University of Reading

An investigation into the residential electricity demand, device use and activity patterns of older people in Reading, UK

Thesis submitted for the Degree of Doctor of Philosophy

School of Built Environment

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Abstract

The UK residential sector accounts for about one-third of overall electricity demand. The proportion and rhythm of this demand are projected to change largely due to projected changes in household characteristics such as demographic structure, energy-relevant practices and the changes in the ordering and structure of each day during the week. The UK population is ageing and future levels of electricity demand will depend not only on energy-efficiency gains, changes in the work-life length and structure, but also more on the activities of older consumers. The relationships between device use and activity patterns can shed light on the timing of residential electricity demand. This study analysed the timing of some energy-relevant practices enacted by over 65 year-olds in Reading, UK. The aim of this study is to investigate the pattern of the energy-relevant practices by older people.

This study was carried out between November 2015 and February 2017 using meter readings and appliance-use diaries. These provided a snapshot of the timing of selected device (shared) use, the pattern of kWh demand and the frequency of use for other devices for seven consecutive days. From these, I developed energy intensity indexes and time slots to enable comparison of the most significant kWh readings within and across days. The frequencies of households using the selected devices were used to indicate the synchronicity (coming together) of device use.

Meters were installed in participating households for a week during which the occupant(s) filled-in time use diaries for selected devices in a mostly 4-hour time

slot and indicated the frequency of use for other appliances. The meter readings were recorded every 60 seconds and aggregated in alignment with the diary time slots. This enabled the determination of the variation and rhythm of electricity demand and electricity demand intensity. Frequencies were employed to describe the pattern of use of the selected devices.

The findings from this study suggest that the single and two-person older households differ significantly in their pattern, intensity of electricity demand and device use. For instance, two-person households seem to have higher levels of routine and internal synchronisation than single households.

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Glossary:

Energy-relevant practices: doings that had a real-time or deferred direct bearing on electricity demand of a household. For instance, real-time kWh demand can be watching TV, and the deferred kWh can be in the case of battery-powered devices.

Household: a person(s) that normally resides at an address.

HVAC: heating, ventilation and air-conditioning.

ICT: information and communication technology.

Intensity of demand: the percentage ratio of the kWh readings throughout the day or the week. The numerator was the kWh reading for a time slot and the denominator the highest kWh for the day or week (intra-day and inter-day respectively).

Older people: people over the age of 65.

Single household: a household that is normally occupied by one person.

Synchronicity: when activities are carried out during the same time slot.

Two-person household: a household that is normally occupied by two persons who are over the age of 65.

Typical day: a day or days during the week when a household does not reach its maximum inter-day index.

Chapter 1 : Introduction

1.1 Motivation for the study

In the UK, the characteristics of a household, including age, influence the pattern of domestic energy demand Huebner et al. (2016). Despite this, very little work has been done to investigate the electricity load profiles and practices that constitute the demand patterns of older people. In general, very little is known about how energy is used and how it varies in everyday life (Anable et al., 2014). At the national level, census data shows that the population of over 65s (older people) grew nationally by about 0.3% in mid 2014 from the preceding year (ONS, 2013). Reading can be pointed out as an example in the UK of an ageing society, a phenomenon where there is a growing population of older people within a society (Tinker, 2002, Richards, 2018). Reading Council (2017) indicated that people 60+ are projected to grow from 15%-22% of Reading's population by 2039. This trend makes it pertinent to understand the consumption characteristics of this demographic group as their proportion increasingly shapes overall electricity demand.

Older people's energy demand relates to their time use which Jun (2014) attributed as having a comparatively enhanced discretion in its ordering and variation. The discretion in time use may lead to higher flexibility of demand practices, i.e. the tendency of a household to alter the temporality (ordering and sequencing) of practices that entail energy demand. Flexibility of older people is expected to change as their time budget is potentially more constrained by work as they are potentially expected or can be in full employment for longer than the status quo. As older people work for longer, whether their work would be flexible, taking place at different times during the day and week, from home or not also causes changes in what can be described as a "weekend" in the context of energy demand. I argue the weekend as we know it in the context of energy demand will become increasingly difficult to determine and be less defined even for the same older household. Thus, studying the temporality of what older people do becomes critical in the light of these changes in lifestyles.

Changes like increased access to automated laundry and dishwashing, "binge-watching" etc. are not exclusive to older people but become more important to investigate older people as they grow within the consumer base. In other words, the increased access to these technologies makes the change in the enactment of domestic practices inevitable. It even becomes more important to the structure of UK households as it is changing to more solo living and older residents. Older people may be playing a significant role in the flexibility market which has been estimated at £8 billion annually (Strbac et al., 2016). People's doings reflect the reality of their social context (Heisserer and Rau, 2015) and these projected changes in the everyday life of consumers (older people) may be a major cause of variation in demand (Thøgersen, 2017). Changes such as consumption patterns are invaluable in forecasting demand (Blazakis, 2016). It suffices to say that a combination of these two (ageing and technological changes) phenomena make it pertinent to investigate device use of the most significantly changing age group.

Considering that the timing of appliance use is considered a strong explanatory variable in the rhythms of the week of a household (Winocur, 2005), how much use and how much sharing of use that occurs in these households are of interest to me. Some devices are critical to the existing and expected changes in time use: for instance, computing has been labelled as “encroaching on home time” (Hampton, 2017). ICT, for example, has been directly linked to accelerated temporal patterns of everyday life (Sullivan and Gershuny, 2018). How these would apply to older people is of interest to me.

Research providing empirical evidence of the time and timing of demand has been identified as insufficient in energy studies (Torriti et al., 2015). Changes are also expected in the demand of appliances, and they have been projected to rise by 5TWh by 2020 (Trust, 2011). The impacts of these appliances also lie in potential derivable savings for the consumers. The question of what savings can be made, when, with what devices arises. Appliance use has been identified as having the highest potential for savings of up to 42% (DECC, 2012). With these in mind, it is the intention of this study to contribute to bringing policy and all attention to older users and their everyday consumption practices. Hence, examining these appliances can shed light on the energy-relevant practices rhythms in these households and potential avenues for savings.

In summary, there were five motivations to this study. First, studying the energy demand of older people becomes critical in an ageing society. Second, in principle, older people could bring about higher flexibility in electricity demand, but how this is done is complex and requires a thorough investigation of the relationship between time use, and electricity load profiles. This may lead to redefining some temporal arrangements, for instance, around weekends. Third, changes in technologies in the home will alter older people's energy consumption and may lead to higher demand-side flexibility. This calls for a better understanding of device use. Fourth, the timing of device use has significant implications on how family time is shared within the household. Fifth, examining the timing of appliance use in older people's households can inform policy-makers about potential savings.

The following questions arise: (i) "what is the temporal patterning during the day, and days during the week do electricity demand of older people's households' increase?"; (ii) "which pattern of activities can be associated with changes in electricity demand?"; (iii) "do trends differ significantly between single and two-person older people's households?". The answers are critical to understanding the domestic energy practices. They can influence assessments of demand balancing and understanding co-temporality as well as inform policy interventions that are ongoing in a bid for a low-carbon future. This study seeks to address these questions by providing a snapshot of what constitutes older households' electricity demand. It achieved this by examining their electricity demand pattern and selected device use pattern for a week.

In addition, the distribution of activities and electricity load profiles of older people differs from the rest of the UK population as implied in Gershuny and O'Sullivan (2017) and echoed in a previous UK-wide time use survey ONS (2003) and other international examples like Finland and USA (Niemi, 2009, Robinson and Caporaso, 2009). At the device use level, Zimmermann et al. (2012) highlighted a distinction between the use pattern of audio-visual appliances by older people and the rest of the population and the data from Gershuny and O'Sullivan (2017) implied the same. Hence, the following additional questions arise: (i) "how do their activities within the home relate to electricity demand?"; (ii) "are older people synchronised in their energy-relevant practices?"; (iii) "is there any similarity in their load profile?" and (iv) "are there typical days for each household or do days during the week vary significantly?". These questions largely relate to how they spend their time at home that is, what they do in the context of electricity demand. It is the performance of energy-relevant practices that lead to kWh meter readings. These questions are pertinent as they indicate not just demand but a potential for flexibility of demand. Synchronicity and flexibility of device use are critical to the discourse of energy demand as they both provide an understanding and a partial solution to domestic peak time demand. Peak demand is partly caused by synchronicity. Synchronicity in this study refers to "co-temporality" of demand. It describes a situation where households use similar devices at the same time. Synchronisation of use is of concern because it enhances the understanding of use characteristics and the incidence of coming together of activities, which is critical to energy policy planning. I argue that interventions such as incentives for use or disuse or nudging are potentially most effective at time slots with the highest synchronicity of device use. In other words, policy intervention can be informed by data on synchronicity and other demand characteristics, which is currently unclear for older people in Reading, UK. This study investigated their kWh meter readings with a bid to providing in many ways, a first step in the void of empirical evidence for the investigation of older household's demand. I investigated co-temporality of device use across older households. This allowed me to establish the pattern of device use frequency (synchronicity of use). It also enabled me to investigate and illustrate how "collective" the actions were across the cohort in addition to the intensity of demand. The intensity of demand was expressed in the percentage ratio of the highest kWh readings during the day or the week versus the other kWh meter readings. This enabled me to establish the coming together of their intensity of demand. Hence, I established energy demand intensity, timing, sharing and synchronicity of use of selected devices.

1.2 Aim and objectives of the study

The starting point of this work is that the relationships between appliance use, household activities and older people can shed light on the future of electricity demand and the potential for flexibility. This study investigated the timing and rhythm of the performance of energy-relevant domestic practices by older people (people over the age of 65).

The aim of this study is to investigate the pattern of the energy-relevant practices by older people using a case study of Reading, UK.

Specific objectives are:

1. To deduce the rhythm of practices related to the electricity demand of older people.
2. To investigate the variation of diurnal activity patterns of older people.
3. To investigate of the weekly variation of activities through their inter-day intensity of demand of older people and
4. To investigate of the similarities in device use synchronicity and electricity demand intensity between single and two-person older people's households.

The analyses focus on variation in demand intensity and device use synchronicity as older people went about their everyday life at home.

Below, I illustrate the importance of the above-mentioned objectives.

To deduce the rhythm of practices related to the electricity demand of older people

The rhythms of practices contribute to address "when" related questions. This plays a major role for understanding peak demand and for projections by energy providers and policymakers. I recognise that older households are made up of a myriad of rhythms that do not necessarily consume electricity. An example is reading a book which can be done with natural light during the daytime, but requires artificial lighting after dark. I focused on the rhythm of activities that always require electricity like watching TV, among other activities. The rhythms of energy-relevant practices encapsulate the peaks and the time-referenced troughs of demand. They significantly characterise the nature and intensity of the practices that are performed by older people. In Chapter 2, I explain in detail the significance of rhythms and their definitions. The investigation of these enabled me to partly answer the question of "what do older people do?" in the context of electricity demand and "when?" which is consistent with the overarching aim of this study.

To investigate the variation of diurnal activity patterns of older people

The starting point of this objective is that diurnal variations in activity patterns exist, as demonstrated in the empirical literature on residential electricity demand. Morning and evening peaks are an extreme manifestation of such variation. In line with this position in the literature, older people are expected to start and stop activities during the day intermittently. The timing of activities is central to the question of "when" in the context of "what do people do?" The timing also in part characterises the time budget of the household. For example, the timing and frequency of activities described the structure or lack of it of the older household's day. I attempted to answer when they performed energy-relevant activities. This was central for the understanding of peak activities and what their everyday looked like in the context of electricity demand. The timing of activities is central for the understanding of energy-relevant activities as I can understand their load profiles, which consist of base loads and active demand due to these variations. I investigated this variation collectively and by separating two groups of older people (single and two-person households). This enabled me to characterise the (dis)similarity between solo living and two-person living. This is important for energy demand projections as household composition is projected to evolve towards more solo living.

To investigate the weekly variation of activities through the inter-day intensity of demand of older people

I investigated energy-relevant practices in older households for seven consecutive days. This enabled the investigation of the household's variation of practices that occur at least once a week. The variation of practices results in variation of intensities of demand. The literature has a near consensus on this variation being highly correlated with the weekday and weekend. I sought to investigate this based on (i) the premise that older people are a relatively understudied socio-demographic group and (ii) my belief that the weekday characterisation of demand and intensity variation in the span of a week originated from the societal norm of a working week. These two issues leave the question of “does the weekday/ weekend characterisation of the intensity of demand apply to older households?” The relatively sparse empirical evidence on this socio-demographic group inspired me to query this implied generalisation in the literature.

Depending on the socio-economic profile, it is currently the norm in the UK for older people not to be in full-time (5-day or 40-hour week) employment. However, this is gradually predicted to change as older people can be expected to work for longer as the previously widely used retirement age of 65. Meanwhile, people in full-time employment by-and-large have a comparatively obvious and sometimes predictable pattern of intensity of demand over the week. This is alluded to in widely available time use data (such as the 2000/2001 UK time use survey) as they are expected to peak in the mornings and evenings when they are home and demand often falls to near the base level when they are at work. In the case of older people and my cohort, especially, this pattern of active occupancy-dependent demand may not apply as most of them self-identified as retired and or volunteering as their current occupation status. Thus, it leads to the question "does their variation of demand intensity suggest that the working week as we know it is different in their case?" This weekend disparity (or not) is significant to energy demand projections and generation as the population ages.

To investigate the similarities in device use synchronicity and electricity demand intensity between single and two-person older people's households

Here, I investigated the "coming together" of the selected energy-relevant practices. This coming together describes peaks, which are caused by societal synchronisation (Torriti, 2017). I also sought to identify those activities that indicated a strong(er) commonality of doings and the time slots at which they occurred. Metrics on the synchronicity of demand outlined in Section 3 enabled me to observe how actively the cohort engaged with selected devices. The varying synchronicity of use enables providers to anticipate characteristics of loads as we know what older people are doing. The synchronicity of device use also provides empirical evidence to guide policy direction on requirements for kWh demand of these devices, standby features among other regulatory measures that can be implemented to make demand-side management easier for the households and reduce or control their active and standby demand, for example.

Thesis overview

This thesis is divided into 6 Chapters. Chapter 2 presents an overview of the time use literature and investigates this study's approach to explaining the variation of energy-relevant practices. Chapter 3 presents the Methods and Methodology that I employed to address the hitherto-mentioned research objectives. In Chapter 4, I present the results from the frequency of households in-use of selected devices and indexed meter readings. These enabled me to provide a visual and numerical representation of the rhythms and synchronicity of demand and device use. In Chapter 5, I discuss the results and their relevance to each research objective. In Chapter 6, I provide the conclusions from the study, implications and interpretation from the results in the preceding Chapters and recommendations for further study.

Chapter 2 : Review of Literature

2.0 Chapter Summary

This Chapter consists of a review of the time use literature within the context of domestic energy demand associated with social practices carried out by older people.

It reviews studies that investigated the timing and temporal characteristics of energy relevant practices of older people and reviews social practice research situating it in domestic demand with a focus on temporality. I also investigate domestic demand in terms of variation, intensity and synchronicity of demand and describe the role older people play in the above-mentioned streams of literature.

Furthermore, this Chapter reviews the time use literature in terms of the problems addressed in this thesis. An introduction to the Chapter is in 2.1. It provides an overview of the context of this study and potential alternative lenses. Section 2.2, provides an insight into older people in the UK and Reading specifically. Section 2.3 explains time within the context of this study. Section 2.4 discusses time use with subsequent subsections in time use, energy demand, variations in time use and rhythms and intensity of time use. Section 2.5 entails social practice theory within the context of energy demand.

2.1 Introduction

Previous studies have investigated older people's time use (Jun, 2014). Others have examined device uses in general Palmer et al. (2013); Zimmermann et al. (2012); Coleman et al. (2012); Palmer and Cooper (2013) and everyday energy consumption (Jones, 2013). However, they did not capture the combination of: the total demand, intensity of demand, synchronicity of their device (shared) use patterns and rhythms of practices that require energy by older people. These gaps are critical in understanding the timing and temporality of practices that involve energy demand by older people which this study intends to contribute by using a two-pronged approach.

There are several possible approaches in the literature to investigate different aspects of energy demand and (older) people's timing and temporality of practices that involve energy demand. A myriad of possible approaches such as economic and socio- demographic influences on energy demand among others were reviewed in (Guerra Santin et al., 2009, Jones and Lomas, 2015, Wallis et al., 2016). For example, building characteristics, the design of the dwelling, the age of the dwelling, household characteristics and ownership/ tenure characteristics are possible lenses (Ibid). Furthermore, many classifications exist on how to investigate domestic energy demand such as top-down and bottom-up (Swan and Ugursal, 2009), direct and indirect (Wallis et al., 2016), ABC (Shove, 2010), using Markov chains (Richardson et al., 2010, Torriti, 2014). Even within the time-use sphere where this study is intended to sit, multiple approaches exist such as time-measured, time-felt and time-ordered (Nansen et al., 2009). They described time-measured as "chronometric", time-felt as "chronoaesthetic" and time-ordered as "chronomanagement" (Nansen et al., 2009).

In this study, unlike most studies that adopt one of these approaches, I attempted to adopt an innovative method utilising two approaches. I utilised time-ordering where I identified co-temporality of the practices that used the selected devices. Alongside this, I adopted a time-measured approach where I measured the kWh meter readings which are associated with the practices that entail electricity demand in the household. Previous studies have also investigated domestic everyday energy consumption from the practice lens (Hole, 2014, Drysdale et al., 2015, Jalas and Rinkinen, 2016). The above-mentioned studies have contributed to the discourse of domestic energy demand by suggesting different methods of perceiving and investigating time, time use and timing and temporality of energy demand. For example, conclusions in Hole (2014) on page 16, it included three key questions: "what meanings, benefits and associations are bound up in the everyday consumption of energy? Do energy practices have a temporal dimension to them and if so, how does this impact upon their performance? How do the social systems in which lifestyles have become embedded and the social processes, interactions and arrangements within households shape and reinforce patterns of energy consuming practices?"

However, the study of domestic electricity demand is yet to address the issues of synchronicity of demand, intensity of demand, timing and temporality (Torriti et al., 2015) as it concerns demand of older people. These are discussed in this study.

The approach in this study offers a distinctive perspective, attending less to individual choices and more to the collective development of modes of appropriate conduct in everyday life. I chose to use the practice approach which exists in studies such as Shove et al. (2015); Friis and Haunstrup (2016) while applying time use diaries as a tool which has been investigated in Jalas and Juntunen (2015); ONS (2003); Gershuny and O'Sullivan (2017) and focusing on older people's time use as in (Jun, 2014). Altenative approaches to the practice lens which exists in previous similar studies like the socio-technical approach in Jones (2013) and the behavioural approach in (Drysdale et al., 2015). A review of the literature on practices discussed in 2.5 implies that there are often overlaps in the understanding, interpretation and application of the practice and behavioural lenses in the energy demand literature.

First, I draw the distinction here that not all behaviours are a practice, but all behaviours can form part of a practice in the context of energy demand. For example, turning on the recording of live TV is a behaviour which constitutes part of the practice of watching TV. This distinction can be drawn from "routineness" which is characteristic of a practice (Schatzki, 1996). In other words, a practice can be described in-part as when a behaviour can be characterised as "routine".

This study through the practice lens investigated selected energy-relevant practices to provide a snapshot of what the demand, demand pattern, device use and energy demand intensity was as a result of the enactment of these energy-relevant practices. Second, a practice suggests "collective action" Schatzki et al. (2001) unlike a behaviour that addresses and focuses largely on the peculiarity of a household or an individual. For example, if this study were to investigate the electricity demand of only one household as a case study, it would constitute a behavioural study. This study investigated the co-temporality of the use of the selected appliances between 59 older households. As a result, establishing and visualising the temporality and co-temporality of demand. These two attributes of this study distinguish it from a behavioural study as the (behaviours) peculiarities of the rhythm of demand of each household are acknowledged, but the focus remains the performance of and the rhythm of the selected energy-relevant practices as a category (single or two-person household). The routine attribute of a practice was also reflected in the recruitment, sample and sampling techniques adopted throughout this study. In other words, I selected activities and devices that were evident to a previous UK-wide time use study which employed diaries such as ONS (2003) that these device uses occurred at least once a week (indicating repetition and routines) for investigation.

Third, conceptually, another distinction between behavioural approach and a practice approach is the characterisation of time and practices as being interwoven and interdependent at their core (Shove et al., 2014, Moran, 2015). In other words, time relies on practices to be felt, measured or ordered. They reiterated that practices applied time's different attributes and this description. This is not applicable to behaviours to the best of my knowledge.

In this study, I investigate time use by a demographic group vis-a-vis some of the relationships between electricity demand, household activities and what (older) people do. Although Nicolini (2012) suggested that practices were beyond simply “what people do,” I chose to adopt practices within the context of “doings” because it enabled me to “zoom in” on specific elements of practices (doings and agents) while I omitted other aspects of practices such as sayings. I acknowledge this is a limitation in this study.

Practice theory has been appraised as having the following features of; being a routinized form of bodily doings and action Schatzki (1996); Reckwitz (2002); Nicolini (2012), highlights human agency Nicolini (2012), incorporates knowledge and intention (Reckwitz, 2002, Nicolini, 2012). Despite these, practice as a lens has limitations.

Of the many limitations of the practice lens, the two I find most significant are its lack of consensus among practitioners as to what constitutes a practice and the discursive nature of practices (Nicolini, 2012). The adapted Figure 2.1 below from Gram-Hanssen (2009) highlights how there can be different elements to the arguments as to what practices are and what makes up practices.

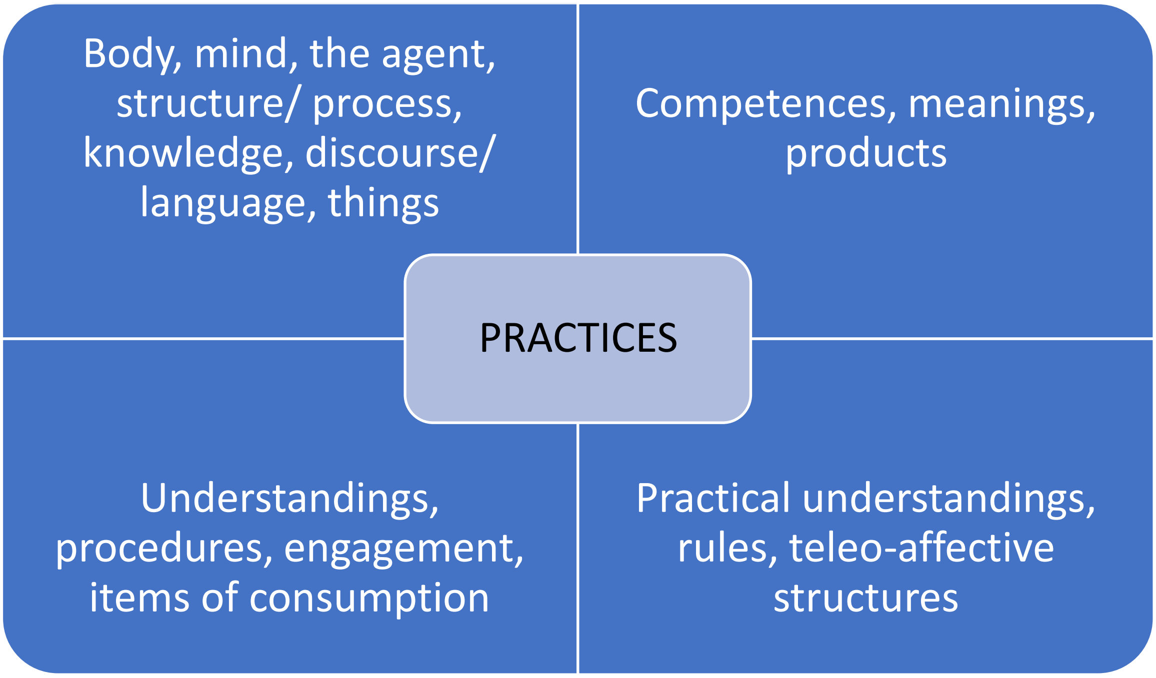

FIGURE 2.1 ELEMENTS IN THE UNDERSTANDINGS OF PRACTICES.

Adapted from (Gram-Hanssen, 2009)

Also, practice theory implicitly suggests that the agents (people) have little or no autonomy (Roberts, 2016, Ellsworth-Krebs, 2017) over their rhythms and routines although, Nicolini (2012) contradicts this as mentioned above.

From my understanding, when factors such as *Kairos* Haandrikman et al. (2004) come to play when examining practices "zooming in" (at the household level), agency of the household is emphasised. The "when" of practices only occurs when *Kairos* is established. An example of this is "the weekend" when *Kairos* may suggest that some activities may be performed more, less or differently, which is distinct from other days during the week. While practice theorists acknowledge the role of material arrangements, they often fail to acknowledge that without material arrangements, practices may not exist as we know it (Ellsworth-Krebs, 2017). An example relevant in this study is the absence of Wi-Fi in a household. This may imply that access to the internet and practices that require internet access is significantly constrained (Walker, 2014). Although, this study did not investigate how time-constrained the households are, it assumed that the material (infrastructural) arrangements for the selected practices were in place (Walker, 2014). The existence of these material arrangements contributes to shaping their time and how their time-uses compete during the period these households were investigated (time slot of shared use).

Hence, the socio-temporal organization of daily practices is the starting point of this study. Is it the basis of understanding the way norms are developed and are reproduced around technologies? How does a group of people develop, maintain and use technologies in conjunction with selected infrastructures? Time is the basis from which practices have a recursive relationship to exist and on which electricity demand can be measured and estimated. I reviewed the empirical evidence for this study examining the conceptualisation of time in the context of this study, time use and practice theory.

A reference to time is core in all decisions made in response to and in understanding of energy demand. Although, there are different philosophical understandings of the concept of time, I focused on understandings that are can be best related to electricity demand of older people while acknowledging the veracity of other lenses.

Electricity demand can be described as varied and relatively seasonal (McLoughlin et al., 2012). Its variation is a given, and almost all energy studies attempt to identify how, what, why and when these variations happen with a bid to result in achieving demand reduction, increased predictability or simply in an attempt at demand flattening (Zhou and Yang, 2016). The plethora of appliances involved enhances the complexity of its investigation (Strbac, 2008). Several approaches have been investigated utilising policy tools such as off-peak pricing mechanisms which I understand as largely entailing incentives for the timing and pattern of demand. These perhaps contributed to the slow progress in demand-side management as appliance stock and use differ and do not necessarily correlate. The approach of this study is in many ways a first step in understanding synchronicity of (shared) use rhythms, temporality and timings by older people. This contributes to the extensive work on domestic energy practices by Southerton (2013); Walker (2014); Browne et al. (2014); Torriti (2017)which have not specifically addressed the growing and potentially changing needs of an ageing UK population as indicated in Section 1.1.

The process of collecting, organising and storing observations of domestic time use is not new and is also subject to a wide range of approaches. Despite these, there have been insufficient studies on different typologies of households, especially with regards to the older cohort (Jun, 2014). In addition, due to the heterogeneous nature of the data from the meters, we adopted the use of "local maximums" Fulcher (2012) to express the maximum intensity of demand, and the frequency of the households was used to visualise the clustering of activities (refer to Section 3.4.1). Using the local maximums enables the investigation of attributes of frequency and intensity (Fulcher, 2012) which are expressed in this study as percentage intensity of demand rather than their kWh values. As shown in Section 4.2.2 and Section 4.3.2, the local maximums of the numbers of households using the selected devices and the maximum intensity of demand were highlighted by each time slot of the day across the week (refer to Section 3.4). I adopted this approach to enable comparison between the different readings and to even out the maximums of the households. This study attempted to partially fill the gap in research of time-dependence of social practices, which has received insufficient attention empirically (Torriti, 2017). I investigated as shown in 4.2 and 4.3, the time slots of the maximum intra-day intensity for the same household across the week to establish the inter-day maximum and across households to identify the time slots that indicate coming together of local maximums. Utilising it alongside the time use tool provided a “snapshot” approach to identifying the four key objectives of this study: variation, intensity, sharing of use and synchronicity of demand and energy-relevant practices among older people. It enabled this study to compare temporal order and “hot” and “cold” spots of timing of activities, which result in demand peaks and troughs. This gave an insight into the everyday life of the elderly cohort. In other words, this study investigated the interaction between a place, a time and expenditure of energy (Lefebvre, 2004) of older people thereby providing an insight into the practices of this cohort.

