Collective	25%	48%
	Individual responsibility in adjusting comfort	Individual	52%	54%
		Collective	44%	45%
		Nobody does	4%	1%
	Frequency of adjustments made on energy use	Daily	48%	30%
		Weekly	1%	3%
		Monthly	17%	22%
		Seasonally	13%	19%
		Occasionally	18%	19%
		Never	3%	7%
	Adjusting heating in home	Partial home heated	50%	57%
		A few hours home heated	20%	27%
		Whole home heated	30%	16%
	Importance placed on saving energy	Very important	47%	23%
		Less important	53%	77%
	Satisfaction with energy efficiency in their home	Very satisfied	17%	9%
		Less satisfied	83%	91%
	Use energy in off-peak hours		30%	31%
Category 4: Managing energy in the neighbourhood (high conformity, high social reach, high social strength willing shifters)	Engaging with neighbours	Very common	26%	7%
		Less common	74%	93%
	Number of neighbours that participants were friendly with	11 or more	18%	12%
		7 to 10	32%	25%
		4 to 6	36%	38%
		1 to 3	12%	22%
		0	2%	3%
	Frequency of engaging with neighbours	Daily	24%	13%
		Weekly	31%	30%

		Monthly	24%	38%
		Yearly	15%	17%
		Never	6%	2%
	Meeting points	Home	56%	51%
		Garden	52%	42%
		Public	100%	100%
Category 5: Regularity in management rhythms	Conveyed managing energy in a regular manner – daily and weekly rhythms			

In terms of managing energy in the home (category 3), participants conveyed a need to *prioritise comfort and leave decisions to the (energy) system or others.* In addition, Reactive managers conveyed an irregularity and inconsistency in monitoring, adjusting, and checking energy use and were reluctant to shift their activities to benefit others.

In 18% of Archetype 3 and 22% of Archetype 4 managing energy was seen to take place monthly, rather than as regularly as in Proactive Managers. Similarly, their monitoring and checking are conveyed to take place in an irregular and less frequent manner. Saving energy is seen as both individual and collective responsibility, such as switching off standby, engaging in actions such as in Archetype 3, turning off the lights regularly (76%), swapping a bath for a shower (50%), less time in the shower (43%), and keeping the heating on low temperatures (43%) and in Archetype 4, turning off the lights regularly (61%), swapping a bath for a shower (42%), less time in the shower (39%), and keeping the heating on low temperatures (39%).

Comfort was given priority when discussing ways to manage energy use. Participant 011 discusses the pivotal role of comfort in their energy use practices. *"If it is too cold, if it is, you know under room temperature that I can bear I don't feel happy. I don't feel healthy, so we manage energy regarding comfort mainly.*" They also note how not a lot of adjustment takes place, and most adjustment decisions are left to others (in the home) or systems to adjust.

Moreover, the discussion of smart home controls implies a reactive approach to energy consumption based on external factors, such as outdoor temperature.

> *"I only switched on two weeks ago and I think I will only keep on as long as the outside temperature is below, whatever, 15 (degrees). Only because the outside temperature dropped so much, I switched on the heating equipment. And then that heating equipment also is on like a smart home control for the off-peak times."* (Participant 012)

Some participants introduced a casual approach in their households, where energy consumption is monitored without a deep, active involvement.

> *"Christy I am not checking it just generally when they show even later."* (Participant 007)

Lacking smart meters, in some samples, illustrates a more detached connection to energy usage, relying on sporadic checks communicated by the energy company.

> *"Well, I don't have a smart meter, and I don't really check my energy usage regularly. It's twice a year, based on the total units that have been used, and I get communicated that through the energy company."* (Participant 005)

One participant discusses taking a reactive strategy driven by a noticeable increase in bills. The potential of smart meters is highlighted, but practical challenges such as building infrastructure are also noted.

> *"I guess I take a reactive approach, which means if I notice my bills getting high, then I start thinking about how I can reduce them. I haven't done anything practical. I have considered getting a smart meter in the past, but it wouldn't have been convenient in my previous building. I lived on the top floor, and there was no way to connect the smart meter to the meter and the supply. It would have been too much of a hassle to deal with the providers and other things. So, it hasn't been a top priority for me."* (Participant 008)

In terms of identifying with their neighbourhood and future capacities to manage energy in neighbourhoods (category 4), they conveyed a low sense of belonging, mostly seeing their own home unlike others and neighbours from a dissimilar background or social status. 74% of samples in Archetype 3 and 56% of samples in Archetype 4 identified 75% with their neighbourhood, and mostly conveyed knowing between 4 to 6 neighbours seeing them on an irregular basis mostly in the street.

When asked to describe their neighbourhood, they would often describe their neighbours' homes as dissimilar to theirs and their neighbours as different to them either in terms of 'being from another place' or 'having different jobs or interests'.