In recent times, detailed time use of households and their various peculiarities have received considerable research and policy attention with the most recent 2014/2015 UK time use study being Gershuny and O'Sullivan (2017). Studies using time use surveys at home have been carried out at different scales ranging from cross-country to the municipal level (Widén and Wäckelgård, 2010). This study sits at the municipal level as all the households were recruited in Reading, UK. Despite the geographical extensiveness of previous studies like ONS (2003); Gershuny and O'Sullivan (2017), insufficient effort has been made to "zoom in" on the typologies of households. This is perhaps understandable as efforts have seemingly geared towards national representativeness of the sample and less emphasis on municipal application. This is significant because previous studies to varying degrees acknowledge significant variation in the attributes of different municipalities and countries. Although, this may raise another question of the potential dichotomy between local, in-depth data collection of time use studies that would be comparatively (geographically) limited but targeted application and impact on local policies versus larger studies that tend to be tailored towards national policies. The need for local (municipal) applicability seems inevitable if the proposed carbon reduction targets are to be met because municipalities often differ significantly in their domestic demand characteristics. An example of the gaps in previous larger time use studies in the UK is the widely acknowledged insufficient attention paid to the older population which has indicated a trajectory of growth (Jun, 2014). The participation of older households varies significantly as not all counties are ageing at the same pace (if at all) thus making the case to address the extent to which policy attention may be paid to the nationally ageing population differently. Thus, I embarked upon this study to fill the research gap regarding municipal applicability and partially fill the current insufficient database on the rhythms of energy demand by older people. There has not been much research on the older cohort (in time use studies), despite the widely accepted data on the growth of this subset of the population compared with other demographic groups in the UK (Whitworth, 2011). A study like Jun, (2014) also highlighted that a limited number of time use studies adequately represent this subset of the population. A common limitation of similar studies are insufficient secondary data and limited generalisation of results. Older people have also been identified as an understudied cohort that was comparatively characterised as increasingly wealthy spending more time at home and having changing lifestyles that have a direct bearing on energy demand (Hitchings and Day, 2011). These imply the importance of time use studies to understand the intensity of demand are rhythms of demand of older people, which this thesis attempts to contribute.

2.2 Older people

This Section briefly investigates the older cohort. They were investigated within the context of being consumers of electricity, their time use and electricity demand practices. A "cohort" can be described as a group of individuals who share a set of characteristics in common, although subject to measurement errors (Bernard et al., 2011).

Being old, older or elderly is subject to varied and often vague and contrasting interpretations and social constructions. This study refers to older people as people over the age of 65 (Hilmer et al., 2012); (Ferrucci et al., 2016); (Hooper et al., 2016) and older households as those occupied mostly by older people. Across the world, the perception of old age differs sharply. For example, countries like Japan and the UK have a contrasting approach to chronological "old age". The former culturally enjoins citizens (octogenarians and older) to engage in physical activities while the latter previously encouraged retirement from active life. Also, time use research in these two countries are also largely skewed accordingly (Jun, 2014, Orimo, 2006, Chatzitheochari, 2011). I investigated the relationship between practices that consume energy and temporalities. A household refers to a person(s) that can be identified by an address (Yates, 2016). With respect to time use, older households in the UK and similar countries are consistently characterised by both classic literature such as Herzog et al. (1989); Cutler and Hendricks (1990) and more recent research Gauthier and Smeeding (2003); Jun (2014) as having the following characteristics:

Different time use on the aggregate level from the other demographic groups:

- Less paid work
- Less physically demanding leisure
- More time spent doing home-based activities
- Restricted/ Limited number of activities
- Spending more time alone
- Spending more time watching TV and carrying out religious activities
- More time on personal care
- More time for health check-ups
- Variations in the level of activity level within the older age groups

Many studies claim that over 65s decline considerably in their activity level (McKenna et al., 2007). They observed the contrary for many over 65s and observed that there is insufficient data regarding the potential diversity and heterogeneity that over 65s exhibit. In the context of energy demand, the relationship between the age and electricity demand can be described as reciprocal and the relationship between age and heating as positive (Wahlstrom and Harsman, 2015). In other words, they claim that older households can be characterised by higher HVAC demand than other age groups and lower demand for other devices and uses. Although, other research, the age of the respondents accounted marginally for the explanation of the variation in demand of households (Bell et al., 2015).

In earlier research, Freund and Baltes (1998) observed that over 65s adapt to the ageing process via selection, optimisation and compensation. They described selection to refer to the choice of certain activities over others by older people because of limited ability and or time. When these choices are made, they are intended for "optimisation." A situation where energy and time are dedicated to the most rewarding of the selected activities at all given times. They describe compensation as occurring when older people being faced with a reality that optimisation is unattainable for some activities, replace them with other activities. Although, I argue this is mostly visible in the oldest old, older people (in the UK) exhibit "selection" earlier due to retirement. This affects their time use. This is potentially changing soon due to the state pension age. This change suggests a potential change in the lifestyle of over 65s (older people) which would affect their electricity demand as electricity demand is intrinsic to their lifestyles. Time-use surveys will help identify where older people have demonstrated these adaptation attributes in their pattern of electricity consumption. These changing lifestyles of older people have been characterised as having "significant energy impacts" (Hitchings and Day, 2011). I understand these "impacts" to mean a change in the rhythm and intensity of demand to which this study sheds some light on.

Until recently, with the indication of policy towards a state pension age, the UK had a phase of retirement, which was distinct from work life (Jun, 2014). The cohort I investigated sheds light into the pattern of how older people spend their time at home in the context of domestic practices that entail electricity demand.

Different social groups organise and utilise their time at home differently (Winocur, 2005). For example, TV use is an integral part of the spare time for most households. TV use has a strong bearing on the routine of the household (Winocur, 2005). This study among other routines investigated (shared) TV routines as they are deeply entrenched in the doer and can be carried out by inattention (Highmore, 2004).

2.2.1 Older people in Reading, UK

Insufficient time use data and information on older people is a UK-wide challenge. Up-to-date data on time use of older people would shed light on potential energy planning implications, and the energy impacts that an ageing town like Reading has and would have. My visits to the Reading Council Office in-person and their website suggests that most of the publicily available information is census-centric and or poverty-related. Also, the Council's data on older people is largely skewed towards health and economic vulnerability. Almost all the evidence I could find on older people from the Council made specific reference to poverty and health metrics. Although, older people are increasingly wealthier than other age groups (Hitchings and Day, 2011). In addition, in Reading, there has been no work to the best of my knowledge that investigates the occupancy patterns, demand patterns (load profiles) and the domestic practices of older people which this study attempts to address. These gaps have implications for planning among other implications for Reading, UK as detailed in Section 6.3 as older people are projected to constitute at least one-fifth of Reading, UK's population by 2039.

2.2.2 Older people: time use and appliance use practices

In recent years, there has been an increase in interest in the investigation into the time use by older people (Jun, 2014). Yet, recent studies highlighted that time use of older people are few and insufficient despite their projected increased and changing participation in domestic practices (Chatzitheochari, 2011, Brounen et al., 2012, Jun, 2014). The "significant" energy impacts highlighted by Hitchings and Day (2011) have not gained enough research and policy attention. They did not specify what these impacts were. I assume that these would impacts would include demand pattern and flexibility of demand as they alluded to changes in use and flexibility of demand. Demographic characteristic is one of the four explanatory variables that are responsible for about one-third of the variability of demand across households (Huebner et al., 2016). Age is also one of the factors that are to be accounted for when simulating energy demand for homes (Motuziene and Vilutiene, 2013). This implies that rhythm and timing of demand, which emanate from some practices are attributable to the age of the occupant. These notwithstanding, mixed findings and marginal impacts of demographic characteristics on domestic energy demand were echoed in Jones and Lomas (2015); Bell et al. (2015).

Jun (2014) observed that time use by older people is more discretionary than other cohorts within the population. Although, other studies identified flexibility of time use on weekends and employment status as significant explanatory variables that make a household's demand distinct (Hufnagel, 2008, Anderson and Lin, 2015). These suggest either or both can be explanatory variables for domestic energy demand. I make this claim because older households are increasingly going to fit into mixed types of employment such as volunteering, retirement, underemployment, etc. The state pension increases the chances of having older people working for longer or in households with mixed types of employment. These have implications for domestic practices as synchronisation and shared use can be affected by improved opportunities to stay in full-time employment by older people. Although this study collected data regarding the employment status of participants (refer to Figure 4.4 and Figure 4.14), it relied only on the household characteristics of being older (single or two-person) and the time and timing of their electricity demand.

The time and timing of demand have been characterised as insufficient in energy studies (Torriti et al., 2015). In addition, variability of time use is also expected to be significant as people join the older age group (Jun, 2014, Newing et al., 2015). In the case of Finland, Jalas and Juntunen, (2015) observed that the energy intensity of activities of over 65s was significantly different from the other age groups for the different household activities they investigated. I assume that potentially, the situation is similar in the UK. In contrast, the use of age to characterise use may be dated, discriminatory, arbitrary and misleading (Oates et al., 1996).

Niemi, (2009) suggested that retirement triggered a significant change in the time use of individuals and households. Although this age group may not all be retired, several members of the cohort may experience significant changes in their commuting time and the time they spend at home. This was echoed in Aerts et al. (2014) where they observed that people over 65 had a distinctively different time budget from the other age groups as this is reflected in their occupancy patterns, which indicate that they spend more time at home.

Over 65s significantly differ from other age groups' time use pattern according to Robinson and Caporaso (2009). For instance, in the U.S., they observed that they spend on average 25 hours per week watching TV. They did not provide the duration for the rest of the population but in the case of the UK, the data from Gershuny and O'Sullivan (2017) suggests that older people spend less time watching TV compared to the rest of the population. There is also a strong link between the socio-demographic attributes of a household and their energy demand and energy-saving practices (Abrahamse and Steg, 2009). Examples include the use of energy-saving bulbs and general disapproval of waste of energy. Wallis et al. (2016) however, disagreed with the notion of using socio-demographics to explain differences in household demand, although their focus was on adolescents. They noted that higher number of occupants does not translate into higher demand and attributed the demand pattern to the practices that the households engage in. The demand practices of older people in the UK living in fuel poverty, for example, were observed by Chard and Walker (2016) as rationing energy use less than other age groups. This study did not investigate fuel poverty among older households. However, this conflicting evidence suggests the need to investigate the timing and temporality of demand of this cohort because of the changes anticipated in their rhythm of demand coupled with their growing proportion to the consumer base.

Older people and time use, domestic electricity demand and ageing have individually been topical issues in recent times, but insufficient attention has been paid to their intersection. This research intends to investigate this in terms of appliance use rhythms and electricity demand rhythms. The significance of patterns exhibited by over 65's and the potential incidence of a "demographically induced change in consumption" were highlighted in Kronenberg (2009). Despite these, more recently, Brounen et al. (2012) observed that there had been inadequate literature and empirical evidence on how they affect older people. They indicated that despite the awareness of the financial impact of older people's consumption, there has been insufficient reduction/ management of the aggregate consumption. This can be attributed to the rise in demand for appliances (due to their falling prices), a high replacement rate of appliances and the general perception by users that a change to more efficient appliances/ lifestyle is attributable to lowered comfort levels (Røpke and Christensen, 2012). A deeper understanding of older people's demand patterns or routines is required as electricity demand is increasingly infused in activities and practices at home. Interestingly, a strong correlation between the age of the householders and the lighting proportion were observed in Wall and Crosbie (2009). Could this be an indication of the potential impact of older households on domestic electricity demand profile?

The investigation of practices and time use by older people has been limited more methodologically than theoretically. There is a significant body of work that has applied theory in different settings and has often referred to practices as having a "bandwagon" effect. Corradi et al. (2010) and Nicolini (2012) identified six different ways of theorising practices. There is a large body of literature on the application of social practice approach in understanding practices that consume energy Torriti (2014) albeit with limited primary empirical evidence. A widely noted example is the lack of consensus of what a practice is. Understandably, there are also a few time use studies like ONS (2013); ONS (2003); Gershuny and O'Sullivan (2017) due to the cost and accompanied logistical limitations. These have partly led to few time use studies with varying levels of quality and granularity of the data collected. They can be characterised as by inaccurate estimations from the methods employed and the limited geographic area of collection (Gauthier and Smeeding, 2003, Jun, 2014). This study is not exempt from geographical constraints and measurement errors as it focused only on older residents in Reading.

The evidence indicated above from the literature suggests that socio-demographic characteristics (such as being an older household) have a direct and significant bearing on the rhythm, timing and temporality of electricity demand.

2.3 Time

The concept of time is subject to varying and often conflicting understandings and explanations. No single study can do justice to its richness and vagueness as a concept. In this study, I limit my explanation of domestic practices as practices make and compete for time while acknowledging the validity of other variations of understandings of the concept of time. Time can be attributed to be objective, experienced and the "effects" are linked to experiencing time (Fine, 1990). It has also been characterised as being "central" to how living is organised (Psarikidou, 2018). Temporalities are the pillars that make practices stable (Southerton, 2013). The rhythms of demand and device use enabled me to visually and numerically express changes in temporality across the day through the week. The passing of time can be described as a fundamental component of the human experience (Fulcher, 2012). This perspective highlights time as a reference point for describing the human experience. Experiences are a subset of and are referenced with time. In the context of practices, time and practice have a "mutually constitutive" relationship (Shove et al., 2009). Here, they ascribed the reliance of practices on time and vice versa for existence. In other words, everyday life is filled by social practices and practices compete for time. In this context, time is a resource that can be negotiated, symbolized, treated as real at the same time subject to how it is experienced (Fine, 1990). For example, for a practice to exist, it relies on the characteristic of time that enables the recording and organisation of the enactment of the practice. This example given by Shove et al. (2009) highlighted the increased importance of time when practices are enacted in the company of others.

Parting from this, time can be expressed as being "independent of and intertwined with human activity" (Hui et al., 2017). Time being "intertwined" suggests that time can be viewed as a nexus between the occupants and the activity. This understanding has implications, especially with shared practices where time is the nexus between co-occupants in shared TV use, for example. When time is "independent" of human activity, Hui et al. (2017) suggests time and temporality being synonymous. Other authors like Michelson (2015); Moran (2015) contrast with this characterisation as they allude to seasons and natural cycles as temporality and not time. They characterise temporality to be the ordering and sequencing attribute of time in which cycles belong. Thus, highlighting the contrasting understandings of time earlier mentioned. From a time-geographic perspective also, Hellgren (2014) reiterated that "it is impossible not to use time."

The time-geographical perspective investigates how people use resources in their everyday life (at the micro level) (Ellegård, 1999). Hägerstrand (1970) proposed it to be a framework to investigate the relationships between constraints and human activities in a space-time context. The time-geographical perspective is used for time use studies to explain the pattern of activities of individuals. These contrasting understandings of time are the basis for conceptualising (the concept of) time in the case of this study as time "when," "how long" underpins the lens of this study.

The mutually constitutive attribute of time and practices was echoed by Moran (2015) who described time as "practices of time," "diversity of time into a single dynamic" and that the studies of time are parallel and isolated. Time is also characterised as very variable, somewhat cyclical, interwoven and situational (Adam, 2013, Michelson, 2015, Moran, 2015). The interwoven nature of time is such that "everything is cyclical repetition through linear repetitions" (Lefebvre, 2004). An example of this applies when a hypothetical household does their laundry once a week. Once repeated it becomes cyclical even if the household decides to enact the practice of laundry less than or more than a week since the last enactment. Moran (2015) associated time and social practices. The time literature is diverse and the concept of "passing" or "spending time" is inextricable from the human existence. Time was characterised as being a resource that accommodates practices which compete for time (Friis and Haunstrup, 2016). Time is organised in everyday life, mainly in two ways: when several doings are performed at once and when one doing is performed at a time Lee (1999) which results in temporalities.

The above examples illustrate the complexity of explaining time and time use measurements such as the medium of exchange, time periods, time in language, time frames and growth and death "when" Moran (2015), "what," "how," "for how long" which inter alia could significantly influence the final output of time use studies. The nexus between the activities such as the aforementioned can be recorded in a time series (Fulcher, 2012). There is some evidence that suggests that time use is a useful source of data that is widely synthesised and recorded across the social research sphere (Shove et al., 2009, Torriti, 2017). In the case with this study, it informed the research design and findings. While it is not expected to have common themes from the various time use studies as the research aims and objectives vary, common structures exist.

The interpretation, explanation and understanding of time vary even within the social practice realm. According to Moran, (2015), at the conceptual level, time is an "enacted, material, social practice that organises the functions of temporality." This adopted concept of time implies that time can be measured, interpreted and understood with the parallel lens. Through this lens, this study sees two main dimensions of time "*Kairos*" and "*Chronos*" (Haandrikman et al., 2004). The *Chronos* refers to measured time, and *Kairos* refers to "living time" or the "right" or "proper" time (Haandrikman et al., 2004, Hui et al., 2017). There are three approaches to time use: time-measured, time-ordered and time-felt (Nansen et al., 2009). I applied "*Chronos*" and time-ordering of the practices in a time series by examining the load profiles throughout the day, and the week of collection recorded chronologically from "6 a.m. - 10 a.m." through "after 10 p.m." The *Chronos* expresses the temporal dynamics of the everyday life.

Due to the interwoven nature to the concept of time, this thesis's approach is associated with other interpretations of time with an emphasis on contextual application. I derive from the arguments of Moran (2015); Shove et al. (2014) at the conceptual level practices apply time in different dimensions/ attributes of time such as the ascendant, accelerating, the medium of exchange, time frame inter alia (Moran, 2015).

Southerton (2003) summarised time as a tool that can be used to organise an array of temporality functions; some of which are present, past, future, synchronisation, speed, delay and repetition among others. These functions of temporality, however, transcend different occasions and uses of time. Examining this temporality through appliance use was adopted and similar arguments occur in Richardson et al. (2010) as "time-correlated appliance use." If we are to understand the timing and scheduling of the practice of device use (and the implications for energy demand), we need to develop approaches to identifying and analysing sequential patterns (Mattioli et al., 2014) and rhythms of shared and individual practices that entail electricity demand.

In accordance with the arguments above, the following strands of the use of time use diaries can be investigated: duration, tempo, sequence, synchronicity, clusters, rhythm, and periodicity (Southerton, 2006, Michelson, 2015). These strands were employed in part and investigated in the organisation of the data. In Section 2.4, I inferred their application to this study.

The timing and temporality of performance of practices shape material arrangements. Material arrangements, as defined by Schatzki (2010), describe the nexus between agents and materials that enable the performance of practices. Arrangements enable the understanding of practices that entail energy demand because 'the arrangements amidst which practices are enacted are not only social: arrangements include substances of all kinds, including natural phenomena along with man-made fabrications' (Schatzki et al., 2001). Social practices are connected to and determinative of arrangements. Social practices are performed subject to temporality whereas material arrangements 'exist' (Schatzki, 2010). In other words, arrangements exist longer than any instance or moment enactment of practices. Arrangements, including energy only have meaning within, and in relation to, the practices in which they are performed, and through which they are reproduced (Shove et al., 2014).

Temporality can be described as rhythms characterised by the nexus that produces eurhythmia, polyrhythmia and arrhythmia (Nansen et al., 2009). Understanding the dynamics of energy demand and the variation which occurs is a matter of studying the ordering of social practices. This ordering of social practices I argue relies largely on how time is used and experienced. Domestic time can be perceived broadly to be of four kinds: necessary, contracted, committed and free time (Hellgren, 2014). This description of time incorporates how time is used and experienced and the flexibility therein. A more recent detailed explanation of the perception of time and time use can be found in Sullivan and Gershuny (2018). This study, however, did not investigate how they perceived each time slot but investigated how the households used their time in the context of the selected devices. This fed into the diary approach employed in this study as (shared) use of the selected devices was investigated. I applied time to the measurement and an account of the activities that were under study alongside time-slot referenced kWh meter readings.

2.4 Time use

Time use research attempts to provide a quantitative account of people's activities and practices, and they are typically recorded using electronic or paper diaries (Michelson, 2015). A time use diary exhibits a systematic approach to recording a set of activities within a population (Michelson, 2011). Time use refers to a summarised recording of how individuals spend and allocate their time typically over a twenty-four-hour period to a week (Nations, 2005). Within this twenty-four-hour period, the diary is typically broken down into a finer resolution such as 10 minutes as in the case of Richardson et al. (2010) and in this study, a relatively coarser resolution of about four hours (except for after 10 p.m. time slot). Analytically, clock time use falls into two broad categories: sequence and aggregated analytical approaches (Hellgren, 2014). The sequence approach can be characterised as focusing on timing, singling out activity as the unit of analysis, limited in the statistical methods that can be used and effective only in very small samples. The aggregated approach is attributed to be macro-orientated and largely assumes that clock time can be predicted, and activities can be isolated from their context. The main difference between the two lies in the focus which is timing for sequence approach and the length of time in the aggregate approach. Time "expenditures," or more precisely, the allocation of time varies across various classes of activity (Gershuny, 2011). Time use is widely studied and increasingly so more recently (Chatzitheochari, 2017). Time and household-related practices find a coherent conceptual and methodological space in time use research. Exceptions exist with qualitative analysis in Southerton (2006), in which the temporal rhythm for the day was characterised by practices, which hold a fixed position in time. At the same time, I argue that insufficient research exists in the critical analysis of time use within the context of domestic demand and explanation of its interplay across a spectrum of activities as well as its application in real-life energy demand gaps in knowledge and use characteristics. For example, tea time which has historically been associated with surges in demand during times of peak TV demand. The 2018 World Cup is a case in point where demand was expected to spike at times when England is playing as has been the case in previous world cups. This research attempted to fill the gap by applying time use to discerning the timing, intensity and synchronicity of demand as it relates to older people.

Time use in households can be characterised as "monochronic", "polychronic" and "dovetailing" (Kaufman-Scarborough, 2006). The "monochronic" household was characterised by Kaufman-Scarborough (2006) as having one major or primary activity at a time without interruption in the activity. This typology does not always apply to energy-relevant activities as households can pre-set or delay the use or performance of the activity. In other words, the ordering and sequences may be subject to change. An example is the recording of live TV to be watched later or programming the dishwasher to a predetermined time. The dovetail or cyclical time use was described by Kaufman-Scarborough (2006) as activities that can be broken down into smaller chunks and can be integrated with other activities in an often cyclical or repetitive manner. This type of time use characterises energy-relevant activities. For example, households can be watching TV while having dinner or washing dishes and doing the laundry at the same time.

The polychronic households have several activities going on at the same time with no rules as to when they take place or the sequence of the activities. I argue that households may not necessarily be one or the other. They may at different times, on different days or seasons/ occasions consume differently. This is because of the widely acknowledged variability of demand. Findings as indicated throughout Chapter 4 suggest that households may be fluid across these typologies over the course on a day or a week. I argue these classifications describe more of the nature of "activities" of a household at a point in time.

2.4.1 Time use research and energy demand

A question which researchers have been seeking to address for sometimes relates to what methods and data are best suited to measure the timing and temporality of residential electricity demand. Various models have been deployed, from stochastic predictions of appliance use to weather-related deterministic models. The most frequently collected data on domestic energy demand consists of the type of building, occupants' income, appliance ownership and the bill-related price of electricity (Swan and Ugursal, 2009, Suganthi and Samuel, 2012). Although, algorithms of loads may help predict demand, and they could also influence practices by the amendment of designs such as timers (Dlamini and Cromieres, 2012). They may be limited in application as they do not incorporate the myriad of appliances that have different times and hence the complexity of respondents. For example, several devices such as laptops, taps and TVs may be on all at the same time with some battery-powered and be plugged in during use. Also, the uses of algorithms impact the nature of analyses and agency of the practices. For example, algorithms based on data that was collected in a household with fluidity across activity levels would provide inconclusive or misleading demand profiles. Also, the uses of algorithms delegates agency of the practices to a software rather than the actors as these results are usually generalised to a population. Thus, I made the decision to collect first-hand kWh readings and device use timings from a select segment of consumers.

The above-mentioned variables are not able to explain intra-day load profiles as they do not reveal when people are at home and what they are doing at peak and off-peak times. The starting point of this thesis is that the timing of older single and two-person household activities played a vital role in explaining the timing of residential electricity demand (Torriti, 2017). This is in line with a recent inter-disciplinary research approach which consists of employing time use data (i.e. tracking residential users in and out of the household) like Higginson (2015); Palmer et al. (2013); and linking them to residential electricity demand based upon previous work by Wood and Newborough (2003); Firth et al. (2008) who distinguished between deterministic and stochastic timing of appliance use. These refer to the two ends of the spectrum of use characteristics. The deterministic use being completely predictable and the stochastic demand being unpredictable use.

Time use data has been used before in domestic energy demand modelling work in the UK e.g. Richardson et al. (2008); Richardson et al. (2010); Torriti et al. (2015)

France, Wilke et al. (2013), Spain, Santiago et al. (2014) and Sweden (Widén et al., 2009, Widén and Wäckelgård, 2010, Sandels et al., 2014). These studies largely rely on either time use diary data or using Markov chain models based upon a combination of primary and secondary time use data. Whilst Markov chains have proven effective at regenerating electricity load profiles for domestic dwellings, the temporal distribution of load profiles at peak time needs to be addressed further (Torriti, 2014). In designing the analytical framework of this thesis (see Chapter 3), I take this into account by combining meter readings with time use data I derived from appliance-use diaries.

Time use research can be described as a "systematic pursuit" that entails the recording of people's activities over a specified period (Michelson, 2015). In the context of energy demand, a time use approach entails the adoption of the notion of energy intensity using time as a denominator to establish comparisons in daily life (Jalas and Juntunen, 2015). They explained the attributes of time use research to include the understanding of private consumption vis-à-vis the active use of goods and services thereby highlighting "equality". When acknowledging equality, households can be expected to perform the same sets of practices despite a significant difference in the household income and cost of the device (Jalas and Juntunen, 2015). Although, this study did not observe poverty or wealth per se, it was pertinent to mention that somewhat ubiquitous devices were chosen for "equality" of participation. For example, the cost of a TV ranges widely, yet nearly all the households could potentially partake in the practice of watching

TV. In this study, I adopted the time use approach by examining the active use of appliances. Worthy of note is that I assumed "equality" among this study's cohort.

This work also assumed that the external temperature has an indirect and minimal effect on time use among older people with respect to the devices under focus. HVAC use, devices and households that use electric heating were excluded in this study. Other drivers such as the potential country-specific nature of load profiles and source of heating that have been investigated as major influencers of the intensity of demand were assumed as being minimal in effect. Although, countries like France which has a higher proportion of electric heating compared with the UK which has a higher proportion of gas heating indicated similar intensities of demand though spread out (Pilli-Sihvola et al., 2010, Hahn et al., 2009). This study also assumes that the week data was collected is representative of their daily rhythm and timing of their demand practices *ceteris paribus*. An overview of the time use as an approach was extensively explained in Southerton (2009); Hellgren (2014). Some of the weaknesses with this approach highlighted in Hellgren (2014) include insufficient emphasis on the sequence and rhythm of activities, which does not effectively highlight the constraints the individuals are subjected to. Other limitations of time use approach include reliability of the diary samples, recording and coding of the activities and accounting for multiple experiences of time (Southerton, 2009). The relations between the context and the activity and the order of activities and the time they occurred were also highlighted as a limitation of the approach. This refers to the multiplicity of how time is experienced by the households which can be subject to change over the period of data collection. One of the limitations that specifically apply to this study is the aggregated approach which lacks granularity to highlight how sparse or otherwise, the activities were within the time slot.

Much of the literature on electricity consumption focuses on appliance use. Appliance use is about 14% of domestic demand (DECC, 2012). The practices at home involving, for example, computing devices can be described as "encroaching on home time" (Hampton, 2017). Energy consumption is the result of these "practices" (Warde, 2005). This research investigates practices that relate to electricity demand to create a "snapshot."

2.4.2 Time use and practices

Temporal structures are intrinsic to all work (Fine, 1990). The temporal structure applicable to time use study is such that "no day is average, but I can speak of an average day" (Moran, 2015). Temporality and enactment of practices can be described as "recursive" (Southerton, 2013). In other words, they rely on each other to exist. These enactments of practices can also be characterised as not being a "zero-sum game" (Kenyon, 2008, Kaufman-Scarborough, 2006). In other words, practices are not mutually exclusive in households as multitasking occurs. Some practices are connected and rely on each other (Blue et al., 2016), and the relationships between practices are not fixed (Powells, 2014), Examining multi-tasking is, however, out of the scope of this study.

However, the (dis)use of devices are not only of interest to practice theorists but also of interest to demand-side administrators. They can be summarised to include peak clipping, valley filling, load shifting, strategic conservation, strategic load growth and flexible load shape (Zhou and Yang, 2016). They are intended to reduce the cost to the producers, consumers and the environment as load is shifted off-peak (cheaper times) and reduces the need for backup generators.

Examining the extent to which the uses of a selection of appliances and total electricity demand at home are shaped by the ordering of practices is important to achieving the above aspirations of demand-side administrators. In the context of households collectively, this represents a great opportunity to understand the collective orientation of the cohort towards time. A similar approach was adopted by Kaufman-Scarborough (2006) where they investigated the time-space nexus with regards to appliance use and office-related work using in-part "temporal regimes" (Geels, 2005). I argue that practices and timing of the enactment of domestic practices, which are largely constrained or enabled by the characteristics of the households are vital to understanding and managing domestic demand as in the Dutch example in Kobus et al. (2015) where they explained that even when almost complete automation occurred, the households still needed to change their practices for them to use some appliances differently. This raises the question of agency of practices that entail electricity demand in automated homes. In this study, I mainly focused upon the characteristics of being older (over the age of 65) and whether they lived alone or with one other person to investigate their load and device use profiles.

2.4.3 Variation in time use and practices

Demand variations at different levels of resolution are well documented throughout the time use literature. Very little is known about how energy is used and how it varies in daily life (Anable et al., 2014). Practices can be characterised as having varying degrees of enactment, temporality and context (Powells, 2014). Powells (2014) further explained that these contexts were defined by rhythm constraints, convention constraints and economies constraints. The rhythm or "coupling" constraints refer to the different rhythm qualities associated with the enactment of the practices such as polyrhythms for example (Lefebvre, 2004, Powells, 2014). Convention constraints relate to "improvisational" attributes of the performance of practices. In other words, the flexibility of the practices. Afternoon tea or an evening meal with(out) others are examples. Economies constraints are associated with households' dispositions towards and management of social, natural and financial resources which in turn influence their pattern of enactment of practices. They argued that energy use is not a 'choice' but rather a "consequence" of courses of action (Powells, 2014), watching TV, for example.

I did not investigate the "constraints" but I investigated largely two practices that involve ICT and TV use in the diaries which Powells (2014) characterised as having mass participation during peak times. ICT and other audio-visual devices have been identified as the most common secondary activities (Topouzi et al., 2016). The choice of ICT provides an insight into an aspect of peak demand, which is of concern to all stakeholders. The use of ICT also provides a deeper understanding into the energy-relevant patterns of practices as they not only participate in peak demand but also are “common” secondary activities. The timing of their use is critical because they are varied in characteristics. The most significant of which I argue is that their (shared) use does not always coincide with meter readings because they can be charged independent of use. This informed the use of both the diaries and the meters as either would not fully capture the (shared) enactment of the selected practices (Topouzi et al., 2016). This study investigated the variation that occurred diurnally and across one week, which encompasses weekday, weekends. “Special days” such as bank holidays were excluded.

2.4.4 Weekday, weekends and unusual days timing and temporality

What constitutes a weekday or weekend is socially and contextually defined (Zerubavel, 1989, Michelson, 2015). This implies that what or when a weekend is subjective and situational. At the societal or national level, for example, in some countries like Saudi Arabia, Friday through Saturday are “weekends” and some others like the UK observe Saturday and Sunday as weekends. At the individual or household level, peculiar work commitments like shift work or flexible working schedules may result in work-free weekdays (Monday through Friday) and or weekends (Saturday and Sunday). In other words, distinct demand is subject to the specific societal constraints (such as work or school) the household is subjected to (Blue et al., 2016, Powells, 2014). The weekend can be described as a social institution embedded in everyday life with attributes of structuring time and space (Walton and Ebrey, 2014). Households are expected to have more time to engage in activities that are reserved for when their social circle has synchronised availability. This time is spent alone or in the company of others

(Powells, 2014). The “weekend” is a distinct way in how time is produced or spent and how time is valued which is distinct from the other days of the week (Walton and Ebrey, 2014, ås, 1978). The “weekend” is also implied in load profiles (Sandels et al., 2014). Several studies distinguish between weekend vis-à-vis weekday time use activities as it is implied that this is vital to describe synchronicity across the week (Browning, 2012). These notwithstanding, a day can be characterised by morning and evening peaks in demand with variations across households (Torriti, 2012, Yohanis et al., 2008).

More recently, an analysis of the 2014/2015 UK time-use by Anderson (2017a); Anderson (2017b) indicated a significant distinction between the infrequent performance of practices such as laundry and ironing. Practices like cooking, which he observed followed a constant pattern through the week. His analysis also suggested a clear distinction in the level of activities between Monday-Friday being generally higher than Saturday and Sunday during peak times (16:00-20:00).

Five strands of loads were identified in the synthetic load profile model by Fischer et al. (2015). Two of the strands were the distinction of the days during the week, noting that Saturday and Sunday were distinct from each other. The second strand they indicated was the influence of meteorological (weather) seasons. They also divided the “drivers” for domestic consumption into two: thermal energy needs and daily activity needs. Similar arguments can be found in Taylor (2010) where they observed that the UK demand profile consisted of five cycles of demand: Friday, Saturday, Sunday and Monday while Tuesday to Thursday had similar intra-day cycles.

The load pattern is most importantly determined by the day of the week (Hippert et al., 2001). They also suggested weekday/weekend dichotomy. I argue that the principle of the demand being influenced by the day of the week is premised on the working life (Torriti et al., 2015). For example, if the household is not in full employment or in flexible working arrangements, the day of the week provides less structure to the day. The rhythm of enactment of practices is also influenced by this. In other words, a Monday or Thursday, for example, have comparatively less meaning (in terms of constraints of activities they can engage in) to retired, shift-work, unemployed, flexible working and part-time working households. Households can decide to do all their weekly energy-relevant chores on these days in addition to the existing competition between all other practices for their time. This study did not investigate what each day of the week means in general or in the context of time budget. I recommend this for further studies to give a deeper explanation as to why, when and how demand occurs for retired and other non-full-time working households.

In another account by Anderson and Newing (2015), there was greater differentiation in the weekday than on the weekend demand among the groups they observed. In other words, there was "temporal differentiation" (Anderson and Newing, 2015). This temporal differentiation could be because of a myriad of factors which I argue could benefit from further studies as to the question of "why" the demand volume and intensity variation occurred less on weekends in their sample or similar samples. A question that would be worthy of investigating in their study is “did they have similar time budgets?” In the case with this study, when talking about synchronisation, I was looking ‘vertically’ at the data. For a given moment in time, I was basically asking about the variety of practices in which people are engaged that I observed. In other words, “what is the variation of occurrence and intensity?” These arrangements of variations were explained by Mattioli et al. (2014) as having distinctive features both of timing and duration.

As a result of the expected changes in the demand and household characteristics and the increasingly peculiar time budget constraints, I argue against the labelling and generalisation of a day of the week as a “weekend” or “weekday” demand. These labels intuitively assume the working life which may (not) apply to households. With the extension of the state pension age and the changing nature of work, education and societal norms and constraints, I allude that a “weekend” can occur when the time budget of the household permits and not on any predetermined day. Results in Chapter 4 and the discussions in Chapter 5 elaborate on this.

I argue that there is an insufficient empirical basis for the weekday/ weekend generalisation or descriptions in time use studies for the following three reasons. First, I argue that most-recent time-use studies do not collect data from one participant for at least a week. This does not allow for a weekly pattern (if any) to be established per household. Hence, there is limited primary data to support the weekend descriptions of energy demand. These weekend characterisations are well documented throughout the literature despite widely acknowledged inter-day variations often within the same study. The widely used random selection of days for data collection and analysis per household does not allow inferring any routine and or repetition in the rhythms of social practices by the households. However, 7-day results from exceptions like McLoughlin et al. (2013), suggested that the days were distinct and no discernible weekday-weekend dichotomy of variation.

Second, variations (the ordering and sequence) during the week are difficult to assume and generalise because mixed and contrasting findings occur (Browning, 2012). Browning (2012) suggests that less distinction was based on the day of the week and Richardson et al. (2010) indicated otherwise. What (older) people do and how their day is ordered can be closely aligned with the day of the week Hippert et al. (2001) and the peculiar constraints associated with each day for the household.

Third, characteristic of the household is a well-documented explanatory variable for time use, and energy demands pattern. Yet very few studies like Krantz-Kent (2009) have focused on different typologies and demographics of households to establish how, what and timing of demand vis-à-vis the weekday/ weekend characterisation of demand.

This thesis attempts at highlighting the variability of energy-relevant practices both intra-day, as observed by most time use studies, and inter-day for one week. This investigation is relevant for the following reasons: the intra-day comparison was used to establish peaks of demand and demand intensity, which contributes to the body of evidence for the investigation of these two aspects of demand across the UK population.

The inter-day demand contributes to the body of literature such as Hahn et al. (2009); Pilli-Sihvola et al. (2010) that explain the variability of demand and by inference, the demand intensity across different days during the week. The inter-household variability is widely studied in the literature Palmer et al. (2013), but this study takes it a step further to highlight the variability within the same household intra-day and inter-day. This study also compares within and across two household types (two-person and single older households). The results are detailed in the Findings Chapter (Chapter 4).

From the above-mentioned, I argue that the "weekend" is perhaps synonymous with unusual demand within the context of the week and has less to do with the day during the week itself as practices compete for temporal location daily. An unusual day within the context of this study is the day the maximum inter-day index was reached. I investigated the time use for a week, hence I established the variations that were peculiar to each day during the week.

2.4.5 Temporality

In the context of coordinating, scheduling and managing time, a rhythm can be described as an "unfolding" that entails the nexus between discipline and harmony (Nansen et al., 2009). It can also be described as a resultant effect of ordering our day into routines Highmore (2004) and a subset of and comprised of "multiple temporalities" (Bell et al., 2015). It is one of the attributes of temporality (Lee, 1999). A rhythm is an attribute of time, and time has multiple rhythms (Shove et al., 2009). In everyday life, rhythms are an exhibition of tensions that exist in the "juggle" of daily practices and the peculiar circumstance which I argue fits into the wider sociocultural context and not the technology in isolation as explained in Ozaki and Shaw (2014). In the context of energy use, it can be expressed as a measure. That is, the "interaction" between energy use, place and time (Lefebvre, 2004). Rhythms can also be characterised as eurhythmia, arrhythmia or polyrhythmia (Lefebvre, 2004). These rhythms can be interconnected as a result of the practices that they originate from (Blue et al., 2016). Lefebvre (2004) explained eurythmia as harmonious rhythm embodied in one system. For example, in a household, different rhythms of activities are in concert to enact the practice of cooking. He described isorythmia to mean the equality and the coincidence of rhythms. For example, a household may choose to enact the practice of cooking and watching TV at the same time. Arythmia is a "pathological" situation when rhythms go awry. In this study, I investigated polyrhythmia as this characterises everyday life as explained in Lefebvre (2004) as having diverse combination of rhythms. The diversity of rhythms cumulatively results in varied synchronicity and intensity of activities and demand.

Rhythms and routines co-exist and are interdependent, not "rival" (Shove et al., 2009). Routines are associated with repetitiveness (Schatzki, 1996) which can be explained through rhythms (Lefebvre, 2004). Social practices vary not only from one location to the next, but also in timing and temporality(Lefebvre, 2004). Much of the literature acknowledges the role of time in ordering practices when measuring rhythms. Furthermore, the potential for creating dependence on the measurements of time, which may not be defined in nature, but are processed by the space and time in which practices are performed is acknowledged. Walker (2014) described rhythms as the "dynamics of repetition and beat" and explained that energy demand had rhythms that occur at different time scales. He went on to identify "energy rhythms" for the day, the week and the season. This suggests a time frame for rhythms.

Routines, rhythms and synchronicity are subject to different levels of flexibility of shifting. These variations refer to the activities that occur during the cyclical repetition (day and weekly cycles) and linear repetition that result from practices (Lefebvre, 2004). Activities have been characterised as "taking time" and having a duration (Ellegård and Cooper, 2004). In this study, I investigated only the (shared) performance within the time slots and not the exact duration of performance on the activity.

Synchronisation can be described as the mastering of a set of temporal routines (Fine, 1990) which can connect activities that are not in the same sequence (Jalas and Rinkinen, 2016). It can also relate to the overlapping of different sequences (Nansen et al., 2009). I understand synchronicity as it relates to coordination of temporal demands, which explains the relationship between rhythms Friis and Haunstrup (2016) and the overlapping of the doings. The "coordination of practices" around certain times during the day can be attributed to contribute to peak demand (Hui et al., 2017). Households have their peculiarity as it relates to practices that consume energy. The feature of synchronised use within households has been widely investigated and fully explained in Sullivan (1996);

Connelly and Kimmel (2009); Browning (2012); Powells (2014) as being actively present within two-person households. This study, however, takes synchronicity a step further by examining inter-household synchronicity between two-person and single households. It enables this study to highlight the coming together of practices that relate to the consumption of electricity. I explain in detail in Section 3.4 how the above was operationalised.

Previous attempts to describe the timing of energy demand in relation to social practices have focused on issues of synchronicity of practices, sequencing and (lack of) flexibility (Walker, 2014, Shove et al., 2014). Electricity load profiles are the result of an infrastructure that simultaneously services those multiple 'doings'. Social practices have characteristics, which define the way energy demand is consumed (Shove et al., 2015). They are habitual, synchronised, varied, sequenced and contingent (Walker, 2014).

Synchronisation is the shared timing of same or similar activities regardless of the space while synchorisation refers to different activities performed in the same space (Kärrholm, 2009). A space he characterised as being associated with, affected and defined by territoriality Kärrholm (2007) in the case of this study, a residential address. Peak residential electricity demand is the outcome of many energy-intensive practices happening at the same time (Friis and Haunstrup, 2016). Similar phenomena of "coming together of practices" or "shared pulse" at different times during the day were observed in the UK Powells (2014) and Ireland (McLoughlin et al., 2013). Societies are made up of overlapping rhythms Powells (2014) of practices, which can be interconnected (Blue et al., 2016). For example, food preparation can overlap with family time. The nature of practices that entail electricity demand for appliances is such that it tends to follow reoccurring patterns, which included weekly and daily patterns (De Silva et al., 2011).

Demand is more unpredictable when the respondents do not live with children (Torriti and Hanna, 2014) although that study excluded over 65s. This suggests that the presence of children implies a coordination of the ordering of practices that entail electricity demand. The most important feature of the load profile is the "daily load factor" which was defined by McLoughlin et al. (2013) as the "measure of the "peakyness" of the load profile of the customer." The following factors should be considered for the effective characterization of load profiles: intra-day, daily, variations between consumers and the seasonal effect on demand (McLoughlin et al., 2013). In the context of this study, I argue that the intra-day and daily demand are sufficient to characterise the load profiles in the context of energy demand related practice research. This is why HVAC was excluded which Taylor and Buizza (2003); Yao and Steemers (2005) associated to the seasonal variation in demand. Second, practices that entail electricity demand are enacted at different time scales such as daily, weekly, monthly and annual cycles of which annual and monthly cycles are outside the scope of this study. In addition, variation in enacting practices between consumers is expected as no two households are exactly alike in the attributes of use and or users. Furthermore, meter readings can be unusually high if, for example, a household has inefficient lighting or uses electric heating and has poor or inefficient insulation. In these cases, load profiles alone do not characterise the practices that entail electricity demand per se as readings are affected by leaking energy. In this study, households with electric heating were excluded, but I did not exclude households based on the efficiency of their lighting and or heating. These instances of inefficient lighting, etc also make a case for a departure from the complete reliance on load profiles when examining practices that entail electricity demand as the load profiles (kWh meter readings and the demand intensity) become unreliable. This study employed a two-pronged approach examining their load profiles and use diaries to reflect their demand and to partly describe their time use when interacting with the selected devices.

Devices and their peculiarities play into the timing of demand in different ways (Mattioli et al., 2014). The ways in which they do this include the modification of the relation between space, time and energy demand. Although, Mattioli et al. (2014) described technology as not being 'innocent' as they are themselves integral to the conduct of specific practices (Shove et al., 2015). Furthermore, battery-powered devices and other devices like recorders for TV programmes can contribute to the rhythm, sequence and ordering of practices that entail electricity demand. For example, TV programs can be watched on varied devices thus stretching the relationship between time, space and the electricity demand. It also affects the "routine" practices in the case of recording live weekly programming. The routine here is altered with the aid of technology. Other energy-relevant doings such as "binge watching" can occur: a situation where a user decides to watch TV or any other audio-visual device for prolonged hours at a time instead of the shorter span of time for each session or an episode of a program. The technologies of recording live TV and streaming TV enables the emergence of this practice. With these in mind, the pendulum shifts back to the user who would increasingly have access to these technologies thus emphasising the need to investigate the timing and intensity of demand.

Energy intensity is the amount of electricity per unit of output of electricity consumed (Kwon et al., 2016). Energy intensity is an index utilised to determine the energy efficiency (Feng et al., 2009). In the context of practices, Topouzi et al. (2016) highlighted that some activities were less “electrically intensive” than other activities that occurred at the same time. There, they seemed to equate kWh readings with intensity of demand. I express intensity as an index (ratio) of the highest timeslot kWh meter reading and the kWh meter reading for the time slot of interest in the day or the week (intra-day and inter-day index/ intensity respectively). I detail this in Chapter 3. The notion of the intensity of demand explains the variation between households with similar use patterns (Jalas and Juntunen, 2015). I also utilise indexed intensity of demand to compare households’ kWh meter readings. The comparison of the intensities of demand enables me to contextually compare households and investigate if energy-relevant practices across time slots synchronised (see Chapter 4). I investigate varying load profiles. Loads can be summarised into short, medium and long-term loads (Hahn et al., 2009). The short-term being intra-day demand, the medium term being demand for a week or one year and long-term being demand profiles exceeding one year. The short and medium-term load profiles were investigated in this research.

In this study, I investigate “unusual” time slots during the day across the week when loads were at the maximum intensity of demand, and the activities had the highest synchronicity of demand. Michelson (2015) referred to it as defining the "nature and extent of human activity." I explore how older people spent their energy-relevant time within a week. In summary, I adopted in part "social synchronisation" Walker (2014) of some practices at home such as TV watching, laptop use among others with details on the relationship between the rhythms of these households in terms of their intensity of demand, and the synchronisation of use was explored. These set of devices were also characterised by Nansen et al. (2009) as shaping rhythms that constitute daily life.

2.5 Social practice theory in the context of energy demand

A practice can be referred to as a "concrete human activity" Schatzki (1996) which encapsulates doings, understandings and the ideologies that surround the activity in question (Schatzki et al., 2001). In other words, practices are associated with "doing" Barnes and Schatzki (2001) and "knowing" (Baynham, 1995). Fuglsang and Eide (2013) interpret practices as the topos (nexus) between knowing and doings. It is the practices that structure the enactment within the circumstances as the agent (Southerton, 2013). Shove et al. (2014) observed that understanding patterns in energy demand are associated with the understanding how social practices develop, change and interact. They also indicate that practices determine present and future trends of energy use. Energy demand is an interaction between users and appliances (Wall and Crosbie, 2009). How this "interaction" occurs manifests in practices, but for this interaction to occur in the first instance, ownership (Foulds et al., 2016), functionality, utility of the appliance inter alia all converge. This research investigated practices within the context bodily doings (Schatzki (1996); Schatzki (2010)) that are associated with selected appliances within a spatial context (at home) over a week. Thus, it is an investigation into "what" (older) people do in terms of specific practices. In other words, I focused on the "performance" and (doings) Gram-Hanssen (2009) not the "practice as entity" Schatzki (1996); Heisserer and Rau (2015) which can be interconnected (Reckwitz, 2002, Blue et al., 2016). Consequently, the view of practices of this research is "practice as performance" (Browne et al., 2013). That is: what people do (using the selected devices) and how they perform the practice (when and whether the performance is shared).

Practices have been utilised in classic studies like Bourdieu (1977), and the aforementioned contemporary social practice studies all identified practices as a meaningful way to investigate and explain complex events without bias to agency or social construct. Wills et al. (2016) suggests that contemporary interpretations of the theories of practice have three cardinal points: the people, the things and the meaning the people attribute to the doings. Practice theory they proposes as a middle ground between these cardinal points.

This "middle ground" can be described as a spider's web with many moving and stationary parts that link events, things, people and places (Wahlen and Laamanen, 2015, Wills et al., 2016). Despite the considerable research on social practices and practice theory (Schatzki (1996); Warde (2005); Schatzki (2010); Shove et al. (2012)) there is still ripe debate around what a practice is and what it is not. These notwithstanding, practices are attributed to have three key elements; materials, competence and meanings (Shove et al., 2012). A review by Trizzulla et al. (2016) characterised and summarised the study of practices as having three themes: dynamics of practices, understanding the tension between routine behaviour and reflexivity and the account for the materiality of consumption. Another review by Seidl and Whittington (2014) albeit it was focused on organisational studies categorised practice research ontologically into a spectrum of "flat" and "tall" where the width are "sayings" and "doings." A practice-based approach within the context of energy demand inevitably expresses the consequences of daily life on the "structural contours" of social life (Fuglsang and Eide, 2013). Practices can be interconnected (Blue et al., 2016).

This thesis adopts "practice-as-performance" Schatzki (1996) while investigating dispersed and integrated practices (Barnes and Schatzki, 2001). It also adopts the interpretation of the study of practices as the investigation of "how" doings occurs (Fuglsang and Eide, 2013), hence the investigation of patterns of use. Fuglsang and Eide (2013) described dispersed practices as being characterised by being linked by an understanding or rule that the practices express. For example, dispersed practices include the turning off and on of devices. In the case of this study, the households were asked to report their (shared) use of selected devices. Integrated practices refer to how and when they use the selected devices. It is noteworthy for mention that Schatzki (1996) reiterates that this conceptualisation does not claim completeness but only provides a platform for the investigation of the enactment of practices. I operationalised Schatzki's approach for this work by the investigation of "doings" as a subset of everyday practice within the context of electricity demand. I adopted "practice-as-performance" as the best fit for the nature of the study as I investigated the rhythms of everyday life in the context of energy demand. I investigated within the boundaries of what Schatzki (1996) and Hampton (2017) characterised as "dispersed practices" such as inactive appliance use and "integrated practices" such as cooking. kWh meter readings of the cohort were inclusive of active and passive (standby) demand which Gram-Hanssen (2009); De Almeida et al. (2011) identified as accounting for about 10% of total appliance demand. I, however, investigated the "recursive" nature of practices (Southerton, 2013). I investigated co-temporality and the practices that occurred and the intensity of demand that occurred at the different resolutions of temporality under study.

The collective doings of the cohort reflects the reality of their social context (Heisserer and Rau, 2015). It is interesting to mention that the "sayings" were excluded in this study based upon the premise highlighted in Frederiks et al. (2015); Southerton (2013) where they indicated that what people say they do is not very reliable in the context of energy demand. Vringer et al. (2007) also observed a disparity between stated beliefs about the environment and climate and energy demand.

As observed from a critical investigation into the literature on social practices and practice theory in general, I argue that in the context of energy or electricity demand practices at home, the "doings" alone would suffice to understand practice. I make this argument because evidence already suggests that the "what people do" at home, which is significantly influenced by the characteristics of the household, is one of the major drivers of demand at home. The gap between what people do and what they say they do is well established in the literature (Jarzabkowski, 2004, Sarpong, 2011). This partly stemmed from the argument by Reckwitz (2002) that practice theory stems from cultural theory. Doings is therefore, central to operationalise practices in relation to the timing of energy demand. Doings documented via meters, for example, provide a less subjective proxy for the doings in the household. The patterning of social life is a consequence of routine, collective and conventional nature of consumption

(Reckwitz, 2002). From practice theory, the timing of energy demand can be defined as the result of the socio-temporal organisation of daily practices. Social practices have rhythms (Jalas, 2002, Southerton, 2006). Rhythms introduce the possibility of time-dependence in social practice ordering (Pantzar, 2010).

Both conceptual and methodological challenges in part explain why quantitative assessments of social practices have seldom been operationalized in empirical research. For instance, practices are never identical even if the same activities are repeated. The ordering, urgency, context, etc all contribute to make every experience of watching TV, for example, unique. For example, watching a TV program alone for the first time may result in a different experience from the second time with others. An exception is in the qualitative analysis presented by Southerton (2006), in which the temporal rhythm for the day is characterised by practices, which hold a fixed position in time. A conceptual challenge such as the extensive "a-theoretical cataloguing" (Nicolini, 2012) refers to the explanation and description of the doings largely leaving out the "so what" of the theorisation of practices. Nicolini (2012) also highlighted that more needs to be done to adopt a practice-based ontology and analyses should be premised on this. I in addition contend that if the "what" of practices is yet to be widely unified, the "how" of the methods (the challenge of establishing the best method persists). For example, the often-overlapping understandings of a behaviour and a practice enhances the challenges of what the unit of analyses is or should be.

In the realm of social practice, time use has been identified as a reliable proxy indicating spatiotemporal activities (Warde et al., 2007). Walker (2014) explained that patterns of time use and social practices are interlocked. This thesis focuses on the intensity of demand and synchronicity of demand, which are all resultant effects of “doings.”

In recent times, there have been significant studies (Anable et al. (2014); Anderson and Lin (2015); Torriti et al. (2015)) on (domestic) practices, electricity demand, rhythms, self-reported appliance use, the intensity of demand and synchronicity of demand individually and some studies combining a few of these attributes of the doings together. However, research is yet to operationalise practices related to electricity demand for specific demographic groups. Energy-relevant practices also affect peak demand, the potential for demand shifting, nudging and other demand-side management strategies that are currently in place or to be implemented via policy. This argument was echoed in Jalas and Juntunen (2015). Policies relating to smart meters, (time of use) tariffs, device standards, financial support, advice and information, fair treatment and planning have not fully harnessed the benefits of the practices of older people. For example, smart metering provides information for the users on their kWh demand but does very little in telling them how they can use this information. Furthermore, policy makers assume that there would be a net conservation effect because of this knowledge. In other words, demand reduction, peak flattening among other policy intentions. The focus of policy may be more effective when targeted on specific practices having in mind their heterogeneity. For example, addressing TV use patterns within the context of the heterogeneity of its use. For policy intervention, I argue that specific empirical evidence of the practices that surround the use of devices is essential to facilitating appropriate policies that can be tailored towards temporality (time-focused), intensity of demand (kWh–focused) and time of use and peak demand pricing. They are time-focused when the devices have been identified as having highest synchronicity of use. Policies can be formulated to address the peaks and troughs that occur at identified time slots. For instance, incentivised flexibility around peak times. Policies can be kWh focused when the efficiency of the device can be improved from the manufacturers to reduce kWh demand and standby demand. For example, computer and audio-visual devices can be regulated to have shorter standby times. Policies can be price-focused for fewer frequently used and flexible appliance uses to encourage demand shifting to off-peak times for identified appliances. For example, laundry can be programmed to cheaper time slots, and incentives can be put in place to encourage consumers to own and use this feature on their washing machine. This study provides more empirical evidence about selected appliances that can be targeted in this regard.

The methodological design of this study allows for comparison between meter reading and the intensity of these readings in the context of a day or the week (intra and inter-household), hence shedding light on the relationship between social practices of the elderly and energy demand. The analysis of social practices for a specific socio-demographic group within practices remains debated (Galvin and Sunikka-Blank, 2016). Indeed, by choosing a finite category of people (i.e. the elderly), in this work, I recognise this tension between a Schatzkian view of social practices, which does not leave room for socioeconomic or indeed age-based causal influences on practices and energy use and a view which allows for socio-demographic distinctions (Galvin and Sunikka-Blank, 2016). For example, in Bourdieu people's habitus (i.e. their repertoire of skilful habits) was decisively shaped by their socioeconomic standing.