> *"I'm from Canada, although I've lived in Scotland for 36 years. And I'm here, I feel part of Scotland, but I think in Glasgow people kind of often keep to their own sort of family and friend groupings. It's not always easy to break into those groupings, and in fact, most of my friends seem to have come from other parts of Scotland or other parts of the world. That kind of thing. Not so many from Glasgow. So, I suppose I also. Oh, OK this is terrible. I feel there is a slight class difference between other people in my neighbourhood and me. I have a university education and. And only some of the people that I'm aware of in the neighbourhood would have that and seem to make."* (Participant 028)

Reactive managers conveyed managing energy in an irregular manner – seasonally, ad-hoc and yearly. Reactive managers submitted photos characterised by irregularity, asymmetry, and inconsistency. Unlike Proactive managers, the activities they denote are not based on a singular focus but rather convey a mix of activities that may overlap. For example, photos convey a sense of ongoing messiness, irregularity and lack of clear direction or focus, as these spaces are not fixed but rather are constantly changing over time (see Figure 4). These photos create a feeling of movement, disorder, and inconsistency in a single frame. Often bedrooms convey multiple uses- a workspace, a living area and a sleeping space. There is a mix of furniture, plants, lighting, and clothing not arranged in a specific composition but almost appearing accidentally.

Figure 4: Example of photos uploaded by Reactive Managers conveying their evening.

They conveyed a greater reluctance to shift an evening energy use activity (such as cooking or laundry) to benefit the environment or others. This reluctance shifters group suggested a preference for maintaining the status quo and a potential hesitancy to adopt more sustainable practices. Understanding the motivations and barriers behind this reluctance is important for devising effective strategies to promote energy-conscious behaviour in this group of managers.

This lack of willingness to shift an activity was portrayed to be a commitment that could be made on an irregular basis, fitting around irregular and less consistent energy use activities in an ad hoc manner.

5.0 Discussion and Conclusions

There has been a consistent call from policy and research to enhance our understanding of how a collective response and the corresponding capabilities might develop to support and sustain a society geared towards electrification across various sectors [69, 70], however, this area remains inadequately explored in the literature. There are no accounts to date that have emulated what this may look like and what the socio, spatial and temporal characterisations of such a mode of being might be. Significant work has gone into simulating the future operations of smart energy systems, such as smart grids and smart energy communities, mostly seen to be solved through automated decision-making in the home or neighbourhood [71, 72]. Though this work has helped articulate activities that may be challenging or inflexible to shift [33, 35], and ways that people may respond to shifts through incentivising or similar mechanisms [73], no studies to date have sought to understand or characterise rhythms of energy use in relation to how people identify within their neighbourhood and the energy practices that may be emerging or sustaining as a result. Despite longstanding work in social identity and its critical role in ordering and regulating consumption practices [74], particularly at the spatial scale of neighbourhoods, there have been no empirical accounts in the energy domain to date. Despite longstanding work in social identity and its critical role in ordering and regulating consumption practices [74], particularly at the spatial scale of neighbourhoods, there have been no empirical accounts in the energy domain to date.

The findings in this paper highlight how resident's intensity of identifying with their neighbourhood, plays a significant part in the ways they may respond temporally to future crisis events such as peak load demand shifting. Based on this paper and work carried out in Glasgow and Bristol, 31% of the

sample was willing to shift their energy use peak activities and likely to do so in a regular and consistent manner. So far, crisis planning in relation to electrification has relied mostly on financial incentives, known to be unsustainable and unlikely to be taken up in the future [75, 76]. The evidence offered in this paper offers a new perspective of what could be achieved, by paying closer attention to socio-spatial and temporal dynamics in neighbourhoods. The development and implementation of new interventions that make sense of, encourage, and harness these dynamics can represent an additional frontier for energy policy focusing on decarbonisation, energy efficiency, and demand management.

Further work is needed on a larger sample, that may include not only other neighbourhoods (rural and urban) in the UK but in different national contexts too. There is a lack of diversity in the sample overall in terms of participants' age groups, demography, employment type and home types. Future studies would need to include a broader range of participants. Over 40% of residents in the UK are in fuel poverty [77]It is unclear whether some participants may/may not be in fuel poverty, so future studies should seek to understand and separate the qualitatively different ways that household energy demand is experienced and managed in fuel poor households, compared to others. This would include a focus on the everyday experiences of energy demand explored in this paper but also understand how economic vulnerability can alter social identity: creating senses of shame and exclusion, for example [78]. Fuel poverty is also deeply temporal – with households becoming fuel-poor over time: in response to familial circumstances during the month or year, or in response to global dynamics and price rises. Lastly. future work s may also include children as active members of the household who according to prior studies [79] actively participate in energy management in the home, or focus attention on energy demand dynamics created by child- or –eldercare responsibilities within a household.

Also, whilst the social identity and practice, as well as rhythmic profile found for each type, offer important insights into the characterisation of energy use and demand – we recognise that these are not static and indeed may shift or evolve as personal circumstances change – with participants moving neighbourhoods it may be that they take or shift on other archetypes; in addition, archetypes may manifest in a fluid manner and change over time – future research would need to fully explore this dynamic nature of identity through longitudinal field studies.

Building on the established concept of collective capacity and social infrastructure, future collective behaviours can indeed emanate from the collective itself [80], recognising the generative power of social identity and everyday activities. Research on social infrastructure has long established the idea of collective capacity in the built environment, beyond the notions of cities as households, communities and individuals to a continuous recombination of people's identities and practices [80]. The methodological and conceptual approach taken up in this paper offers a foundation for policy and practice to study and utilise tools to simulate implications of crisis planning in different communities paying close attention to social identities and practices that emerge.

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