2.5.1 Practice (theory), behaviour or habits?

Despite the extensive literature on practices and practice theory, practices are often synonymised implicitly and otherwise with "behaviour" and or "habits." It boils down to the question of what practice is and what it is not. This conceptual debate is outside the scope of this study.

Having said these, the "routine" definition of practices Reckwitz (2002); Holtz (2014) *inter alia* is perhaps the origins of the interwoven understandings of practices that often imply practices are habits and or behaviours. I argue that behaviours and habits are an attribute of and not necessarily synonymous with practices. For example, the practice (routine) of watching TV can be accompanied with(out) the habits of recording live programming and or "binge-watching." The changes (in the practices of watching TV) that may entail as a result of these habits highlighted in this example highlights one of the weaknesses of practice theory in capturing the source of the change as explained in Hole (2014). In addition, in this hypothetical example above, changes can be caused by a myriad of potential causes like social interactions, roles and relationships, which practice theory does not effectively capture. Hole (2014) identified these as critical to the enactment of practices. I argue that they are also important and critical to a change in practices. For example, increased access and use of virtual and voice assistants can change how we switch lights on with bodily movements involving speech rather than fingers. Practices can also be characterised as being connected forming complex webs in such a way that they can "support" and "sustain" other practices (Blue et al., 2016).

The diversity and often divergent understanding of practice theory according to Disalvo et al. (2013) is not a shortcoming of the practice approach. These include epistemological (constructivist and positivist) and methodological (qualitative, quantitative and mixed) approaches. I argue otherwise because it often causes confusion for non-practice theorists and practice theory advocates as they have somewhat extensively philosophised the theory without any clean consensus. A classic example of this is highlighted in the somewhat contradictory explanation of practices as a communal and or individual concept (Pantzar, 2010). This refers to the widely adopted definition of a practice as a "nexus of doings and sayings" (Barnes and Schatzki (2001); Cetina et al. (2005)) and practices being shaped and dictated by cultural meanings (Reckwitz, 2002). I understand these as implying that practices are either one or the other and may be both. This suggests an overlapping meaning. A potential contradiction occurs in Hole (2014) where the author highlighted that "many theories within sociology are not behavioural at all" and then explains that social practice theory is an example of this departure by "adopting a more socially-oriented approach to environmental behaviour…" and also identifying social practice theory as a "popular way of theorizing environmental behaviours." Similar interwoven definitions exist in Holtz (2014) where the author referred to social practice as "an approach to understanding consumption” and at the same time referring to practices as behaviours. Ellsworth-Krebs (2017) suggests that defining practices as “what individuals do” is a potential origin for the equation of practices and behaviours. Whether practices are or can be synonymised with behaviours in the context of energy demand depends on the ontology of the researcher. Both “sides” use similar methodologies and epistemology. In the context of energy demand, the results and empirical evidence that emanate from a behaviour or practice approaches are similar. Although, Ellsworth-Krebs (2017) summarised, to the contrary, that social practice and behavioural approaches contrast with different research objectives and methods. She argued that behavioural approaches have more policy-relevance, which is a critique of the practice approach. These contrasting perspectives potentially have an impact on the structure of energy demand research.

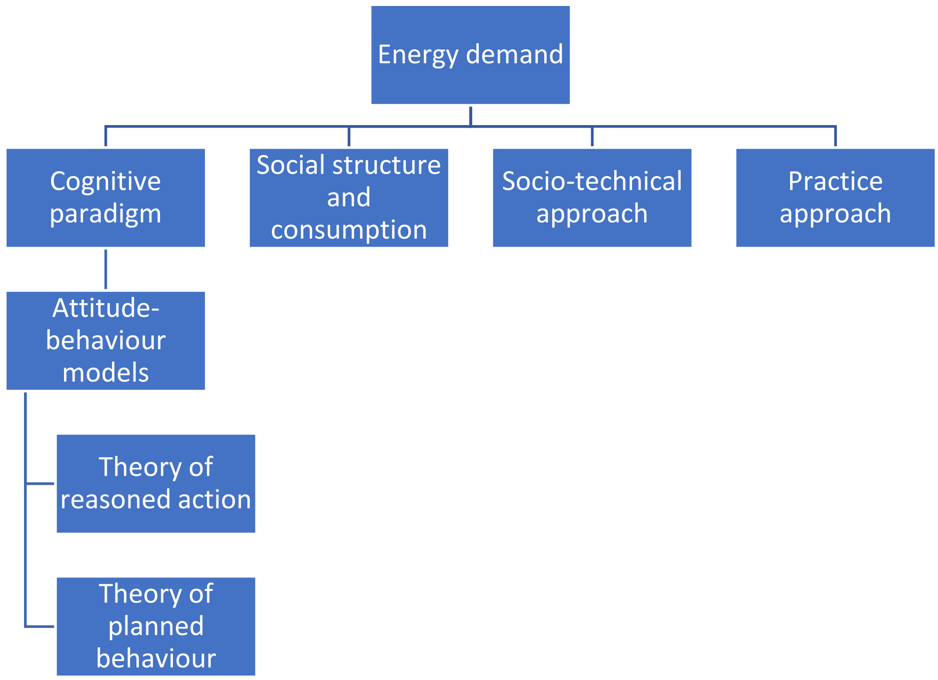

FIGURE 2.2 STRUCTURE OF ENERGY DEMAND RESEARCH

Source: (Roberts, 2016)

The categorisation by (Roberts, 2016) in Figure 2.1 above seemed to suggest a clear distinction between the practice and the behavioural approach which was synonymised by (Reckwitz, 2002). What behaviours are in the context of energy demand practices had also alluded to as doings. At the same time, interpretations or the results of such as behaviours such as activism, private-sphere behaviours among others (Stern, 2000) are doings. As it stands, the use of practice theory implicitly utilises some elements of the above-mentioned approaches. Perhaps, that is what makes practice theory unique and is widely acclaimed as a "middle ground" methodologically by focusing on action rather than the debate between wholism and individualism (Roberts, 2016) and theoretically through SCOT (social construction of technology), (material) cultures approach and examining the enactment and change of practices (Rief, 2012). Other sub-classifications of how energy demand research can be carried out exist in Lutzenhiser et al. (2012); Stephenson. et al. (2010); Gram-Hanssen (2009) such as social theory which entails explaining electricity demand using social constructs, organizational behaviour, socio-technical systems and the consumer's cultural and social peculiarities (Stephenson et al., 2010). Stephenson. et al. (2010) also identified social and environmental psychology. They explained it as encapsulating the impact of information, environmental attitudes, value-belief-norm characteristics, habits and external conditions that influence domestic demand (Lutzenhiser, 2007, Stephenson et al., 2010). Third, Stephenson. et al. (2010) identified technology adoption models. This entails diffusion theories, cognitive dissonance, theory of planned behaviour, self-efficacy and social communication. Lastly, Stephenson. et al. (2010) highlighted micro and behavioural economics as a tool for explaining electricity demand using bounded rationality, framing effects and decision heuristics. This perspective assumes rationality and sufficient knowledge of the consumer to make optimal decisions. This is intended to provide an indication of when consumers take the decision to consume (Chetty and Grinter, 2008).

Domestic electricity demand can be described loosely as an "interaction" between the users and appliances (Wall and Crosbie, 2009). This interaction becomes more visible when practices are translated into real-life policies and the applicability of the theory in solving problems such as energy demand. In other words, philosophical explanations have not made significant progress in empirical relevance (Warde, 2005, Hole, 2014, Ellsworth-Krebs, 2017). Disalvo et al. (2013);

Ellsworth-Krebs (2017) also expanded on the inadequacy of the practice theory in explaining the future as it relies entirely on the present and the past enactment which can be misleading as practice theorists have highlighted the death of the old and the emergence of new practices. In addition to this, practice theory was identified as being limited in examining of the inevitable change in enactment of practices.

It is noteworthy to mention that in the context of energy studies, not all energy-relevant practices have the same pattern or frequency (cold and hot spots) (Southerton, 2013) which Practice Theory does not effectively capture in its explanation (Hole, 2014). Although outside the scope of this study, Hole (2014) indicated the importance of each device in the context of the relationships in the households and the role, each device varies which practice theory is limited in explaining.

2.5.2 Situating practice theory in domestic electricity demand

The performance of practices can often coincide with energy demand (Friis and Haunstrup, 2016). A review of energy studies by Cayla and Maïzi (2015) stated that explanatory variables such as the number of occupants and the occupancy patterns are usually insufficient in explaining the variation in demand across households. I adopted practices of the households as the unit of investigation for this study's cohort. This use was based on the premise that there are no "average consumers" and the inter-household variation in demand has been widely attributable to the use that occurs (Brown et al., 2017), or, in other words, to "what people do." This variation has been widely observed to be consistent in energy research in recent times (Bell et al., 2015). The ontological investigation of practice theory suggests that both the practices, and their enactment are "iterative" (Lindahl and Folkesson, 2012). Practice theories have been summarised as being aimed at "flattening the relationship between scientific and common-sense knowledge" (Nolas, 2014). I partly adopted the Shatzkian approach to practices by examining what people do.

Some researchers Shove and Walker (2010); Mattioli et al. (2014); Higginson (2015) conceptualised the relationship between social practices and energy demand. This thesis focuses solely on "practices as performances" as detailed in (Schatzki, 1996). This approach was adopted to establish the relationship between households' doings and electricity demand (intensity). Energy demand has been described as "pervasive" and "entangled" in the enactment of practices by Ozaki and Shaw (2014) who also noted that the inherent characteristics of sustainable technologies affect how everyday practices are enacted. An example of this is the existence of programmable washing machines. The use of this implies that the practice of washing can be done at any time and without the active occupancy or engagement by the user as at the time the washing machine runs.

The invisibility of electricity demand is widely acknowledged (Ellegård and Palm, 2011, Naus, 2016). I argue that a practice approach reduces the invisibility of electricity use as it highlights the "doings" that are responsible for the kWh readings. Aune et al. (2016) argued that everyday life routines are slow to change as they are embedded with comfort and convenience. Thus, I expect that the performance of the practices by this study's cohort over the course of one week represents their everyday life within the temporal frame of one week. Domestic electricity consumption is involved in the operation of the majority of appliances in the home (Wood and Newborough, 2003, Chatzitheochari, 2017). These operation patterns are a direct result of the routines of the households.

From the above, I argue that what people do has changed over longer temporal frames of which is beyond the scope of this study (Pantzar, 2010). For instance, ONS (2014) showed that online shopping by over 65s rose by about 400% between 2006 and 2014. These changes in device use practices have a direct impact on meter readings. Based on ONS (2014), I expect computer use to increase for specific activities such as shopping by older people. This is a gradually evolving practice that affects load profiles. As explained earlier, in this study, I investigated patterns of loads and demand intensity and appliance use that occurred over a week.

Three examples show the dynamics and difficulties of relating practices to residential electricity demand. First, domestic loads have grown in recent years. The most significant in the last decade has been in ICT which this study partly investigated. Røpke and Christensen (2012) projected a 250% growth by 2030 globally although Trust (2011) suggests growth figures were overestimated. Other emerging technologies such as the electrification of cars set a clear trend for a rise in domestic electricity consumption. For example, in India, recent policy direction towards banning petrol cars in favour of hybrid and electric cars and car manufacturers complying indicates a clear upward trend. In France and other European countries, government vehicle policy and car manufacturers indicate a stronger presence of electric cars in the very near future. Also, in the UK, favourable taxations such as potential lower or zero-emission taxes payable are gradually becoming a more prominent unique selling point for new cars by manufacturers. The impact of the electrification of cars is beyond the scope of this study.

Second, devices are increasingly multifunctional, and multitasking can occur during use. These make it imperative and more difficult to identify the specific activity that is carried out when an appliance is turned on. For example, a television can now access radio stations in addition to other multifunctional features appliances now generally possess. These specific activities can give an insight into the potential trend for appliance use. The observation of this specific practice is beyond the scope of this research.

Third, types of load profiles are usually linked to time-space and especially the calendar week. Gottwalt et al. (2011) identified 3 load profile types: weekday, Saturday and Sunday which result in unique demand rhythms. Their findings may differ when considering the specificities of different household typologies, such as the growing proportion of solo living and a growing number of single and two-person older households. Other factors such as flexible working, weekend work and working from home (which has a rising trajectory) alters the previously estimated demand rhythms.

Chapter 3 : Methodology

3.0 Chapter summary

In this Chapter, I explain the research design equipment and procedures used and the rationale behind them. Research techniques and strategies were highlighted in addition to show how the research evolved to the current theoretical lens of practices, and the methods adopted. I discuss the household selection criteria, and the lessons learned. In Section 3.1, the introduction to the Chapter, I address the rationale for the overall research approach. In Section 3.2, I explain the research methods, in Section 3.3 the key metrics that emanated from the methods was explained and finally in 3.4, I explained the sample and the sampling techniques adopted.

3.1 Introduction

Energy demand studies may adopt a wide range of methods appropriate for the aim and objectives of respective studies. This means that qualitative, quantitative and mixed method approaches can be applied to the study of households' energy behaviours and practices. This study was based on an innovative mixed method approach to capturing both device use practices (using diaries) and electricity demand (using meters) of households. The conceptual framework of this study is based upon the following premises:

a. There is empirical evidence that household characteristics partly influence electricity demand characteristics.
b. There is limited empirical evidence on the demand characteristics of older people.
c. Available empirical evidence suggests that older people's occupancy, specific device uses such as TV and other ICT devices are distinct from other age groups.
d. Empirical evidence also suggests that the use of these devices contributes to peak demand.
e. This research helps to fill the gap in understanding elderly people's power use characteristics, including appliance choice, power intensity and timing thereby helping to complete the understanding of household energy practices across the age spectrum and the factors affecting the combined power demand profiles, including the peaks.

The cohort for this study has the following features: being older people who lived alone or with one other older person, who had gas heating and were not encumbered by significant health challenges that restricted their mobility and or occupancy. Other characteristic features of this study's cohort include: being a resident of Reading, being available within a week to fill-in the diaries and agreeing to participate without pay. Previous research has identified time slots where the frequency of use of the selected device was highest, which suggests a "coming together" (synchronicity) of energy use actions across the households. Therefore, this research combines practices at two levels of "zoom"; communally as a cohort and individually (household level). This research is designed to sit at the intersection of an ageing population and what (older) people do (by focusing upon the use of selected devices).

The rationale for selecting the method is consistent with the focus on "what people do." The methodological approach of this work is to understand what the older cohort did differently compared to other age groups as implied in the literature, (please refer to 2.2) and how this results in their specific demand patterns. I investigated electricity demand from a two-pronged approach: quantification of appliance use based on diaries and electricity demand using meter measurement.

The methodological approach benefits from the full potential of existing time use research methodologies. As I alluded to earlier, I identified the gap of either solely relying on diaries as was the case in Gershuny and O'Sullivan (2017) or relying solely on load profiles as in Wood and Newborough (2003). Neither fully capture the complexities of domestic practices and domestic energy demand. As I explained earlier, the instances of automated use, standby use and especially shared use collectively make reliance on only load profiles insufficient in explaining energy-relevant domestic practices. On the other hand, the enactment of practices alone as indicated in diaries do not contextualise the practices in terms of intensity of demand, which is indicative in the load profile characteristics of the household. My approach enabled me to identify when and which of the selected practices was performed and the extent to which they were performed across this study's cohort. These, I argue are vital to demand-side management, understanding peak demand and energy policy formulation to which this study intends to contribute.

Device selection

The rationale for the device selection was based on the literature that suggests ICT devices contribute to peak and standby demand (Palmer et al., 2013, Palmer and Cooper, 2013, Zimmermann et al., 2012). Furthermore, ICT devices are expected to grow in their contribution to peak and total demand Trust (2011) and little is known about their use by the older demographic group. This study sought to clarify in part, and or verify ICT contribution to peaks by capturing the timing and pattern of use by older people. Diaries were used at the device level for (shared) use and meter readings for the entire demand of the household. After the first two phases of this study, the diary approach became apparent as the most feasible and effective for comparability of ICT use across households' ICT use. (Refer to 3.4.2). As explained in 2.4 the "when" and "what" of demand are critical to understanding the practices of older people. The role of ICT was also explained in 1.1. There, I explained among other attributes that these devices strongly explained rhythms as, they “significantly organise routines” (Winocur, 2005). The representation of ICT in the routines of older households was reiterated in ONS (2003); Robinson and Caporaso (2009); Gershuny and O'Sullivan (2017) where I can deduce that for older people in the UK, TV watching can conservatively be estimated to be a minimum of 25 hours per week. The amount of time dedicated to ICT devices by older people partly informed their selection in relation to intra-day and inter-day variation of single and two-person households. These I argue can significantly vary diurnally and across the week.

3.2 Research design

For this study, I designed an approach to understanding the intensity and variation of demand and practices using selected energy-relevant activities of older households. Figure 3.1 illustrates the research design framework and indicates the process I adopted to address the aim and research objectives of this study.

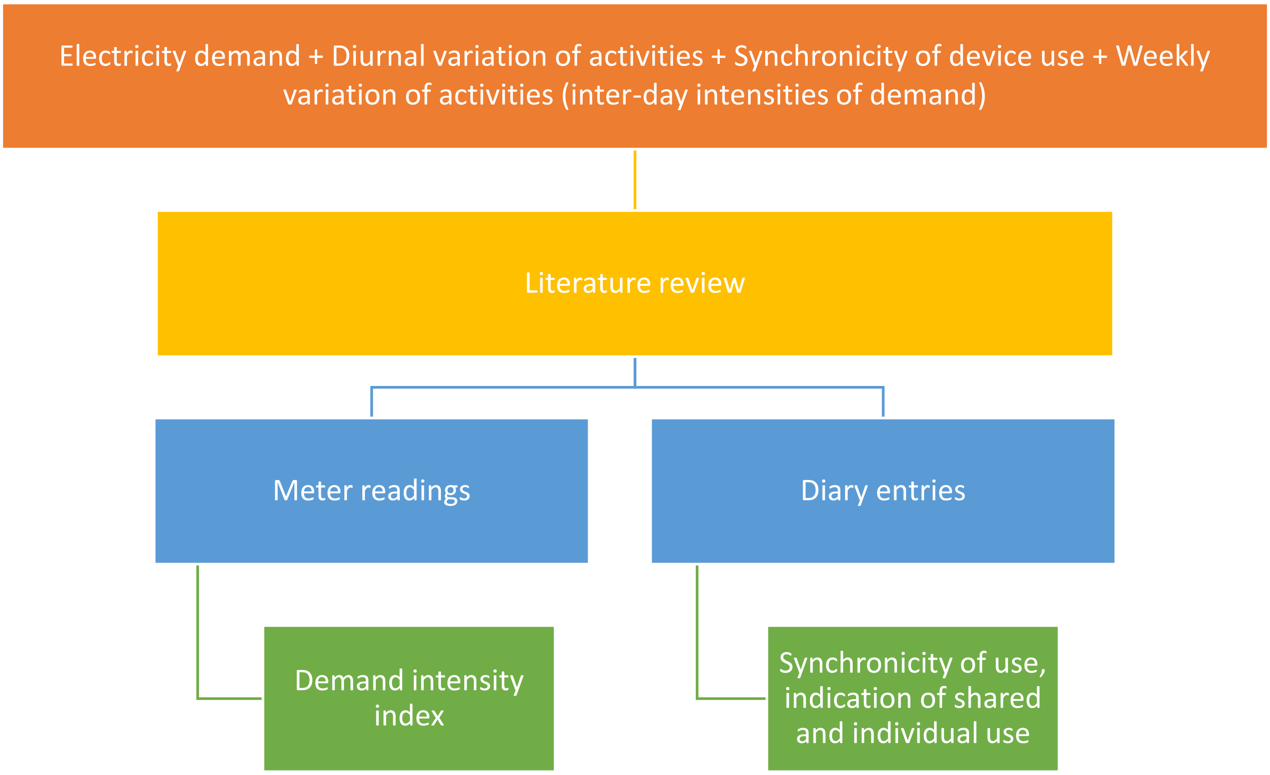

FIGURE 3.1: RESEARCH DESIGN

The research design as illustrated in Figure 3.1 above entailed the process through which I embarked upon this study. A preliminary investigation into the literature through large time use studies and census data like the UK Time Use Survey, 2000 and 2014/2015 indicated that older people do things differently especially around device use. To investigate this, I identified four attributes of domestic time use practices that provide a clearer explanation for this. The attributes were older people's demand rhythms, diurnal and weekly variations of activities and demand, and the synchronicity of device use. Two metrics (consumption and numbers of households) were adopted for this mixed method.

3.3 Research arrangements and setup

3.3.1 Scope, recruitment, eligibility, sample and sampling technique

Scope of the study

This study was carried out in Reading, UK. All the participants were volunteers recruited from leisure centres, places of worship, social groups and referrals from neighbours. Reading, UK was chosen in this study largely due to my logistical, financial and time constraints. I was limited in radial reach because he cycled to all the households. This constraint could not easily be overcome largely because this research is self-funded. As a result, there was limited external financial support available to enhance the radial reach of the households to include neighbouring towns, a wider radial reach in Reading or the South East as examples, which could have potentially made the research and the results more generalisable. The limited budget coupled with the initial phases of this study significantly contributed to prolong the data collection period as I had only two metering devices.

Participant recruitment

Permission was granted by the above-mentioned social arrangements to speak to their members. There, I explained what the study was about and how their participation was required. Participants were briefed about the nature of the study during recruitment. When they consented, they were briefed again on how to fill-in the diaries. They were shown a dummy example. The diaries were deliberately designed to be a simple tick-box exercise with a near 4-hour interval to minimise respondent fatigue. They were asked to fill-in the diaries when they used the selected devices either alone or in the company of others anytime during the indicated time slots. I reminded them of importance of accuracy and the need to act and consume as they would normally do. It was explained to them that anything outside the ordinary would skew the data collected. It was explained that it would not also be useful to them as the use recorded would not help them in making decisions or understanding how they consume the least. Bearing in mind the participants were unpaid, it seemed the cohort was skewed towards energy enthusiasts and those who were generally interested in how and when they consume the most or least. I followed up with scheduled calls based upon their availability and convenience during the week of data collection to ensure that they were filling-in the diaries correctly and regularly. It was essential to me to maintain a genuine and cordial relationship with the participants which was mutually appreciated. It was indeed an amazing experience as I invested an average of four hours per trip to have a conversation with participants, motivate them and get to know them. It was a very human experience and the most enjoyable part of this study. Keeping a good relationship was essential to minimise respondent fatigue and to enjoy myself as the cycling was physically demanding. Just being a listening ear to their many stories about their grandchildren and their travels kept the experience less formal and, in my view, was the key to keeping their interest and participation in this voluntary study. They also gave me a lot of invaluable advice, which made the process a lot more enjoyable. I brought forward my experience in door-to-door marketing and several customer-facing roles to ensure that the participants had the best possible experience. The participants were promised soft copies of the final version of the thesis hand-delivered to their addresses as an additional incentive.

Eligibility

Eligibility entailed that the household was only occupied by persons above 65 years of age and that the household did not use electric heating. Other eligibility requirements included availability for 7 consecutive days and self-proclaimed good health. The age requirement was to ensure that the time use data collected was exclusively for the older cohort, and the non-electric heating requirement was to ensure that the meter readings were not skewed by HVAC. I ensured that the household was available to capture their everyday life and their good health to ensure safety. Additional screening qualities included accessibility of the meter, pet ownership, exclusivity of meter use and broadband availability. I only recruited households that described their meters as "accessible." This meant that they could without any trip, slip or shock hazard see and reach their meter. I excluded households with pets for health and safety reasons to minimise risk of shock. I also excluded households that shared their meter with two or more households. I discovered shared metering on two occasions in a Council property and a private terrace house. *Ab initio,* internet access was a selection criterion as this was necessary to record and transmit the appliance-level meter reading remotely. Worthy of mention is that only one household was disqualified because of poor internet access.

Sample and sampling strategies adopted

This study employed a purposive sampling technique to recruit the households. With this technique, the strategies utilised included snowballing, visits to clubs, places of worship and other civic and social centres. I arranged meetings with the members of different societies to meet them in-person. I was permitted to recruit at a total number of 22 religious centres consisting of 13 churches, 2 temples, 6 mosques and 1 Quaker Centre, 2 cultural centres, 4 clubs and gyms. I also contacted organisations such as AgeUK and the Reading Borough Council to grant me access to recruit households. Due to their confidentiality and safety arrangements, it was unfruitful. In total, at the initial stage, I had consent from 86 households to participate in this study.

Limitations of time, budget and logistics constraints meant that I gave up the possibility of a wider sample size for a more successful recruitment strategy. The initial recruitment was successful as 86 households agreed to take part in the study. Visits were arranged via telephone appointments after meeting in-person for the installation and the retrieval of the diaries and the meters. Of these, only 59 households eventually took part in the third phase of the study after the first two phases to the study. Please refer to Figure 3.2 and Figure 3.3 for the photographs of the devices used in the first two phases of this study for data collection.

FIGURE 3.2: THE RECEIVERS FOR THE 1ST AND 2ND PHASE OF THE STUDY

FIGURE 3.3: THE APPLIANCE ENERGY USE TRANSMITTERS INITIALLY USED IN THE 1ST AND 2ND PHASE OF THE STUDY

1^{st} and 2^{nd} phase of the study

Three phases were embarked upon for this study. These study phases metamorphosed based on the selection of the investigated devices, the feasibility of examining these devices and how its investigation fulfilled the overall study's aim.

The first phase set out to measure the device-level demand of the households using devices shown in Figure 3.2 and Figure 3.3 to measure and transmit device level energy consumption data in addition to collecting diary information. The selection criteria for the devices to be measured were partly based them being "plug-in" devices as this enabled me to isolate the demand of these devices from the entire household demand. The initial test-run was performed in an office environment and suggested that this approach was feasible. However, the challenges of poor signal, missing data and data loss led me to use an updated version of the device (black colour in Figure 3.3). This led to the second phase of the data collection. I changed the capacity of the receiver to overcome the above-mentioned challenges and modified diaries to reflect the reality of ownership, which ranged from multiple ownership to the absence of the selected devices. It revealed the practical challenges of appliance-level data collection as multiple devices being on could not always reflect a use. For example, three participants indicated that they often left their TV on in the bedroom if they were not leaving the bedroom for a prolonged period. This made me begin to question the compatibility of the plug-level data collection with the diaries. In the case of those households and potentially others with multiple TVs, their diary fill-in and the plug-level metering would over the period of data collection have a disparity that I could not at the time ascertain or assess. I chose to continue into the second phase with the plug-level data approach as it was important to collect the data and sort out disparities between receivers not working properly at the time.

In the second phase, I acquired an improved sensor to address the challenges faced in the first phase and to reflect the recommendations of the manufacturer. Data collection was embarked upon with modifications made to the diary to identify the location of these devices. This was initially intended to sort and analyse the use of the devices based on their location. The initial analysis seemed inconclusive due to the different house types and sizes (disparity in room numbers). Furthermore, the signal failures previously experienced persisted. In addition, it became more apparent that the disparity in the use recorded, and the data recorded rendered most of the data near unusable. It became obvious that the plug-level metering device was not fit-for-purpose. Further modifications to the diary were required to address the issues highlighted. Specifically, the location of the device and the plug-level approach were reconsidered. The diary was also modified to reflect the (shared) use of the devices. This led to the third phase of the data collection after the two phases that lasted approximately six months in total.

Third phase of data collection

The third phase of collection lasted about 16 months (from November, 2015 to February, 2017) with periods of varying intensities. This was primarily because of participant recruitment logistics, participant fatigue, limited finances and limitations of the number of metering devices. As mentioned earlier, I cycled to all the locations of recruitment and households. In addition, visitations could only occur when the respondents were available for an entire week. As a result, several cancellations and rescheduling occurred. These affected the pace and progress as I could only schedule visitations when feasible. Participant fatigue was also a contributing factor to the delayed collection. Households were not necessarily interested in doing it again. Hence, I sought out other households. The financial limitations of the research became more manifest during this phase. This research is self-funded thus I could neither fund faster transportation nor acquire more metering devices. Hence, I made do with only two metering devices, which translated into often extended waiting times in-between. Data collection spanned all seasons and excluded national holiday periods, such as Easter and Christmas, and bank holidays. This research does not envisage any significant effects for the time during the year due to these exclusions and the exclusion of HVAC. The exclusions also enhanced comparability as they were asked only to participate when they would have a “typical” or “normal” routine for that week. They were also asked midway and at the end of the week if anything had changed in their schedule during the data collection.

As indicated earlier, there was a drop from the initial number of households from 86 households to 59 in the third phase of the data collection. This was caused by a myriad of factors, including loss of interest, non-availability and distance from the household.

The loss of interest was a result of some of the households that were visited in the first and second phase of the study who lost interest in participating further. Another factor observed by me that led to loss of interest was the length of time some of the respondents waited to be contacted after they had consented. The trial stages meant that I could not contact everyone until the methods and contents of the study were finalised and fully operational.

Another factor was the distance of the household from the University of Reading's campus was a significant bias of this study. I cycled to their homes thus households that were more than five kilometres away were excluded due to logistic reasons. Two of the interested households were further than five kilometres. At this stage, the diary was modified from the first version to address the challenges that ensued in the earlier versions. Further modifications were made to the diary based on feedback from some of the respondents to achieve the dual purpose of minimising respondent fatigue and reaching the proposed research objectives.

Having had two phases of the study, I asked households and got feedback regarding the ease of use and the level of disruption the diaries caused to the respondents. The households largely commented on the number of pages and made valuable contribution to diary modification. This improved its user-friendliness as this is particularly vital because no financial or other inducements were provided to participants. In this study's cohort, four households did not have a TV and used their laptop for infotainment. I made these modifications to ensure that I increase the reliability of the entries in the diaries by making it user-friendly without compromising on the objectives of the study. I also wanted to guard against the Hawthorne effect that this disruption may cause in the household. The Hawthorne effect refers to behavioural changes that result when respondents are observed (Parsons, 1974, Jones, 1992, Wickstrom and Bendix, 2000). Hawthorne effects in the case of this study would have led to unusually low kWh readings. I encouraged the participants to act as they would normally do. I explained to them that unusually low readings would neither be beneficial to them (as they would not know how and when their consumption can be controlled), and for me because the results would be misleading. Because of the above-mentioned challenges, I sought the use of devices in Figure 3.4 and Figure 3.6. Please refer to Figure 3.8 for a summary of the phases of this study.

In summary, the main changes that occurred in the first two phases were;

The device use for metering was changed from plug metering to the clip-type metering for the entire household. Hence, in the latter case, appliance-level metering could not be achieved.

Second, the diary was also modified to reflect the exclusion of plug-level metering to indicate when they used these devices. Furthermore, partly based on feedback from the households, the diary was modified to enhance simplicity to the current tick-box style. The diary was also modified to focus mainly on audio-visuals, and many of the other appliances required only one entry by the households to indicate how frequently they used those appliances, (please refer to Appendix for the sample diary).

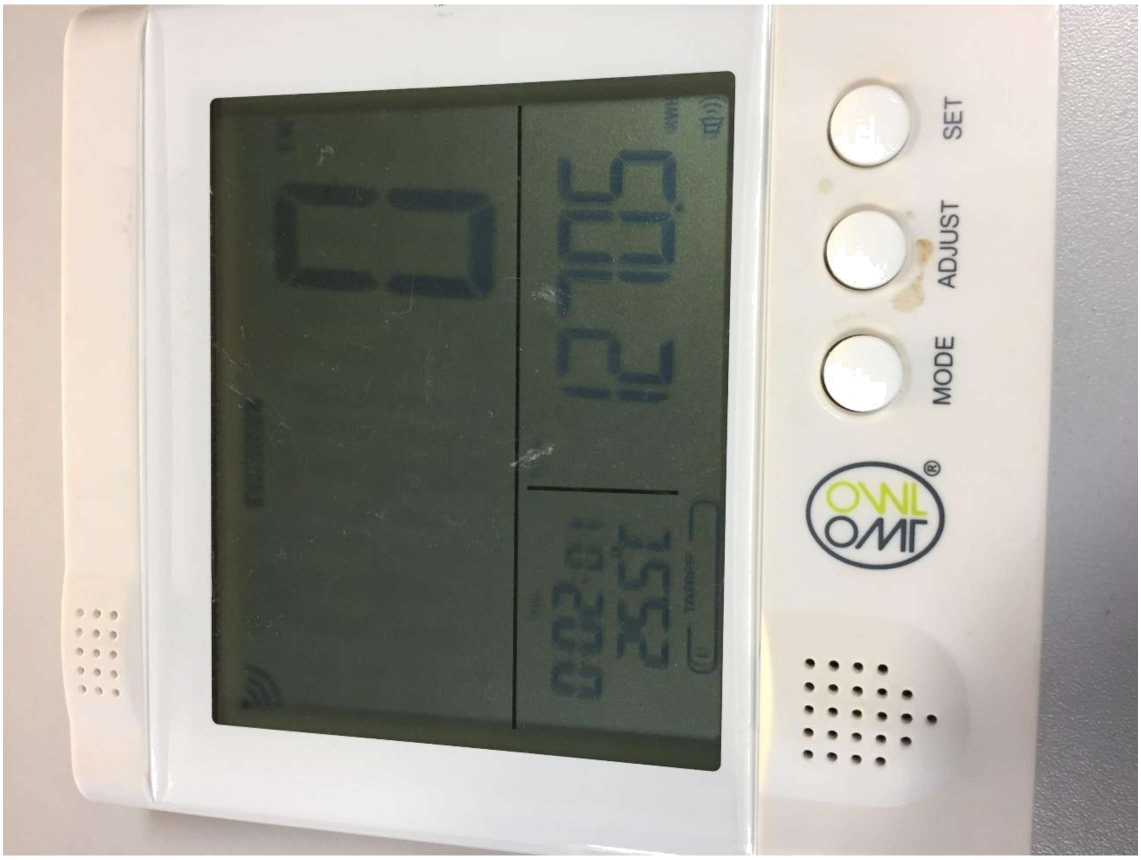

FIGURE 3.4: THE DISPLAY UNIT AND RECORDER FOR THE 3RD PHASE OF THE STUDY (FRONT VIEW)

FIGURE 3.5: THE DISPLAY UNIT AND RECORDER FOR THE 3RD PHASE OF THE STUDY (REAR VIEW)

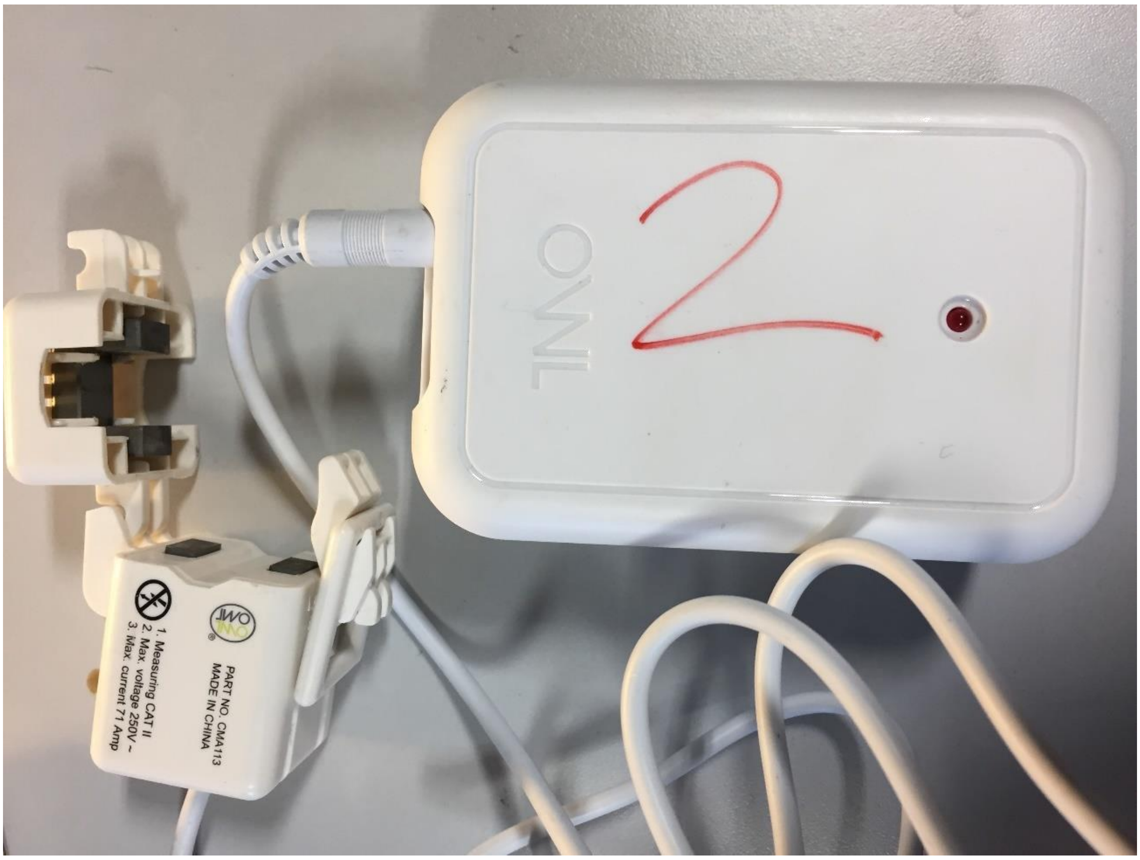

FIGURE 3.6: THE TRANSMITTER AND SENSOR CLIP FOR THE 3RD PHASE OF THE STUDY (FRONT VIEW)

FIGURE 3.7: THE TRANSMITTER AND SENSOR CLIP FOR THE 3RD PHASE OF THE STUDY (REAR VIEW)

Summary of three phases and technical characteristics of monitoring devices

In my third attempt to capture the practices of the older cohort, I attempted to overcome the initial challenges of recording, transmission and storage of the data.

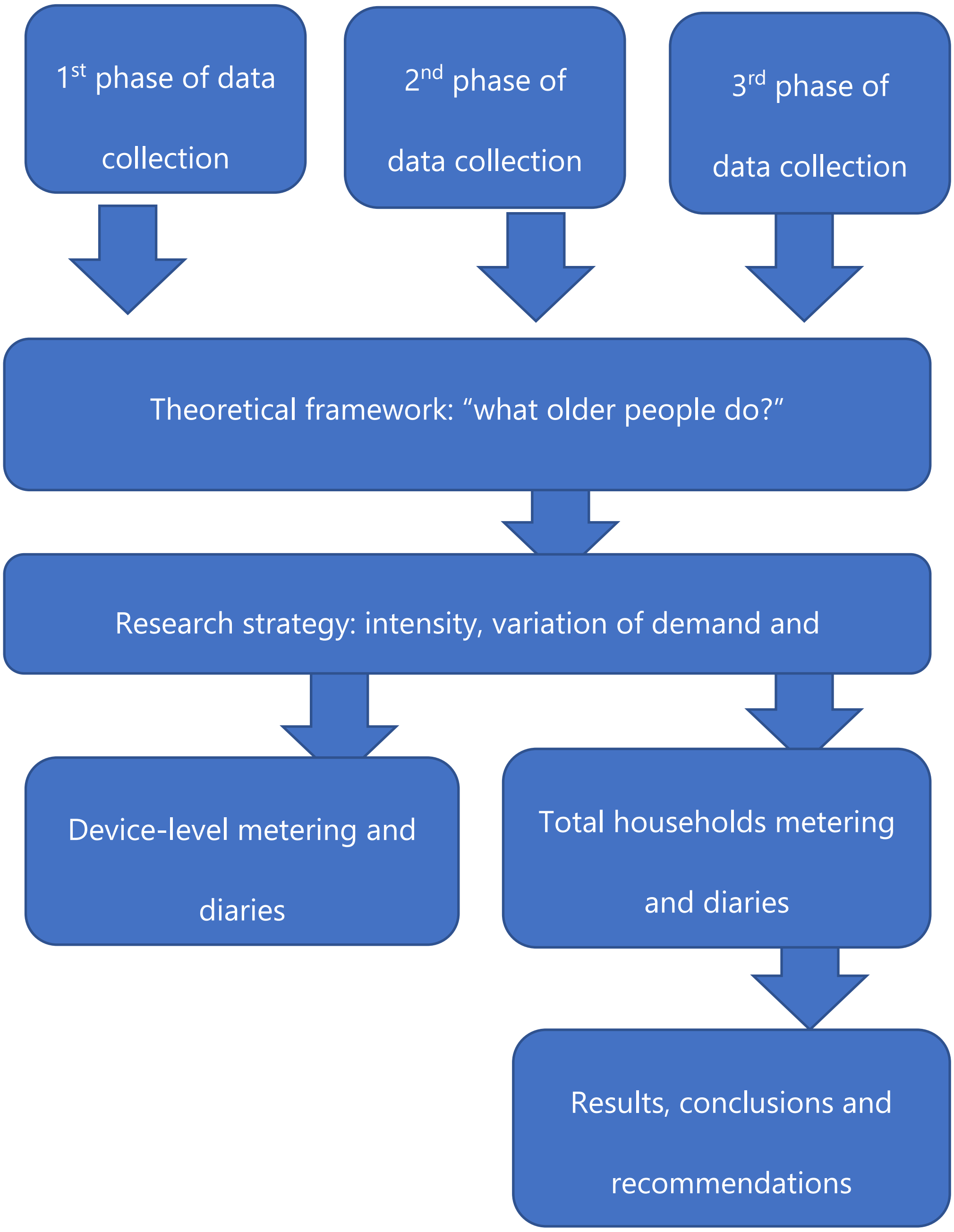

FIGURE 3.8: THE PHASES OF DATA COLLECTION

I used the device made up of two main parts indicated in Figure 3.4 and Figure 3.6. This OWL device had the following features; it was battery-powered; it locally stored the data, and it collected and transmitted kWh meter readings every 60 seconds.

Details of the "OWL" device is as follows;

Battery-powered with 3 AA batteries for the display unit. The display unit showed the real-time kWh meter reading of the household and had the storage capacity of 1Gigabyte of data locally (Figure 3.4 and Figure 3.5).

The battery-powered sensor clip has 2 AA batteries. It had a maximum voltage of approximately 250V and a maximum current of 71 Amps. The clip as shown in Figure 3.7 was fastened to the live cable at the household's meter. The sensor had a flashing light when clipped unto a live cable. This sent the kW meter readings to the display unit where it was stored (Figure 3.6 and Figure 3.7). The phases mentioned earlier necessitated modifying the diary and my research aim and objectives. I now sought to record device use via diaries and the total meter reading of the household instead of the initial approach of plug-level measurement.

The time-stamped data derived was then summed up in accordance to the time slots in the diary. Thus, the readings that appear in Chapter 4 are a sum of all the time points of readings within the time slot approximated to two decimal places. This allowed me to produce charts as in Chapter 4 that showed distinct attributes of the readings in the time slots.

I deviated from the widely used 10-minute resolution in the literature, and I adopted a 4-hour time slot approach largely because the data collection spanned seven consecutive days unlike the widely used randomly selected day(s) per household. The duration of collection per household necessitated long enough temporalities that had activities for clear comparison. I developed the time slots inspired by traditional meal times in the UK. I assumed a higher likelihood of occurrence and cluster of relevant activities around the selected time slots. I sought to observe what happened at around breakfast, midday (afternoon tea time), lunch, dinner and relaxation/ sleep time.

Lessons learned from the phases of the study

The lessons learnt from the first phase of the study revealed the challenges of using Wi-Fi enabled devices in the homes as signal failure rendered most of the device-level meter readings unreliable. The Wi-Fi enabled meters recorded the plug-level device use of the households and transmitted the meter data to a server which I could monitor remotely and store data at a regular interval. This approach was used by me and other colleagues in an office environment with much success. This device proved to be unreliable when replicated in the domestic setting as residents turned off the device completely by accident and the Wi-Fi signal in these households also fluctuated leading to significant loss and incomplete data. The diary used was also modified as the data retrieved did not fulfil the intended research questions. I assumed that the problem was with the device thus I changed the device to the black one (Figure 3.2).

The metering device was not fit-for-purpose for domestic use. I, however, could not overcome unreliable broadband in the households which I did not consider when I acquired the device-level metering device.

I learnt that local storage of data was preferable for electricity demand for research that entails meter readings for two reasons: firstly, it increases the number of potential households that are eligible to participate as internet coverage may be poor or unreliable in the household. The use of Wi-Fi enabled meter data collection though seemed efficient due to remote real-time collection and remote storage. It also entailed the assumption that if the household had internet access, their data bundle and supplier were reliable enough to accommodate the metering device. The use of the Wi-Fi enabled device also posed an additional burden of privacy as I encountered that households were reluctant to grant access to their router and provide the access key to use their network. With these challenges, I recommend for future research on domestic demand, that researchers should avoid reliance on remote or Wi-Fi enabled meter or device-level data collection. The final phase of the study sought to overcome the initial challenge of remote transmission and storage of the readings. An alternative meter with local storage features was used.

The modification of the diaries was collaborative and feedback from the households partly inspired the layout of the diary. Meaningful feedbacks such as fatigue and Hawthorne effects were considered in the modifications made to the final version of the diary. The major changes made were the inclusion of the time slot of use for the investigated devices and the reduction in the number of entries from hourly time slots to four-hourly time slots. A sample of the diary is in Appendix 1.

3.3.2 Time use approach

Time use information essentially focuses on the description and explanation of what people do with their time (Michelson, 2015). These descriptions are at different levels of granularity such as 10-seconds, hourly or in our case, time slots of an approximately four-hour interval. The description of time use spans across different durations, such as one day, two days or in the case in this study, seven consecutive days. The different levels of granularity of the data and the duration of the collection reflect the proposed aim and objectives of different studies. I observed that it was usually the case, especially in time use research for there to be an almost inverse relationship between the level of granularity and the duration of collection. As implied earlier, studies with coarser data like this study tend to focus on a somewhat summarised nature of how people spent their days and complement this with longer duration of collection. Please see Appendix 1 for a sample of the diary used for this study.

Time use studies using diaries

Diaries were used in this study to document the time use of selected appliances. The use of diaries is widely adopted in time use studies. They have been previously explained in 2.4. Despite their shortcomings of bias, incomplete and sometimes inaccurate filling of the diaries among other limitations of this method, they remain the least invasive approach to documenting what people do and how they do it. An important aspect of domestic practice which was mentioned earlier is sharing of appliance use, which cannot be captured via meter readings and capturing this is a major strength of diaries. Alternative approaches such as video recordings can capture shared use albeit a more invasive data collection method than the use of diaries.

Appliance time use

As explained in Chapter 2, this thesis focused on the device use of households as part of the everyday life of the older cohort. Device use is a subset of the time use of the households. The time use approach is widely adopted as it provides a reliable means to investigate practices with a view to connecting the qualitative and the quantitative (Michelson, 2006, Michelson, 2015). The time use enabled me to establish the connection between the "qualitative" which was what people indicated that they did via the appliance use diaries and quantitatively via an indication of the cumulative demand via kWh meter readings. I recognise that reporting errors occur when questionnaires/ diaries are used to investigate practices as households can inaccurately give an account of device use. Additional care was taken to minimise this as reports of the load profile were generated for the view of the households at the end of the data collection period. I made them understand the Hawthorne effect and how that would affect not just the veracity of the results but also their understanding of their demand patterns, which was part of my pitch in recruiting the households.

Zero observations for time use as explained in Browning (2012) can be either be the result of the (lack of) frequency of the data collection, or it could mean a deliberate non-use of appliances. This is a question that exists perhaps as a limitation in almost all-time use studies as most of these rely on 1-day or a few day's data collection. This thesis attempted to overcome this limitation by collecting data for one week. It thus investigated time use for a comparatively longer period than it is widely available through larger data sets. Hence, the incidence of zero observations was minimised to near zero for all practices that have a frequency of at least once a week. Other less frequently performed energy-relevant practices are outside the scope of this study. Although some were captured and indicated in Figure 33 and Figure 35. Seasonal events such as Easter and other bank holidays which have an influence on electricity demand intensity, and variation were excluded from data collection days. This enabled me to provide a snapshot of everyday demand and demand intensity as typical and representative of the average week as possible.

The time use approach enabled me to divide respondents' reportage based on five time slots which I developed (6 a.m. - 10 a.m., 10 a.m. - 2 p.m., 2 p.m. - 6 p.m., 6 p.m. - 10 p.m. and after 10 p.m.). This enabled me to establish how respondents spent their time across the time slots and investigated the variation between them.

The device selection criterion was based on the devices that can be characterised by significant demand rhythms (diurnal and or weekly) and where synchronicity of device use can be established. The frequency and duration of use as indicated in the most-recent UK time use study, Gershuny and Sullivan (2017) were an indication that these devices were deeply entrenched in the everyday life of our cohort. For example, older people in their cohort were indicated to have spent about 300,000 minutes in total watching TV in a week (a daily average of about 151 minutes per household). Although (Gershuny and O'Sullivan, 2017) was not published as at the time of data collection, the findings still indicated the currency and accuracy of previous studies regarding the use of the selected devices. Robinson and Caporaso, (2009) for example, observed that over 65s spend on average 25 hours per week watching TV.

For example, according to Palmer et al., (2013) audio-visual and ICT combined to have a one-fifth contribution to peak demand and even when not in use, they still contributed the largest proportion to standby demand as Zimmermann et al., (2012) observed that computer appliances were in standby mode for nearly 60% of the time. These appliances have also been attributed to "organise" demand based on the weeklong routines established in the household (Winocur, 2005). Drysdale et al., (2015) also indicated that non-HVAC and water heating combined to constitute about 70% of the total consumption in households. Decc (2012) and Palmer & Cooper (2013) imply that the savings potential from audio-visual appliances outweigh other classes of appliances.

On a grand scale, these appliances would increase in significance to over 5TWh by 2020 (Trust, 2011). DECC (2012) indicated that domestic consumption would rise to approximately from 328TWh in 2010 to 411TWh by 2030 with devices having the highest potential for demand reduction by up to 42% (26.3TWh from devices compared to 19.2TWh and 12.7TWh from building improvements and bulbs respectively). DECC (2012) also identified product policy having the highest potential impact on demand reduction.

I argue that the engagement with these appliances provided a partial explanation for the pattern of energy-relevant time use practices performed by older people. Other factors that influenced my selection of devices include “plug-in” (Ehlen, Scholand and Stamber, 2007; Lutzenhiser *et al.*, 2012). This enabled them to be investigated individually as their load could be metered from the plug. This criterion featured more prominently in my 1st and 2nd phases of the study. To enable comparability, I sought out near ubiquitous devices.

3.3.3 Meter readings approach

I understand the meter reading approach to entail the use of temporal-referenced kWh readings to deduce activity and or appliance use in a household. This kWh data could be primary (as in the case of this study), secondary from publicly available data and demand profile data or simulated data. Typically, the use of kWh entails the development of a use or load profile of households as in the case in Wood and Newborough (2003). In addition to this, I developed intensity indexes from the kWh readings as indicated in Chapter 4 and explained the variation of intensities in Chapter 5. The meters used to record the kWh readings are below (Figure 3.4 and Figure 3.6).

3.4 Key metrics

3.4.1 Rhythm of electricity demand

I conducted a rhythm analysis of the electricity meter readings in the households. I define rhythm analysis as the investigation of the relationship between temporalities and, in this case, temporalities in households and the pattern to which they occurred. I investigated the rhythm of electricity demand in the context of intensity of demand. I observed the rhythm of demand in two themes: the "clock time" where I used time slots during the day, and the cyclical rhythms where I used in addition to the clock time, the day of the week. The themes of clock time and cyclical rhythms were derived from Simpson, (2012).

The clock time referred to the time slots during the day, and across the days when activities were performed that resulted in kWh meter readings in the households. The clock time is an effective tool to organise, calculate and establish rhythms when "built, maintained, referenced and trusted" (Moran, 2015). I used clock time/ time slots rather than the duration of the activity as the unit of comparison. As Simpson, (2012) explained, durations of activities are characterised by heterogeneous temporalities with a myriad of qualities while clock time provides homogeneity and quantification and objective accountancy of temporality. For example, there can only be one 4 a.m. for a day while an activity (like watching TV alone) may span from 3:55 a.m. to 4:02 a.m. in a household and in another household, the same activity may span from 4:03 a.m. to 5:59 a.m. This illustrates how the duration of practices is almost never exact within or across households.

As I indicated in Chapter 4, single-use TV across two consecutive time slots does not imply that the household watched TV for the entire time.

I explained in Chapter 2, practices are subject to interruption by other competing practices (inclusive of multi-tasking). The use of duration makes comparison complex and thus I simplified it by using time slots. This allowed me to establish the occurrence of the device uses as the rhythm of the kWh meter readings fluctuated. Simpson (2012) described this phenomenon as having a "form of duration without a beginning and an end." The clock time was utilised to establish the temporalities with the highest and lowest intensities and the highest and lowest quartiles of households. As explained earlier, the kWh readings used for this study were summed up according to the time slots.

The intensity of demand intra and inter-day (index) per time slot was calculated as follows:

Equation 1:

Intra-day index (%) = $100\% * \sigma t/\rho d$

Where ρd = highest kWh meter reading for the specific day

$\sigma t = \Sigma$ (meter readings for the specific time slot)

The explanation and analysis from this study were limited to the time slots where the households reached their maximum intensity of demand of 100%. The maximum intensity of demand enabled this study to investigate, compare and explain the demand across and within the households based on their actual meter readings throughout the day. For example, the intensity of demand during the day enabled me to establish what times of the day demand were most significant (at 100%) in the context of a household, and I could compare that with other households. Time slots where the highest intensity of demand during the day occurred were of significance because demand is temporal in nature. Activities that occurred at these time slots and whether those activities were enacted alone or in the company of others are some of the contributions to this approach to examining the rhythm of electricity demand. The intra-day intensity of demand enabled me to deduce the variation in device use activity levels as estimated in Chapter 4 and Chapter 5.

For example; for a hypothetical household, the intra-day index can be calculated as follows (kWh readings indicated in Figure 1 below and Equation 1 above); 6 a.m. – 10 a.m. (100* 0.91/1.3=70%), 10 a.m. – 2 p.m. (100* 0.9/1.3=69.23%), 2 p.m. – 6 p.m. (100* 1.3/1.3=100%), 6 p.m. – 10 p.m. (100* 1/1.3=76.9%) and after 10 p.m (100* 0.6/1.3=46.15%). For this household, the maximum intra-day index occurred at the 2 p.m. – 6 p.m. time with 100% intra-day index.

TABLE 3:1: AN EXAMPLE OF INTRA-DAY INDEX

Time slot	kWh reading		Time slot	∑kWh reading	Intra-day index (%)
6 a.m. – 10 a.m.	0.91		6 a.m. – 10 a.m.	0.91	70.00
10 a.m. – 2 p.m.	0.9		10 a.m. – 2 p.m.	0.9	69.23
2 p.m. – 6 p.m.	1.3		2 p.m. – 6 p.m.	1.3	100.00
6 p.m. – 10 p.m.	1		6 p.m. – 10 p.m.	1	76.92
After 10 p.m.	0.6		After 10 p.m.	0.6	46.15

Equation 2:

$$\text{Inter-day index} = 100\% * \sigma t / \rho w$$

ρw = highest kW meter reading for the week

σt = Σ (meter readings for the specific time slot)

As mentioned earlier, this study was carried out over a period of one week. I investigated the intensity of demand across the week per household to compare the time slots when the maximum intensity of demand occurred. Examining this enabled me to establish which time slots on which days across the week had a "coming together" or not of maximum inter-day intensity of demand. In other words, if the literature has suggested that older people are perhaps peculiar in their demand characteristics, did their peculiarity have a commonality to it? The peculiarity of the day of the week is seemingly widely implied in the literature, and time use surveys. The use of the intensity of demand across the week enabled me to establish if that was the case for the cohort. These speak to objective 3 and 4 in 1.2.

For example; for a hypothetical household, the inter-day index can be calculated as follows; the inter-day index for Monday 10 a.m. – 2 p.m. slot is calculated as (as in Equation 2 above) 100*1.56/1.99=78.39%.

TABLE 3:2: AN EXAMPLE OF INTER-DAY INDEX

Time slot	6 a.m. - 10 a.m.		10 a.m. - 2 p.m.		2 p.m. - 6 p.m.		6 p.m. - 10 p.m.		after 10 p.m.	
Day	∑kWh readings	Inter-day index (%)	∑kWh readings	Inter-day index (%)	∑kWh readings	Inter-day index (%)	∑kWh readings	Inter-day index (%)	∑kWh readings	Inter-day index (%)
Mon	1.51	75.88	1.56	78.39	1.50	75.27	1.45	72.76	0.97	48.61
Tue	1.91	95.82	1.67	84.15	1.52	76.60	1.74	87.57	1.10	55.48
Wed	1.89	94.77	1.51	76.01	1.52	76.39	1.68	84.38	0.89	44.78
Fri	1.85	92.99	1.82	91.61	1.94	97.48	1.61	81.11	1.08	54.33
Sat	1.81	91.03	1.61	81.05	1.45	72.86	1.59	79.70	1.01	50.93
Sun	1.70	85.23	1.77	88.84	1.75	88.17	1.62	81.49	0.98	49.24
Thur	1.99	100	1.43	71.78	1.36	68.36	1.64	82.60	0.82	41.15

3.4.2 Frequency of device use

As mentioned earlier, this study intends to investigate the coming together of activities surrounding selected devices. The diaries were used to indicate the (shared) use of these devices. This enabled me to establish the synchronicity of device use. A frequency count was done in three main ways: to count the number of households at their maximum intra-day index, the number of households at their maximum inter-day index, and how frequently they used other appliances. The frequency counts of the households using the selected devices were broken down by the day of the week and can be found in Section 4.2.2 and Section 4.3.2 for single and two-person households respectively. As a result, I highlighted the peculiarities of each day in the context of the coming together of the device use and the collective maximum intensities of demand.

3.5 Ethics consideration

This research as implied earlier entailed visits to households of older persons. This entailed significant health, safety, privacy and ethical considerations in the view of the University of Reading's Research Ethics Committee and the organisations I visited for recruitment. I fulfilled the requirements of the University by making adequate health and safety arrangements such as wearing gloves when installing the clips and taking manual handling training. I also ensured that prior to visits, the households were notified to keep their home clear of pets and potential trip and electrical hazards. I furthermore ensured and reminded the household that the installation and placement of the device should be out of reach of pets and children. Privacy (anonymity), consent and freedom of consideration were provided for explicitly in writing as indicated in the sample diary in Appendix 1 and verbally during recruitment and repeated upon installation.

I fulfilled the safety requirements of the organisations that granted me access to recruit their members. I did this by demonstrating that I had fulfilled the University's health and safety requirements, and the data of the households would be completely anonymised. I also provided letters of verification of his identity.

Chapter 4 : Main Findings

4.0 Chapter Description

In this chapter, I describe the meter readings and the time use data I collected from 59 households. It starts with an introduction of the typology of households and a brief description about the nature of data collection and justification for the method of presentation (Section 4.1). In Section 4.2, I investigate the results from single households. Subsequently, I investigate the results from the two-person households in Section 4.3.

4.1 Households investigated

Introduction

For one week per household, I investigated the device use of 59 older households. I present the results below that emphasise the aims and objectives of this study. The organisation, presentation and reporting of this study reflected the adoption of *Chronos* as explained in Section 2.3. I captured the intersection between what older people do in the context of device use and electricity demand. Significant trends and dynamics were highlighted. The findings presented in this chapter were obtained through the following three steps.

First, I started by organising the households based on their occupancy (single and two-person households). This distinction was significant in highlighting the disparity between solo living and living with one other person in terms of the enacted practices, timing, and shared device use, the intensity of demand and synchronicity of demand.

Second, the week was presented in *Chronos* starting from Monday through Sunday. This enabled me to investigate and highlight the vacillation of practices each day of the week; intra and inter-day. This enabled me to highlight and identify any unusual days in the demand and or device use.

Third, days were further broken down into nearly 4-hour slots starting from "6 a.m. – 10 a.m." to "after 10 p.m." It is noteworthy for mention that the time slot of "after 10 p.m." is the exception spanning approximately eight hours. These time slots were used in the diaries and the meter readings. The after 10 p.m., time slot is longer largely because I wanted to break the day down into feasible and sensible chunks when the households would be awake to indicate (shared) use of the selected devices. In other words, active demand. Hence, the results emanating from this time slot may be skewed. The meter readings were initially recorded every 60 seconds and aggregated to the time slots for consistency with the diary entries. This streamlined the focus throughout this study on identifying significant events while breaking the day into reasonable fractions to achieve this. I deviated away from the widely used 10-minute resolution to a broader and coarser image of the practices. The time slots allowed the investigation of intra and inter-day times during the day of maximum intensities of demand and the synchronicity of use of selected devices. The inter-day index was used to observe variation in intensity within the week, and the intra-day index was used to investigate diurnal variations.

I briefly describe the synchronicity of device use using frequency of households. I also highlight the time slots with the highest frequency of households that reached their maximum intensity of demand (intra and inter-day) for easy reference throughout this Chapter. I base my description and inference of the practices of this cohort on the time slots that had the highest frequency of households that reached their maximum (intra and inter-day) intensity of demand. Thus, I address the peculiarity of each day as was hypothesised that the cohort for this study does not necessarily adhere to the widely-referenced distinctive weekend demand.

When they performed these doings was partly a factor of solo living and autonomy of the ordering of the day and week. Thus, I propose (based on my findings), a slight modification of the characterisation of "weekend demand" from the widely inferred to be Friday, Saturday and Sunday to any day within the week that is significantly different from the other days in the load profile. "Weekday demand" I propose should be characterised to refer to demand on any day that bears significant similarity to most of the other days (intra-household).

I observed that the maximum inter-day demand spread across different time slots across the week with no increased intensity on weekends. This suggests that the energy-relevant household practices by this study's cohort are not necessarily bound by the norms that translate into distinctive demand by other age groups. I discuss this fully in Chapter 5.

Other observed devices such as kettle, microwave and toaster did not indicate a consensus of temporality or use. I categorised the age group according to widely used consensus categorisation of 5-year blocks of age for both groups. The sample also focused mainly on homeowners as Brandon and Lewis, (1999) and Yohanis et al., (2008) suggested that the tenancy had an influence on domestic demand. The attributes of the households can be found in Figure 4.4 and Figure 4.15 for single and two-person households respectively.

4.2 Single households

4.2.1 Summary of single households

I investigated 18 single households for this study. The criteria for participants were detailed in Section 3.1. Some of them were; that they identified as being over 65 years old, healthy enough to engage in physical activity, had non-electric heating inter alia. All the Figures reflect data that was collected for one week per household. The legend for figure 4.3, figure 4.4, figure 4.13 and figure 4.14 can be found in Table 4.1.

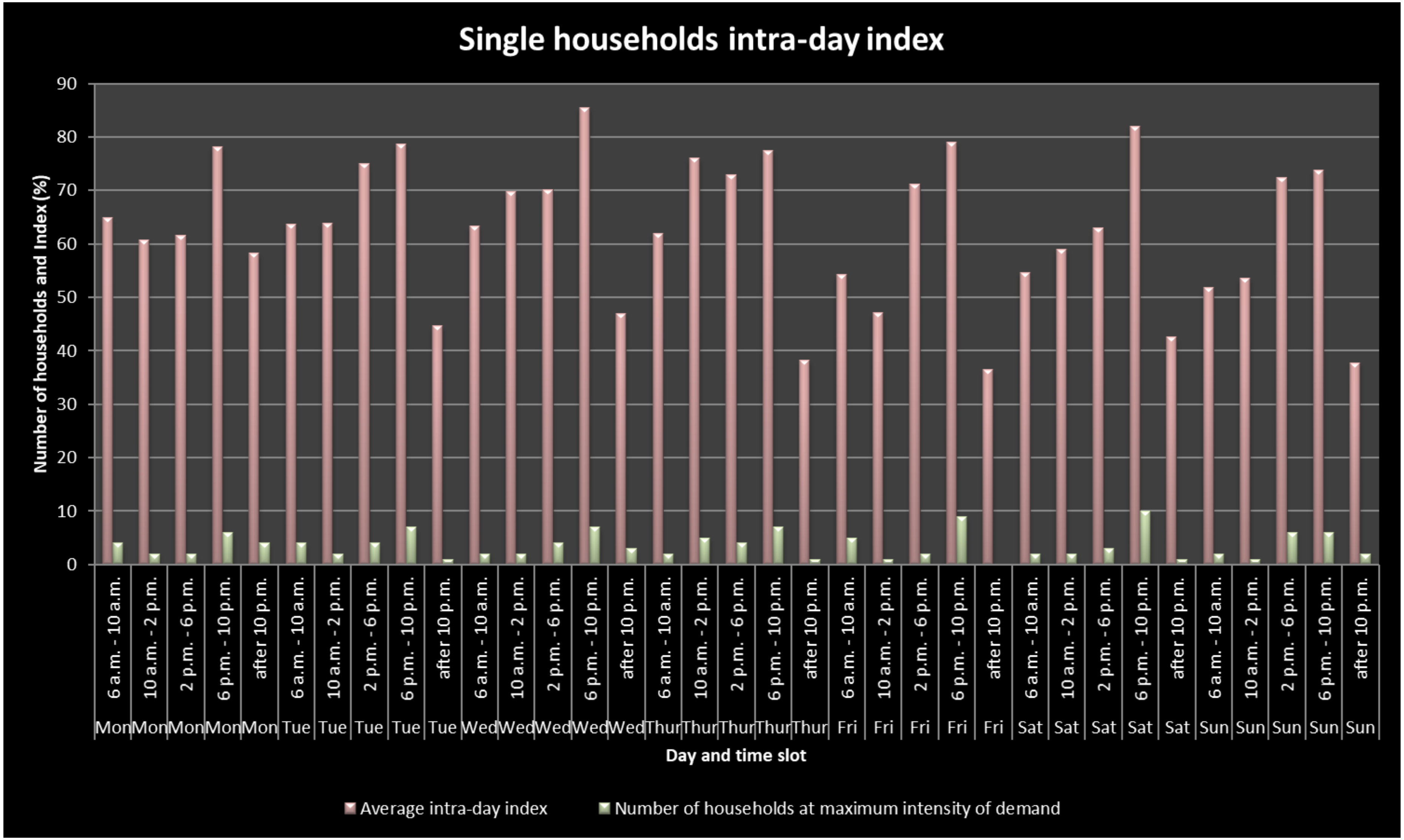

Figure 4.1: INTRA-DAY INDEX FOR SINGLE HOUSEHOLDS AT A GLANCE

Figure 4.1 provides a snapshot of the variation through the week of households that were at their maximum intra-day index. It suggests that on Monday, the concentration of maximum intra-day indexes was split between the 6 a.m. – 10 a.m. and 6 p.m. – 10 p.m. time slots with 4 of 18 and 6 of 18 households respectively. Tuesday, Wednesday and Friday had been similar splits with most of the households at their maximum intra-day intensities at the earlier mentioned time slots. At a glance, Friday and Saturday stood out with the highest number of households at their maximum intra-day index at a time slot. The pattern of the maximum intra-day index can be in part explained from the frequency of appliance use implied in Figure 4.3. Thursday through Sunday cumulatively had the highest average meter readings, although the average intra-day index in Figure 4.1 suggests a daily index peak at the 6 p.m. – 10 p.m. time slot without any day standing out. I assume based upon the rhythm of the maximum intra-day index that the kettle use contributed to the 6 a.m. – 10 a.m. and other times of maximum intra-day index while the electric hob contributed to one of the time slots of the maximum intra-day index for applicable households.

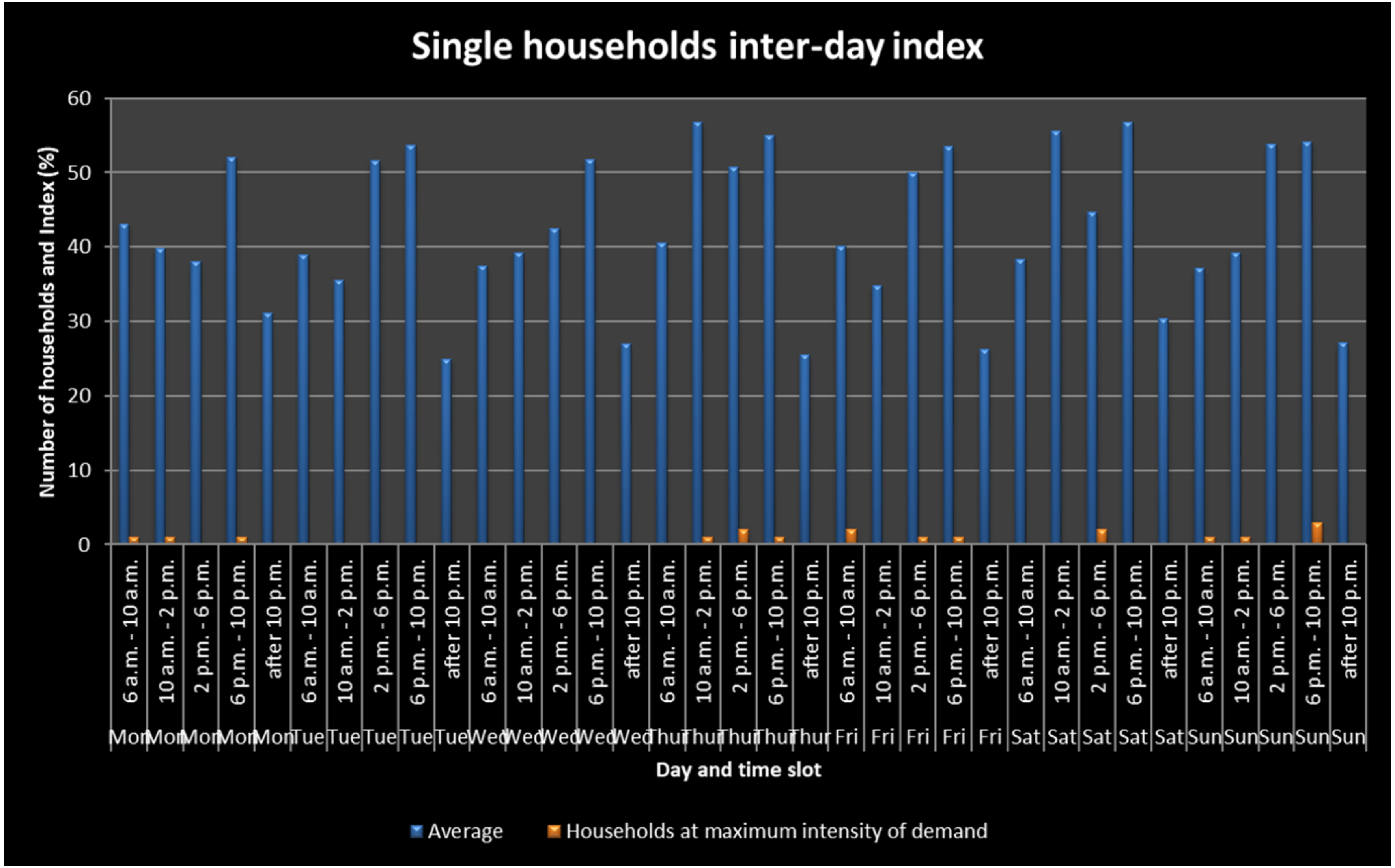

Figure 4.2: INTER-DAY INDEX AT A GLANCE FOR SINGLE HOUSEHOLDS

In the context of the week, I deduced from Figure 4.2 that the fewest energy-intense activities were carried out on Tuesday and Wednesday. The snapshot in Figure 4.1 suggests that 3 of 18 households had their maximum inter-day intensity on Monday. Higher concentration of energy-intense activities occurred later in the week from Thursday through Sunday. From the pattern of the maximum inter-day index, I can deduce that the less frequently used appliances as highlighted in Figure 4.3 were utilised in addition to their daily demand by most households between Thursday and Sunday. The highest frequency of energy-intense activities occurred on Sunday with 3 of 18 households during a time slot. Figure 4.2 suggests a regular average inter-day index with often two daily peaks. This implies that despite households not reaching 100% (inter-day) on Tuesday and Wednesday, there was active demand occurring across the households.

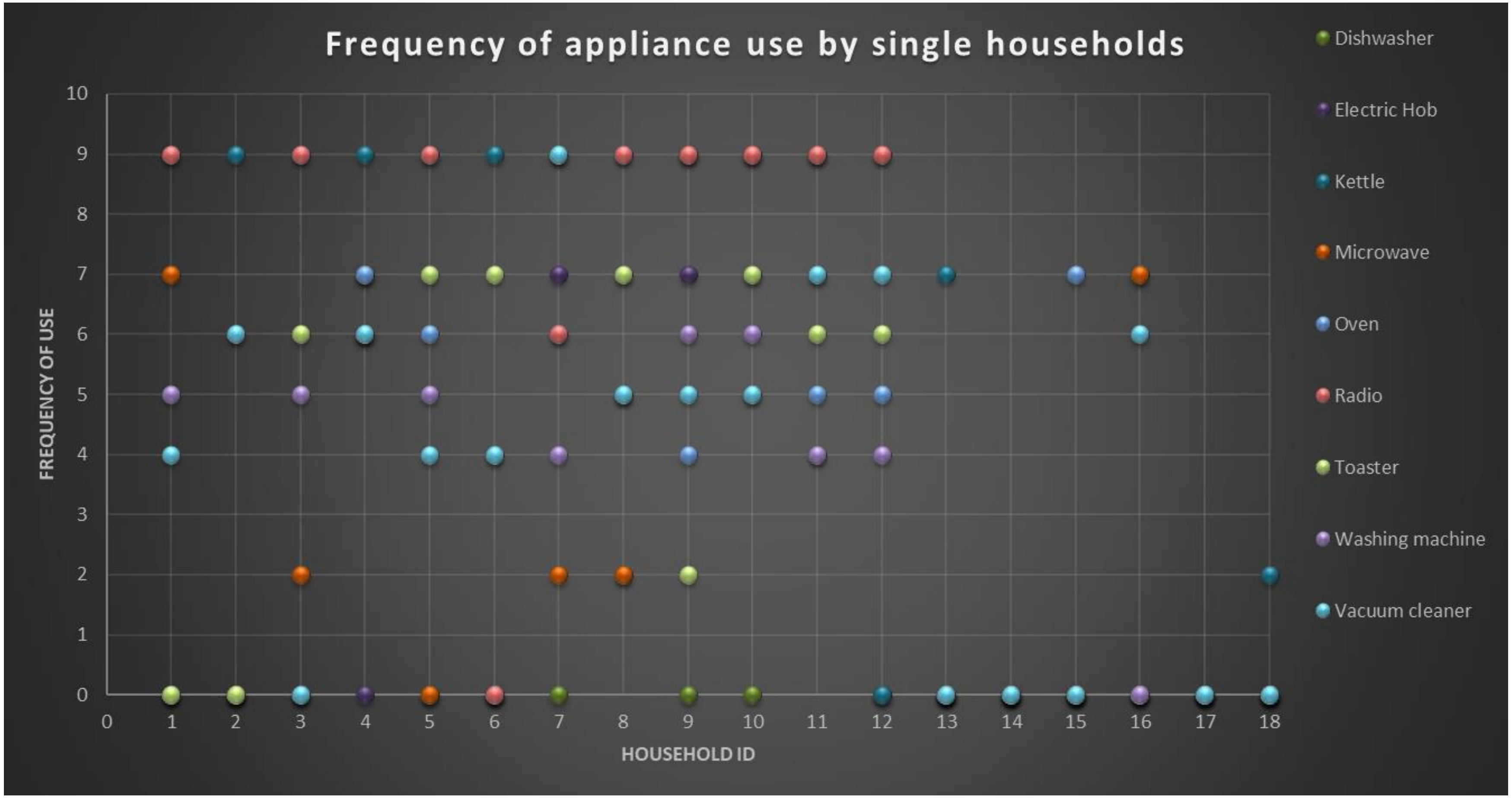

FIGURE 4.3: FREQUENCY OF APPLIANCE USE (SINGLE HOUSEHOLDS)

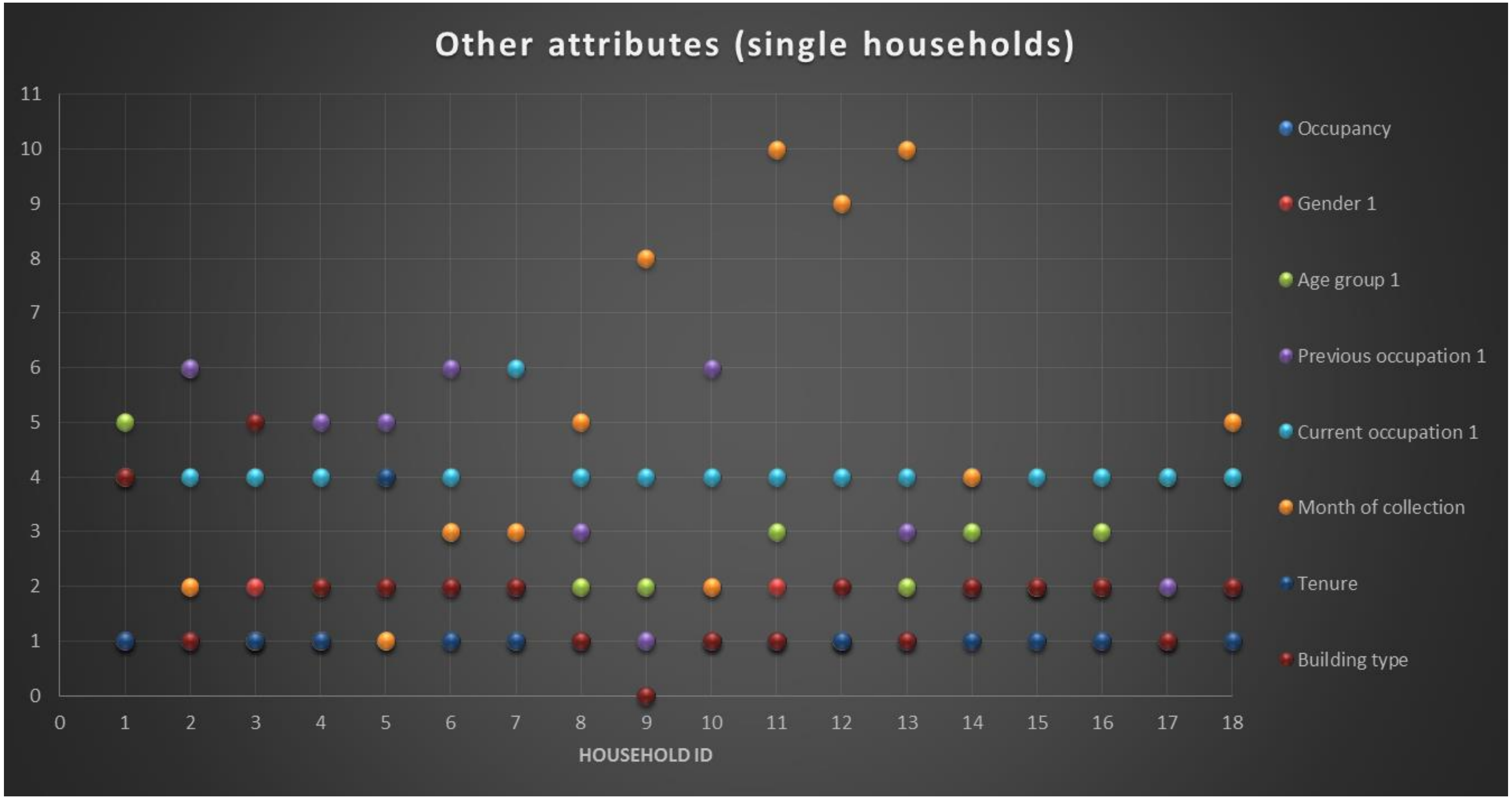

FIGURE 4.4: OTHER SINGLE HOUSEHOLD ATTRIBUTES

TABLE 4:1: LEGEND FOR FIGURE 4.3, FIGURE 4.4, FIGURE 4.13 AND FIGURE 4.14.

Feature	**Description**
Occupancy	single=1, multiple=2
Gender	Male=1, Female=2
Age group	65-69=1, 70-74=2, 75-79=3, 80-84=4, 85-89=5, 90+= 6
Previous and current occupation	1=managerial, 2=clerical, 3=manual, 4=retired, 5=volunteer, 6=others
Month of collection	Jan=1, Feb=2, Mar=3, Apr=4, May=5, Jun=6, Jul=7, Aug=8, Sep=9, Oct=10, Nov=11, Dec=12
Tenure	Owner=1, Local authority=2, Private rented=3, Others=4
Building type	1=Detached, 2=semi-detached, 3=flat, 4=Bungalow, 5=others
The frequency of device use: Dishwasher, Electric hob, Kettle, Microwave, Oven, Radio, Toaster, Washing machine, Vacuum cleaner	NA=0, Less often=1, Once a month= 2, Every 2 weeks= 3, Once a week= 4, Twice a week= 5, More than twice a week= 6, Once daily=7, Twice daily=8, More than twice daily = 9

4.2.2 Single households' device use by the day of the week

Monday

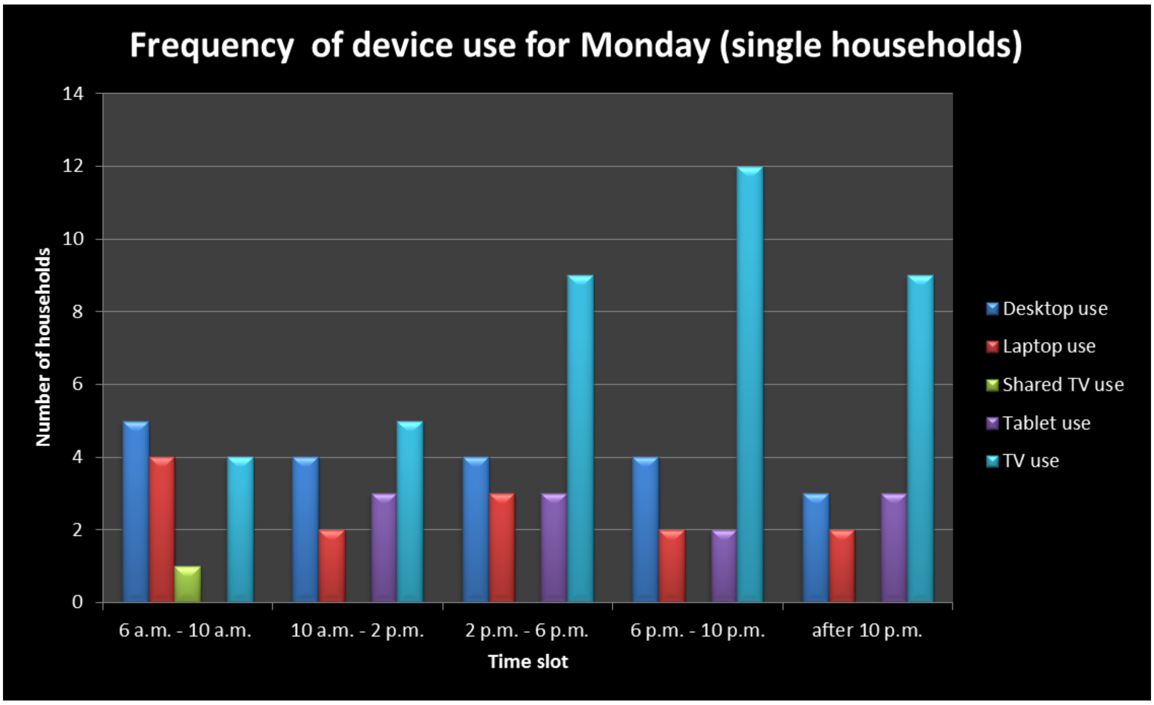

FIGURE 4.5 FREQUENCY OF DEVICE USE (SINGLE HOUSEHOLDS)

Figure 4.1 indicates that more of the households was at their maximum intra-day index at the 6 a.m. - 10 a.m. and 6 p.m. – 10 p.m. time slots than any other time slots. The average intra-day index also followed the same pattern. These suggest that device use was concentrated at these times slots and indicated a dual peak of device use for Monday. When investigated across the week, as indicated in Figure 4.2, about 16% (3 of 18) reached their inter-day maximum on Monday. As indicated in Figure 4.5, the number of households watching TV alone peaked at the 6 p.m. – 10 p.m. time slot with single laptop use peaking at the 6 a.m. - 10 a.m. time slot and somewhat flattening through the other time slots. The pattern of device use suggests that the synchronicity of different devices peaked at different time slots of the day with desktop use highest at the 6 a.m. – 10 a.m.

and tablet use remaining almost stable in frequency of households from the 10 a.m. – 2 p.m. time slot through the day.

Tuesday

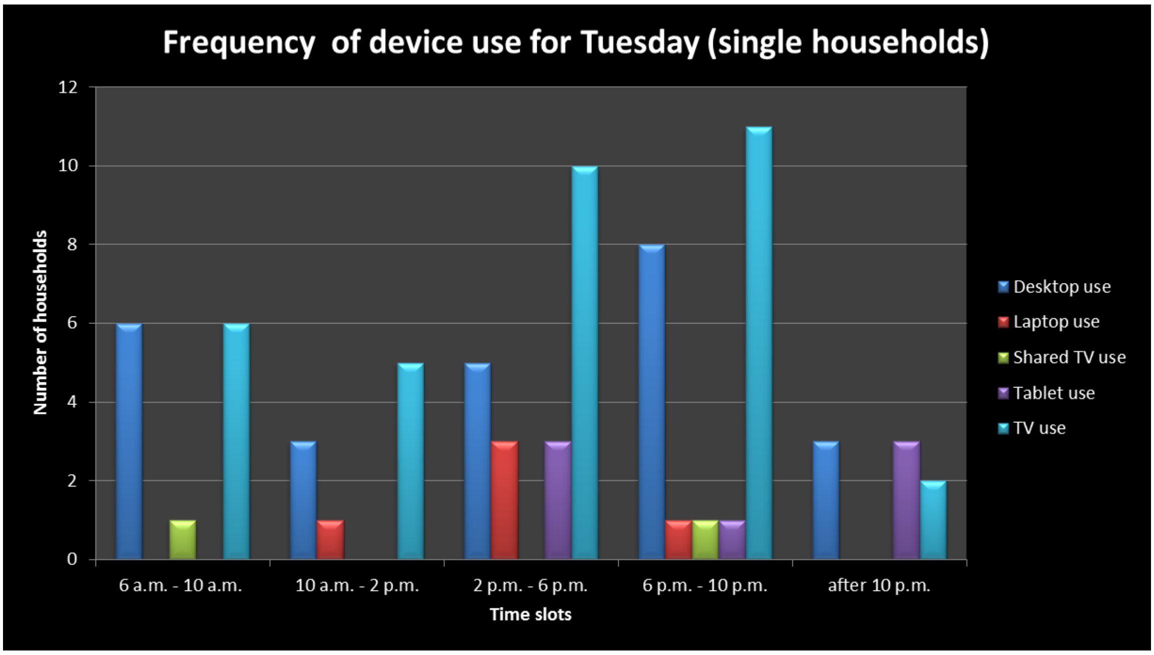

FIGURE 4.6: FREQUENCY OF DEVICE USE (SINGLE HOUSEHOLDS)

On Tuesday, as indicated in Figure 4.1, the number of households at their maximum intra-day intensity declined from the 6 a.m. – 10 a.m. time slot to the 10 a.m. – 2 p.m. time slot where it rose and peaked at the 6 p.m. – 10 p.m. time slot. This suggests that a considerable number of the cohort's kWh meter readings declined initially suggesting fewer energy-relevant activities. None of the households reached their inter-day maximum on Tuesday (Figure 4.2). This suggests that Tuesday was a "typical day" for the cohort as they did not consume with higher intensity than the rest during the week.

In Figure 4.6, the desktop synchronicity of use for desktop and TV use featured strongly from the 6 a.m. -10 a.m. time slot with a similar pattern for both devices declining at the 10 a.m. – 2 p.m. time slot and peaked at the 6 p.m. – 10 p.m. time slot. I deduced from the Figures 9, 10 and 12 that Tuesday was a "typical day" for all the single households. A typical day for all the households refers to a day when none of the households reached their maximum intensity of the week. This day was characterised as indicated in Figure 4.6 to entail the cohort watching extended hours of TV and desktop use.

Wednesday

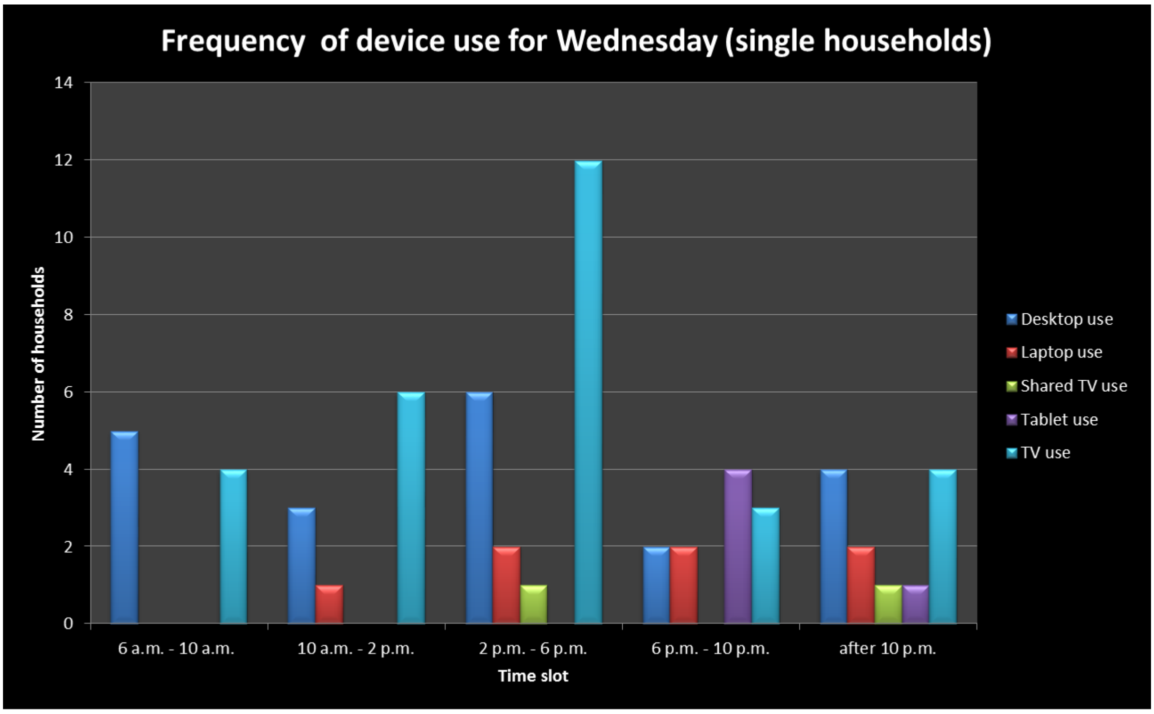

FIGURE 4.7: FREQUENCY OF DEVICE USE (SINGLE HOUSEHOLDS)

On Wednesday, as shown in Figure 4.1, the intra-day demand indicated that the day started with about 11% (2 of 18) of the households at their maximum intra-day index at the 6 a.m. – 10 a.m. time slot sliding steadily to a peak with about 39% of the households having their maximum intra-day index at the 6 p.m. – 10 p.m. In the context of the week, none of the households reached their maximum intra-day index for the week. As with Tuesday (above), Wednesday indicated a typical day as the combination of energy-relevant activities occurring was not the highest for the week.

The synchronicity of device use (number of households) as shown in Figure 4.7, the TV and desktop use had a similar pattern starting at the 6 a.m. – 10 a.m. time slot and rising steadily indicated that the individual desktop use peaked at the 2 p.m. – 6 p.m. time slot and the individual laptop use had the same level of synchronicity across 3 consecutive time slots. The individual tablet use peaked at the 6 p.m. - 10 p.m. time slot with no use prior and only one household using it at the after 10 p.m. time slot. Individual TV use peaked at the 2 p.m. - 6 p.m. time slot with shared TV use by one household at the 2 p.m. – 6 p.m. and the after 10 p.m. time slot.

Thursday

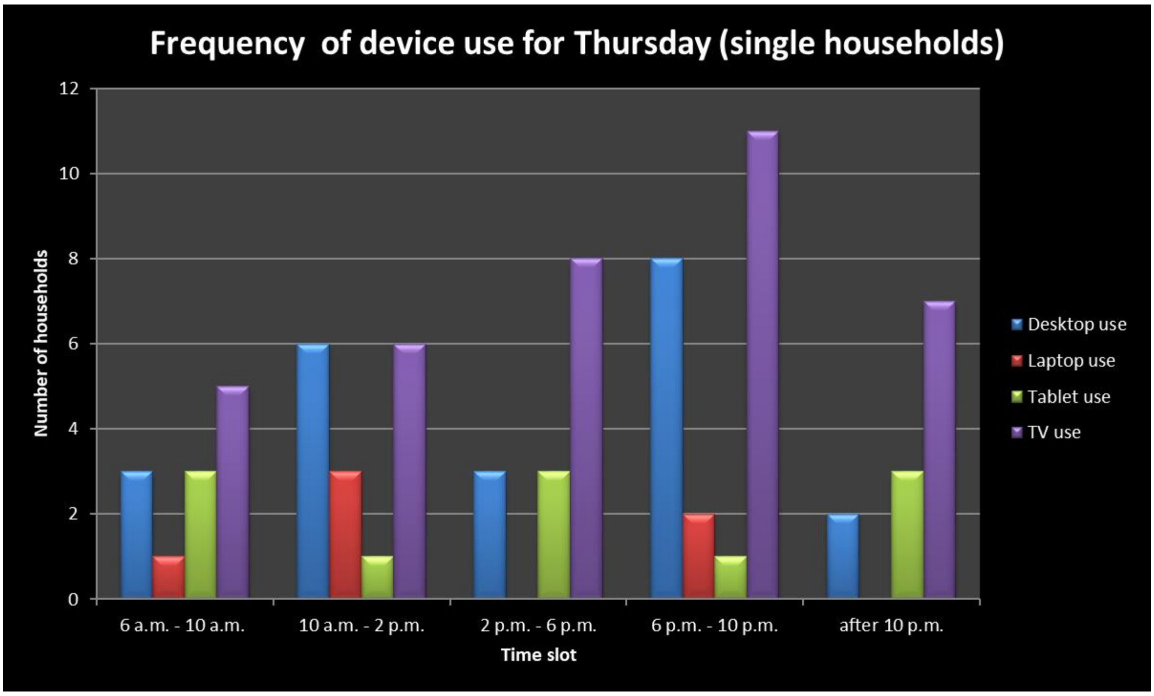

FIGURE 4.8: FREQUENCY OF DEVICE USE (SINGLE HOUSEHOLDS)

On Thursday (Figure 4.1), the pattern of intra-day demand suggested two peaks with about 28% (5 of 18) of the single households at their maximum intra-day intensity at the 10 a.m. – 2 p.m. time slot and about 39% (7 of 18) of the cohort at their maximum at the 6 p.m. – 10 p.m. time slot. In-between these time slots, there were fewer households at their maximum intra-day intensity. In Figure 4.2, the pattern if the inter-day index suggested a clear pattern for the single households. There was no household at their maximum for the week through the day except for the 2 p.m. – 6 p.m. time slot with only about 11% (2 of 18) of the households. In other words, the pattern of intensity of the demand inter-day suggests that Thursday was a “typical” day within the context of the week. Figure 4.18 showed that the TV and desktop were in use from all day, and use peaked at the 6 p.m. – 10 p.m. time slot. The single tablet use fluctuated throughout the day with at least one household using it throughout the day and the same level of synchronicity at 6 a.m. – 10 a.m., 2 p.m. - 6 p.m. and after 10 p.m.

Friday

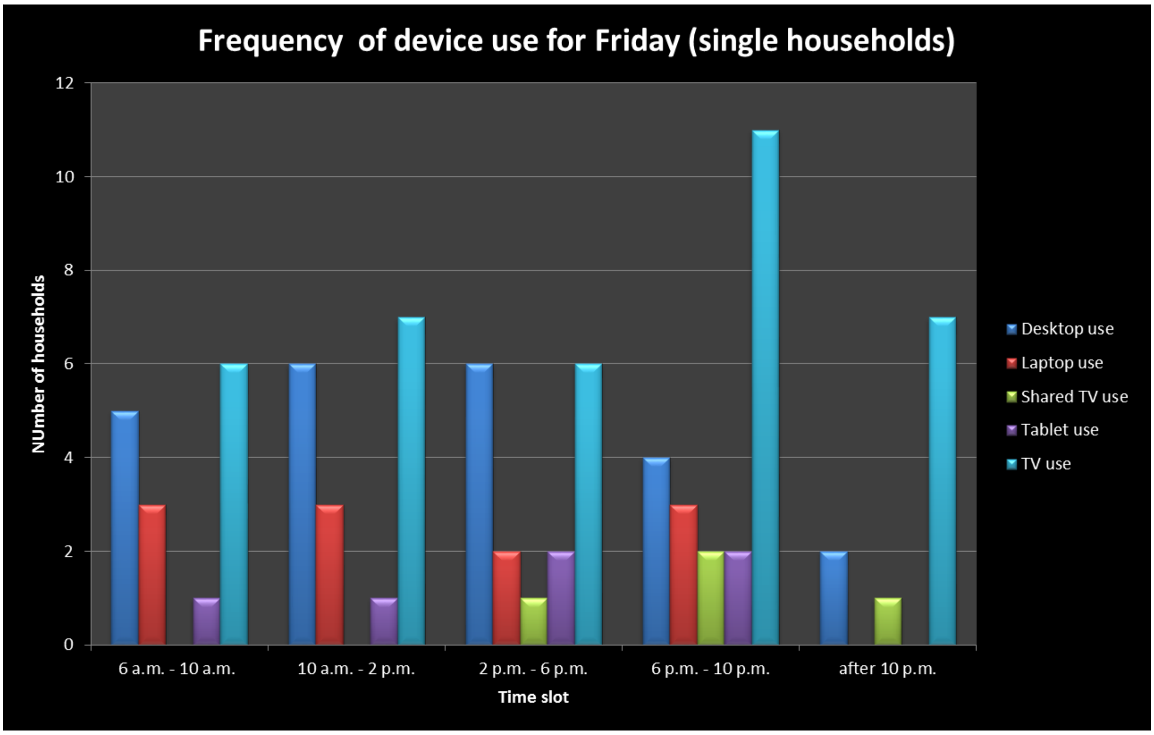

FIGURE 4.9: FREQUENCY OF DEVICE USE (SINGLE HOUSEHOLDS)

On Friday, as in Figure 4.1 above, peak intra-day intensity of demand was at the 6 p.m. – 10 p.m. time slot with 50% (9 of 18) of the households. The pattern suggested that the number of households declined from the 6 a.m. – 10 a.m. time slot with about 22% (4 of 18) of the households to about 5% (1 of 18) and then reach the above-mentioned peak from the preceding time slot.

Figure 4.9 indicated that individual (TV use and desktop use) occurred through the day. The individual (laptop use and tablet use) remained stable for most of the day. The 2 p.m. – 6 p.m. time slot was significant such that six households had single TV use and the single desktop use. Similarly, the single tablet and laptop use was the same at the 2 p.m. – 6 p.m. time slot. Despite these, the peak synchronicity between the devices was dissimilar with only the TV having a distinct peak synchronicity at the 6 p.m. – 10 p.m. while the other devices had multiple peaks through the day.

Saturday

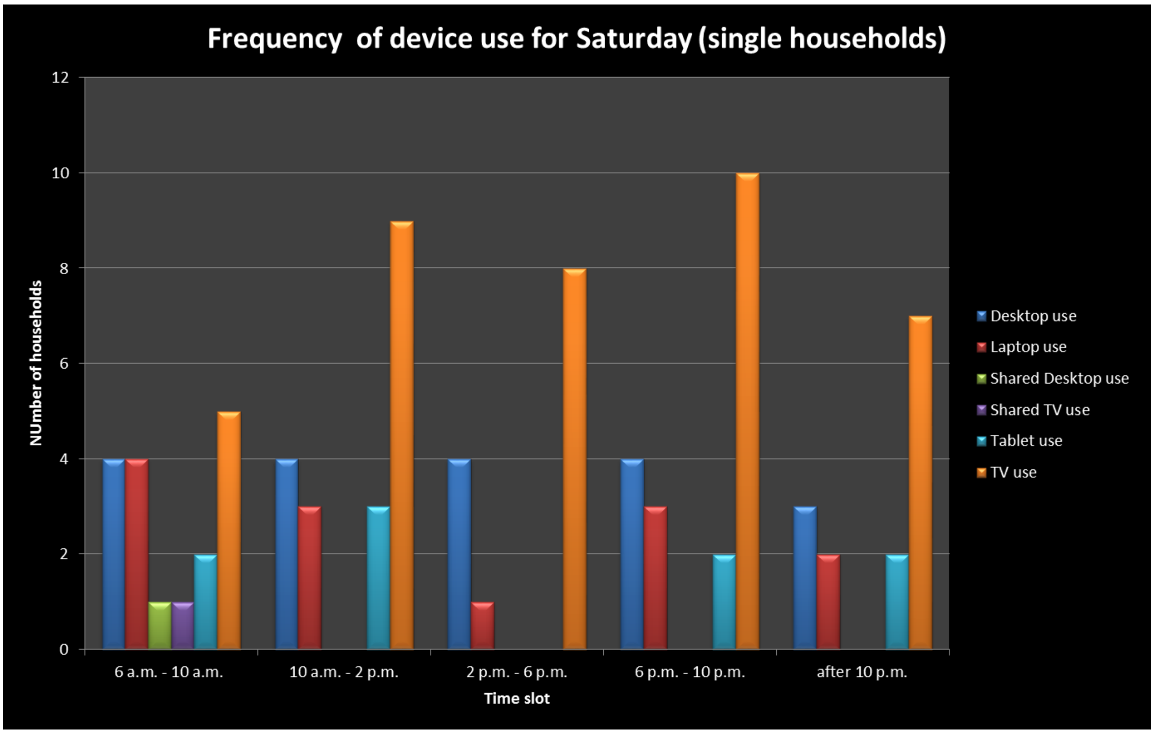

FIGURE 4.10: FREQUENCY OF DEVICE USE (SINGLE HOUSEHOLDS)

In Figure 4.1, the intra-day index suggested a gradual synchronicity of maximum intra-day index as about 11% (2 of 18) of the households had their maximum intra-day index across the 6 a.m. – 10 a.m. until 10 a.m. – 2 p.m., and the synchronicity of maximum intra-day index were highest at the 6 p.m. – 10 p.m. time slot with about 56% (10 of 18) of the single households. The inter-day index (see Figure 4.2) however, had a different rhythm with no household at their maximum for all the time slots except the 2 p.m. – 6 p.m. time slot where about 11% (2 of 18) of the households had their maximum. This suggests that Saturday was a typical day for a majority of the households as they did not perform a combination of energy-relevant practices that culminated in their maximum inter-day demand.

The results indicated in Figure 4.10 suggested that there was an almost stable level of synchronicity of use for the single desktop use through the day as 4 of the 5 time slots had 4 households using it. The single laptop use synchronicity peaked at the start of the day (6 a.m. – 10 a.m. time slot) and seems to decline through the day. The single tablet use synchronicity peaked at the 10 a.m. – 2 p.m. time slot with 2 households using it for 3 of the 5 time slots and the 2 p.m. – 6 p.m. time slot indicating no household use. The individual TV use peaked at the 6 p.m. – 10 p.m. time slot. It is worthy of note that only one household indicated shared TV and shared desktop use at the 6 a.m. – 10 a.m. time slot.

Sunday

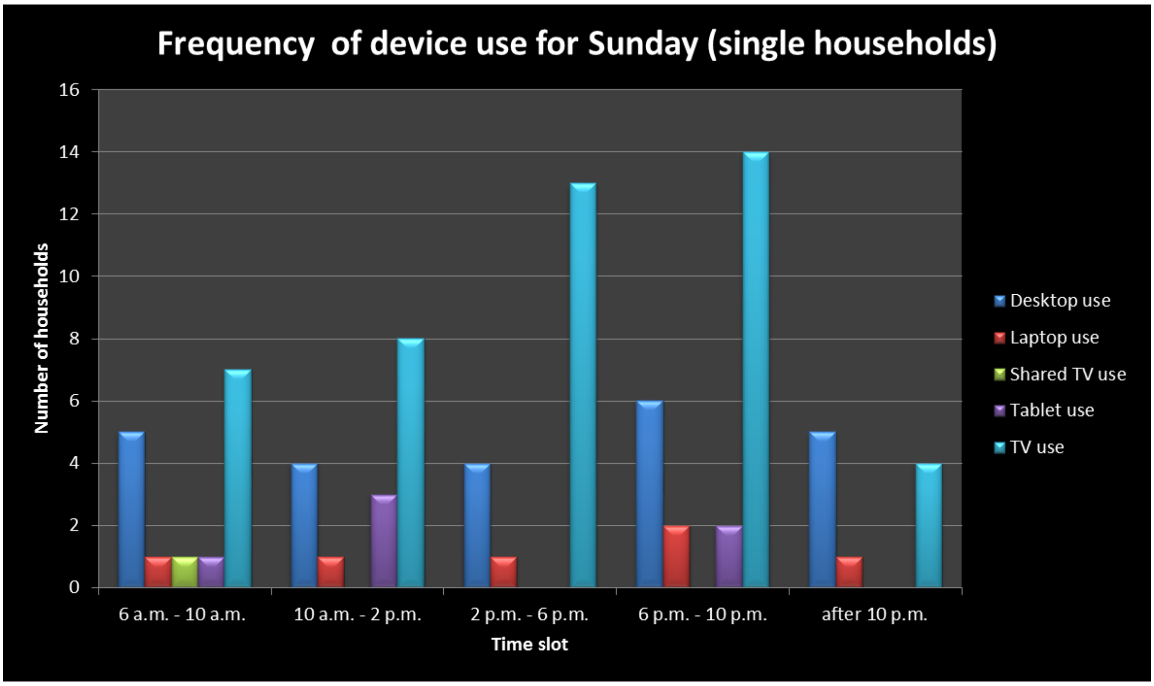

FIGURE 4.11: FREQUENCY OF DEVICE USE (SINGLE HOUSEHOLDS)

As indicated in Figure 4.1, the day started (6 a.m. – 10 a.m. time slot) with about 11% (2 of 18) of the households at their intra-day maximum and declined to about 5% (1 of 18) of the households at the 10 a.m. – 2 p.m. time slot where it rose to a shared peak synchronicity of maximum intra-day index with about 33% of the households at the 2 p.m. – 6 p.m. and 6 p.m. – 10 p.m. time slots. Across the week, as in Figure 4.2, Sunday did not indicate strong weekly energy-relevant activities as the 6 a.m. – 10 a.m. and 6 p.m. – 10 p.m. time slots had about 5% (1 of 18) and about 17% (3 of 18) of the households at their maximum inter-day intensity respectively. The results (as in Figure 4.11) indicated that single (desktop use, laptop use and TV use) featured through the day with their peak synchronicity of use at the 6 p.m. - 10 p.m. time slot.

4.3 Two-person households

4.3.1 Summary of Two-person households

This section features the description and summary of the 41 two-person households that were part of this study. As with the single households in 4.1 above, I investigated these households for a week. Their age groups, device use and ownership varied as indicated in Figure 4.15 below. This section entails the summary of the intra and inter-day indexes. I also describe each day of the week in the everyday life of this cohort from the lens of the intensity of demand (intra and inter-day) and the synchronicity of (individual and shared) demand for the selected devices in the subsections for the days of the week. The focus in this description is the time slots (per day) with the highest intensities of demand and the highest synchronicity of device use. All the Figures reflect data that was collected for one week per household.

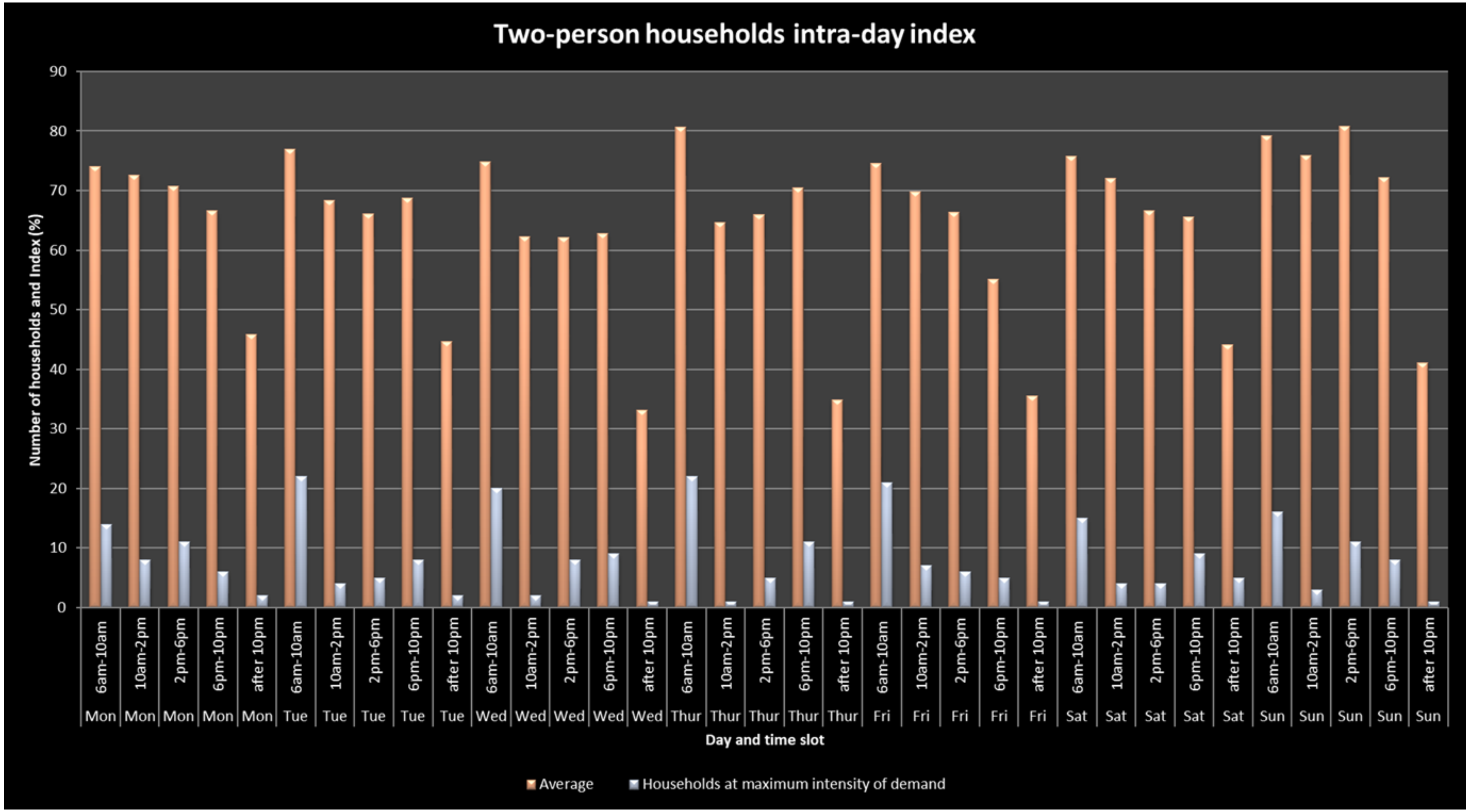

FIGURE 4.12: INTRA-DAY INDEX AT A GLANCE (TWO-PERSON HOUSEHOLDS)

The pattern of frequency of maximum intra-day index in Figure 4.12 above indicates a clear congruence of energy-intense activities at the 6 a.m. – 10 a.m. time slot. The pattern of the average intra-day index in Figure 4.12 suggests same but also indicates that other time slots averaged near the peak except the after 10 p.m. time slot. The lowest average intra-day index is 40%. This suggests that the households had many of their appliances on for prolonged period of time during the week. As I explained earlier, doings that led to demand, as their average indexes have suggested Figure 4.12 comparatively higher meter readings are expected when compared with single households.

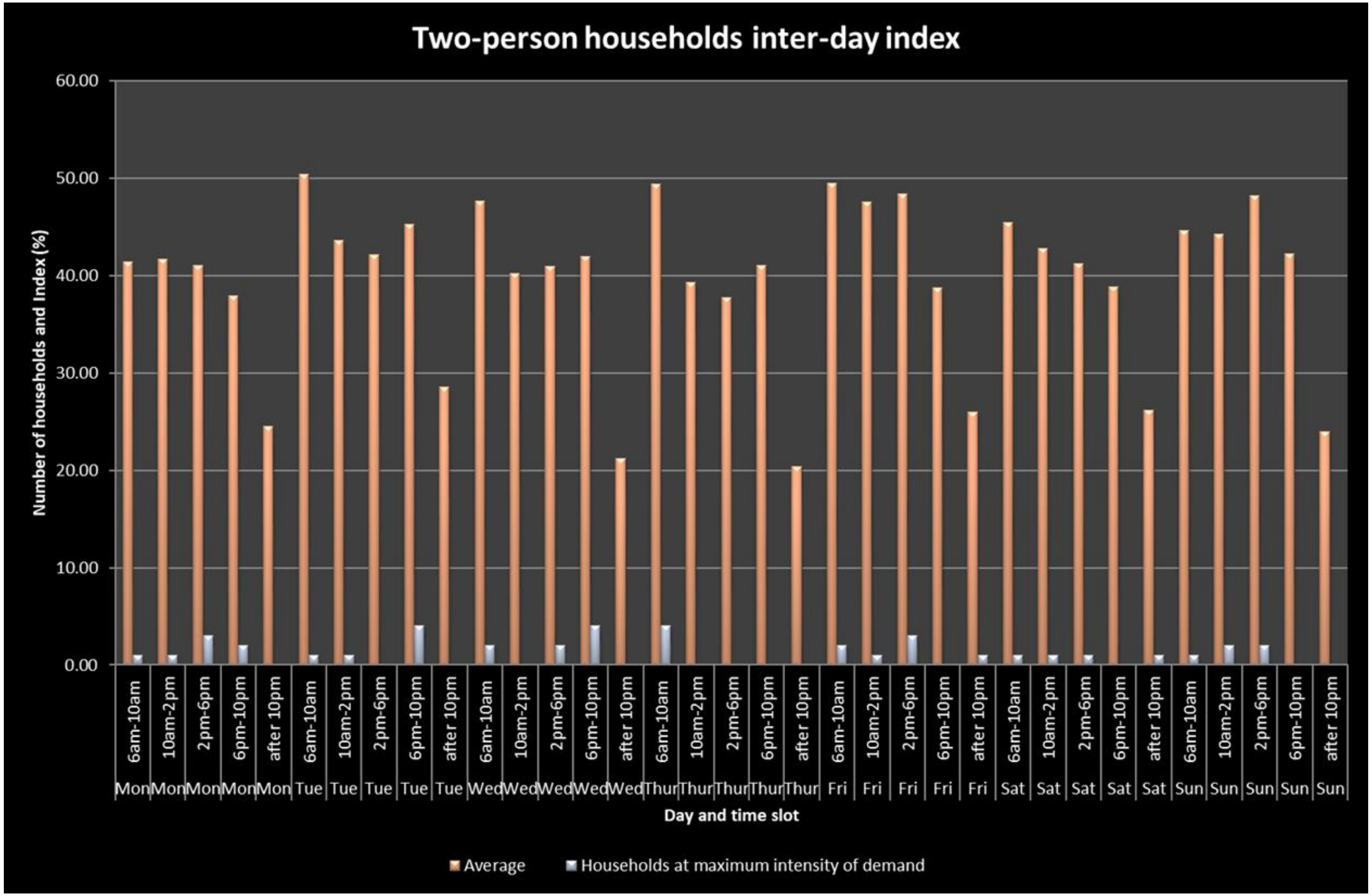

FIGURE 4.13: INTER-DAY INDEX AT A GLANCE (TWO-PERSON HOUSEHOLDS)

Figure 4.13 suggests a clear similarity in the pattern in the pattern of average demand and the number of households at their maximum inter-day index.

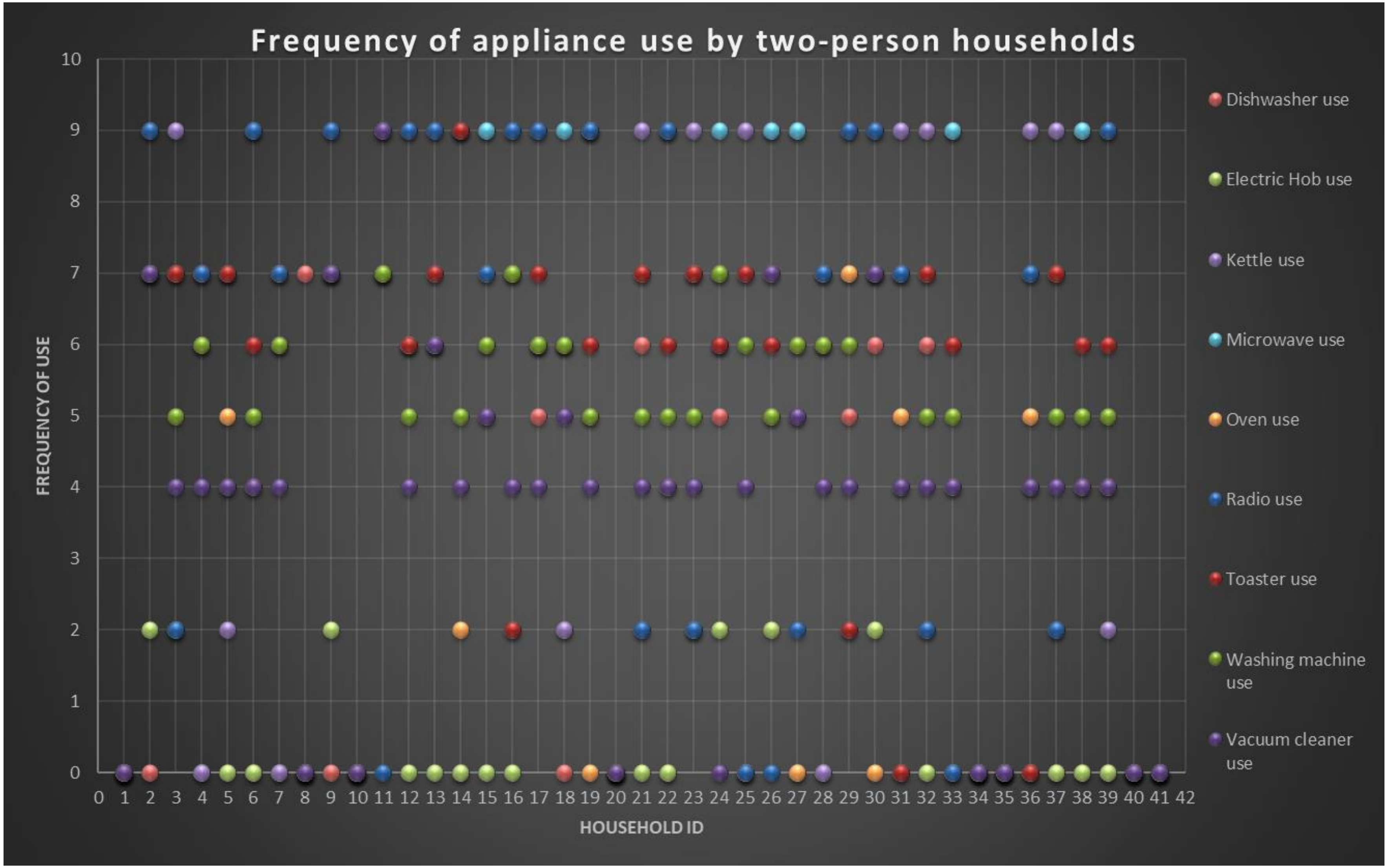

FIGURE 4.14: FREQUENCY OF APPLIANCE USE (TWO-PERSON HOUSEHOLDS)

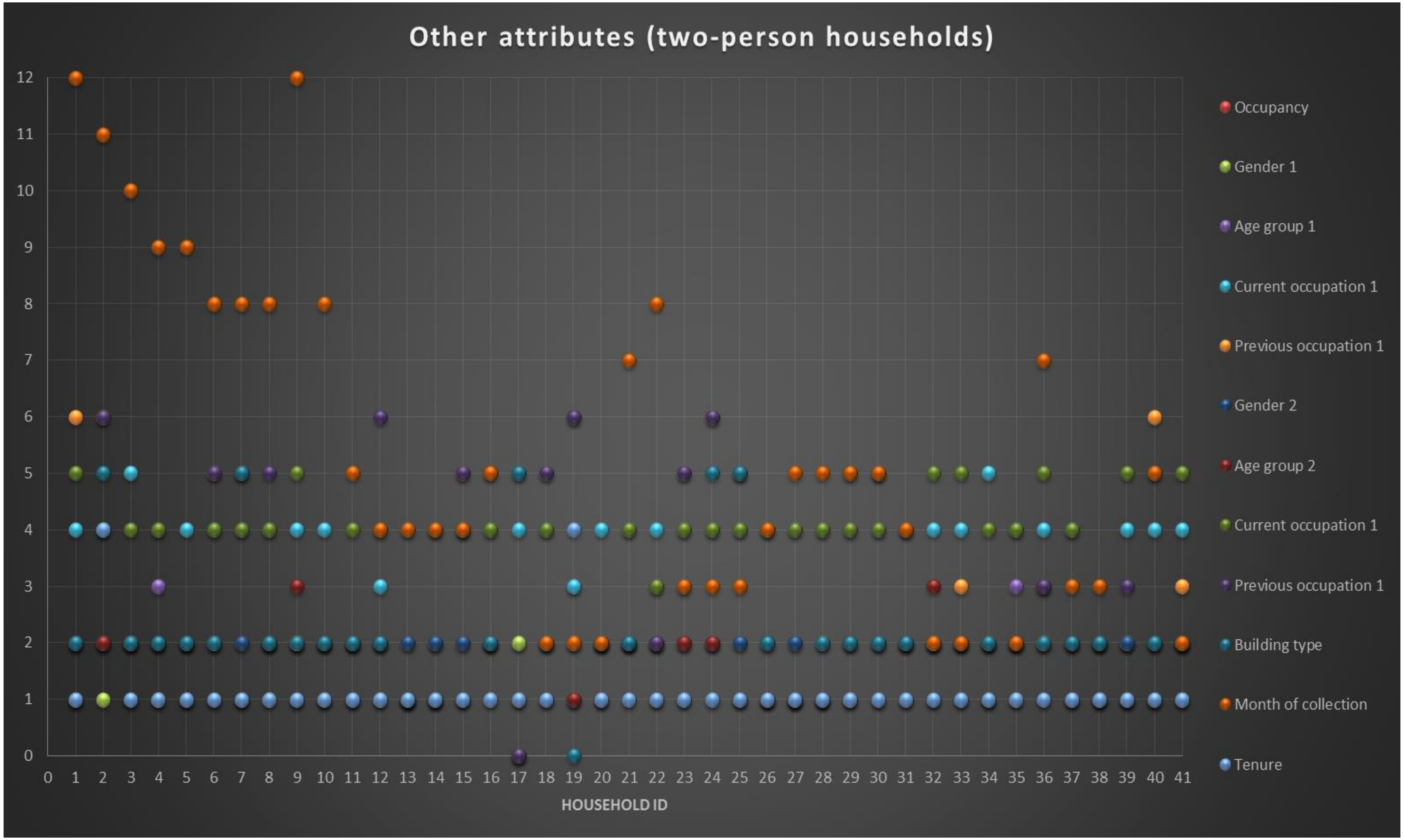

FIGURE 4.15: OTHER ATTRIBUTES (TWO-PERSON HOUSEHOLDS)

4.3.2 Two-person households' device use by the day of the week

Monday

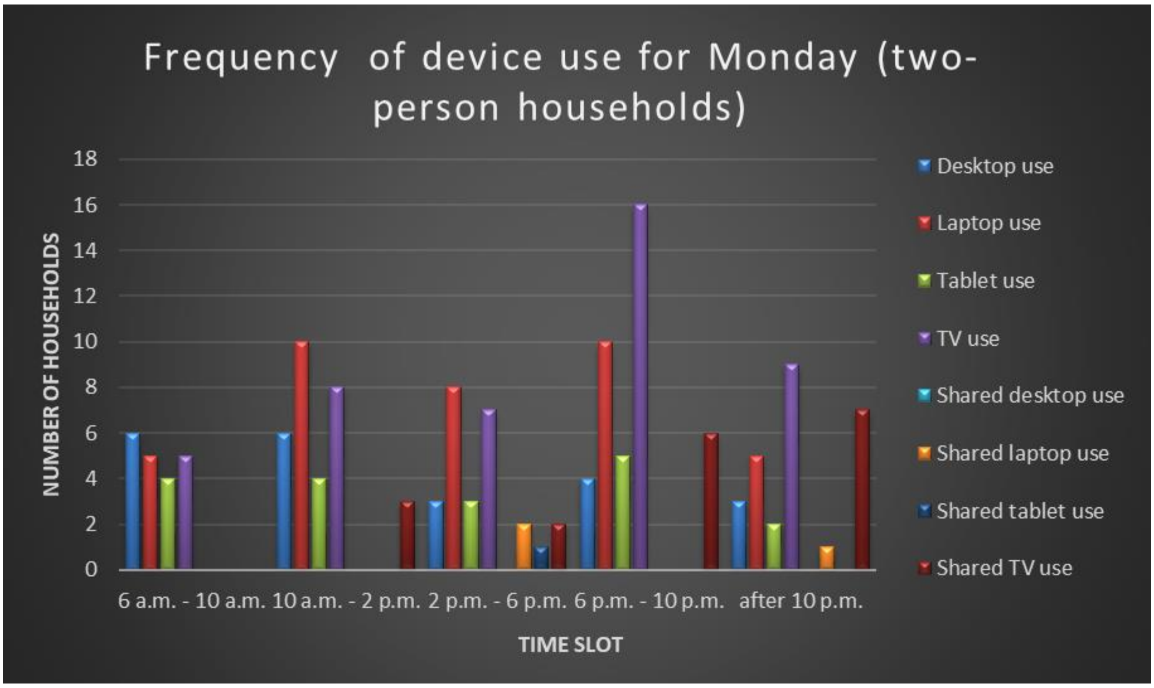

FIGURE 4.16: FREQUENCY OF DEVICE USE (TWO-PERSON HOUSEHOLDS)

On Monday, Figure 4.12 suggested that the intra-day index of the two-person households was characterised with two peaks with the greater of the two peaks at the 6 a.m. – 10 a.m. time slot with about 34% (14 of 41) of the two-person households and the lesser at the 2 p.m. – 6 p.m. time slot with about 27% (11 of 41) of the two-person households. More than one-third of the cohort having their maximum intra-day index at the 6 a.m. – 10 a.m. time slot suggested that the households somewhat synchronised on the combination of energy-relevant activities that led to this for the day. In the context of the week (Figure 4.13) the rhythm was different with one peak at the 2 p.m. – 6 p.m. time slot where only about 7% (3 of 41) of the two-person households reached their maxim inter-day index. The inter-day index suggested that Monday was a typical day for the households as there was no significant agglomeration of households at their maximum inter-day index. The use frequency results in Figure 4.16 above suggests that the synchronicity of TV use (both individually and shared) peaked at 6 p.m. – 10 p.m. with a wavy rhythm throughout the day. Other device uses had multiple peaks with shared use frequency values across multiple time slots.

Tuesday

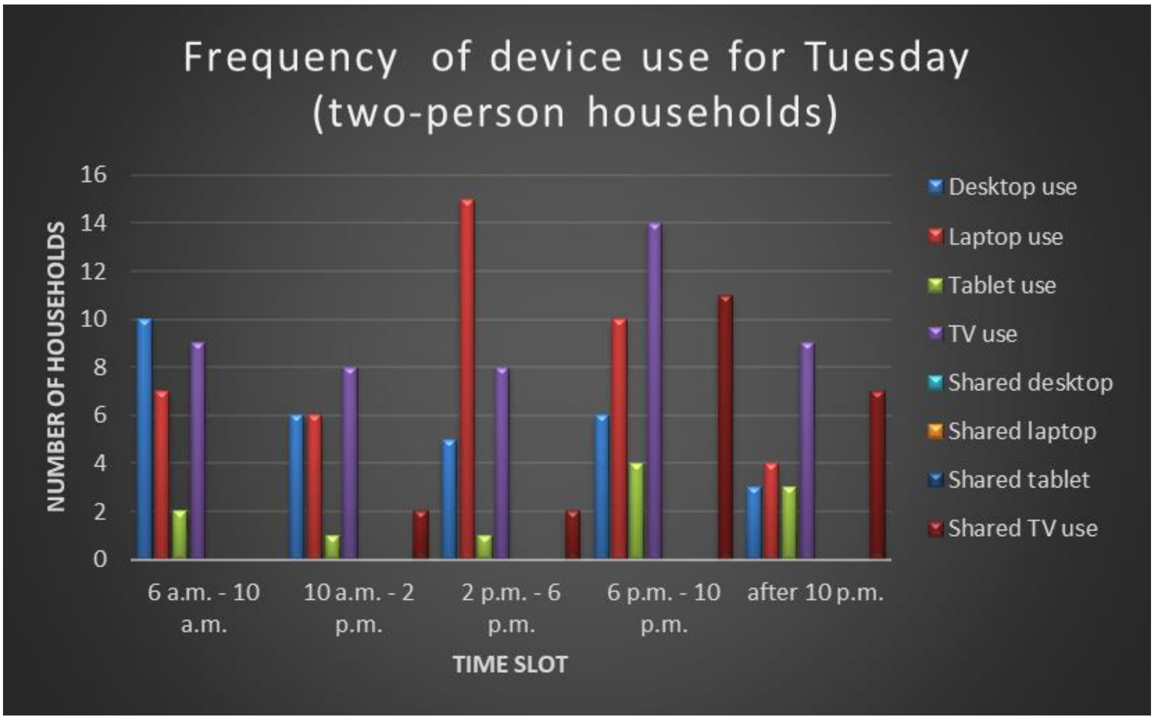

Figure 4.17: FREQUENCY OF DEVICE USE (TWO-PERSON HOUSEHOLDS)

On Tuesday, the intra-day index rhythm (in Figure 4.12) suggested that the highest synchronicity of maximum index was at the 6 a.m. – 10 a.m. time slot with about 54% (22 of 41) of the two-person households. There was a decline in synchronicity through the day as the subsequent time slot (10 a.m. – 2 p.m.) indicated only about 10% (4 of 41) of the two-person households at their maximum intra-day intensity. The 6 p.m. – 10 p.m. time slot indicated a gentle rise in maximum intra-day index synchronicity with about 17% (8 of 41) of the two-person households. This rhythm suggests that the two-person households on a Tuesday were characterised by a morning peak (6 a.m. – 10 a.m. time slot) for more than half of our cohort, and the other half were spread throughout the day. In the context of the week (as in Figure 4.13), the rhythm of demand suggested a clear peak of synchronicity of inter-day index at the 6 p.m. – 10 p.m.

time slot with about 10% (4 of 41) of the two-person households at their maximum inter-day index. However, earlier in the day indicated that about 2% (1 of 41) of the households were at their maximum inter-day index at the 6 a.m. – 10 a.m. and the 10 a.m. – 2 p.m. time slots respectively.

In the case of synchronicity of use, as indicated in Figure 4.17 above, the rhythm of device use suggested single use for all the observed devices peaked at the 6 p.m. – 10 p.m. time slot. The shared TV use synchronicity peaked at the 2 p.m. – 6 p.m. time slot with shared use occurring through the day except for the after 10 p.m. time slot.

Wednesday

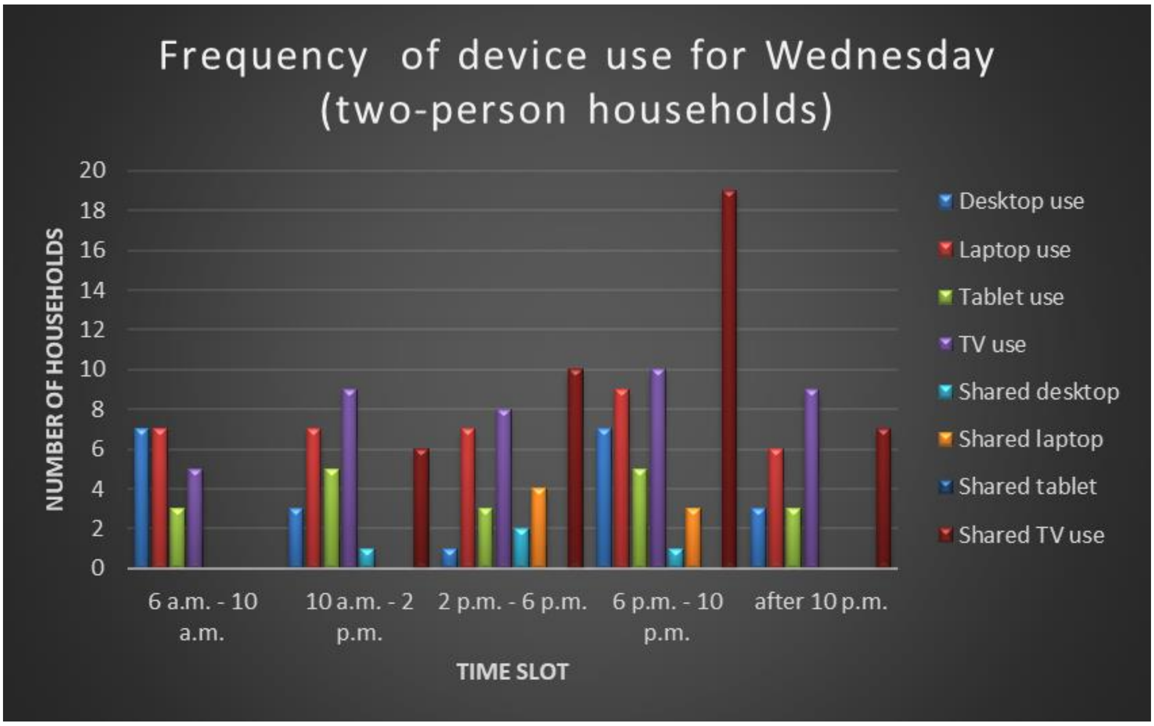

FIGURE 4.18: FREQUENCY OF DEVICE USE (TWO-PERSON HOUSEHOLDS)

On Wednesday, the rhythm of the intra-day index (as in Figure 4.12) indicated that about 54% (20 of 41) of the two-person households reached their maximum intra-day index at the 6 a.m. – 10 a.m. time slot. This peak synchronicity of intra-day index declined to about 5% (2 of 41) of the two-person households at the 10 a.m. – 2 p.m. time slot. Subsequent time slots indicated that about 19% (8 of 41), and about 22% (9 of 41) two-person households were at their maximum intra-day index at the 2 p.m. – 6 p.m. and the 6 p.m. – 10 p.m. time slots respectively.

As indicated in Figure 4.13, the rhythm of the inter-day index indicated that no household was at their maximum inter-day index for the week at the 10 a.m. – 2 p.m. and the after 10 p.m. time slots. Two of the time slots (6 a.m. – 10 a.m. and the 2 p.m. – 6 p.m.) had about 5% (2 of 41) of the two-person households at their maximum inter-day index. There was, however, a clear distinction in synchronicity as about 10% (4 of 41) of the two-person households were at their maximum inter-day index at the 6 p.m. – 10 p.m. time slot.

The pattern of synchronicity of device use indicated that the highest synchronicity of single-use for the devices was all at the 6 p.m. – 10 p.m. time slot. The pattern of shared use was different with peaks at the 2 p.m. – 6 p.m. and 10 a.m. – 2 p.m. for TV and laptop use respectively. All the devices indicated single use throughout the day with varying frequencies of use.

Thursday

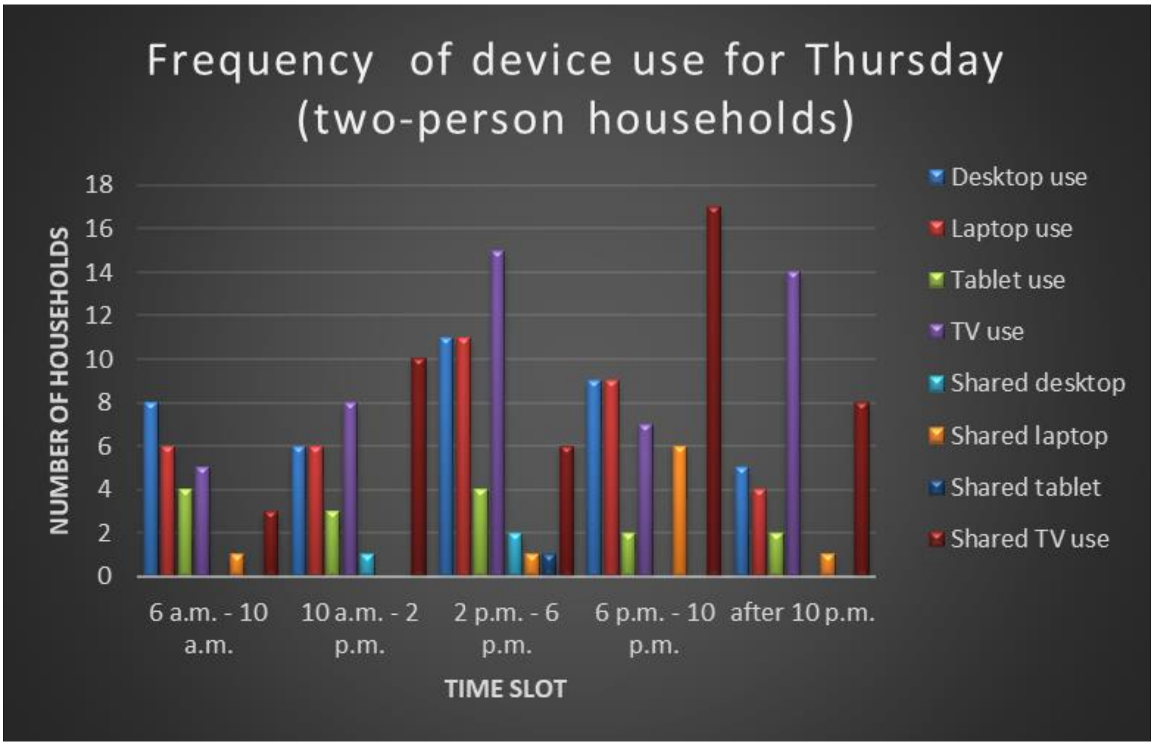

Figure 4.19: FREQUENCY OF DEVICE USE (TWO-PERSON HOUSEHOLDS)

The two-person households' intra-day index (Figure 4.12) rhythm of demand suggested that synchronicity of intra-day maximum intensity was highest at the 6 a.m. – 10 a.m. time slot with about 54% (22 of 41) of the two-person households. The nearest was at the 6 p.m. – 10 p.m. time slot with about 27% (11 of 41) of the households at the maximum intra-day intensity. Two of the time slots (10 a.m. – 2 p.m. and after 10 p.m.) time slots had only about 2% (1 of 41) household each.

The synchronicity of the inter-day index as in Figure 4.13 indicated a clear distinction as about 10% (4 of 41) of the two-person households were at their maximum inter-day index at the 6 a.m. – 10 a.m. time slot, and no household reached their maximum inter-day index for the rest of Thursday.

The synchronicity of device use in Figure 4.19 suggested that there was at least one household sharing a device for at least one time slot. The shared TV use occurred throughout the day during the peak of synchronicity at the 6 p.m. – 10 p.m. time slot. The single use of devices indicated that a peak of synchronicity occurred at the 2 p.m. – 6 p.m. time slot. Same use frequency levels were recorded for single (desktop and laptop use) at the 2 p.m. – 6 p.m. and 6 p.m. – 10 p.m. time slots.

Friday

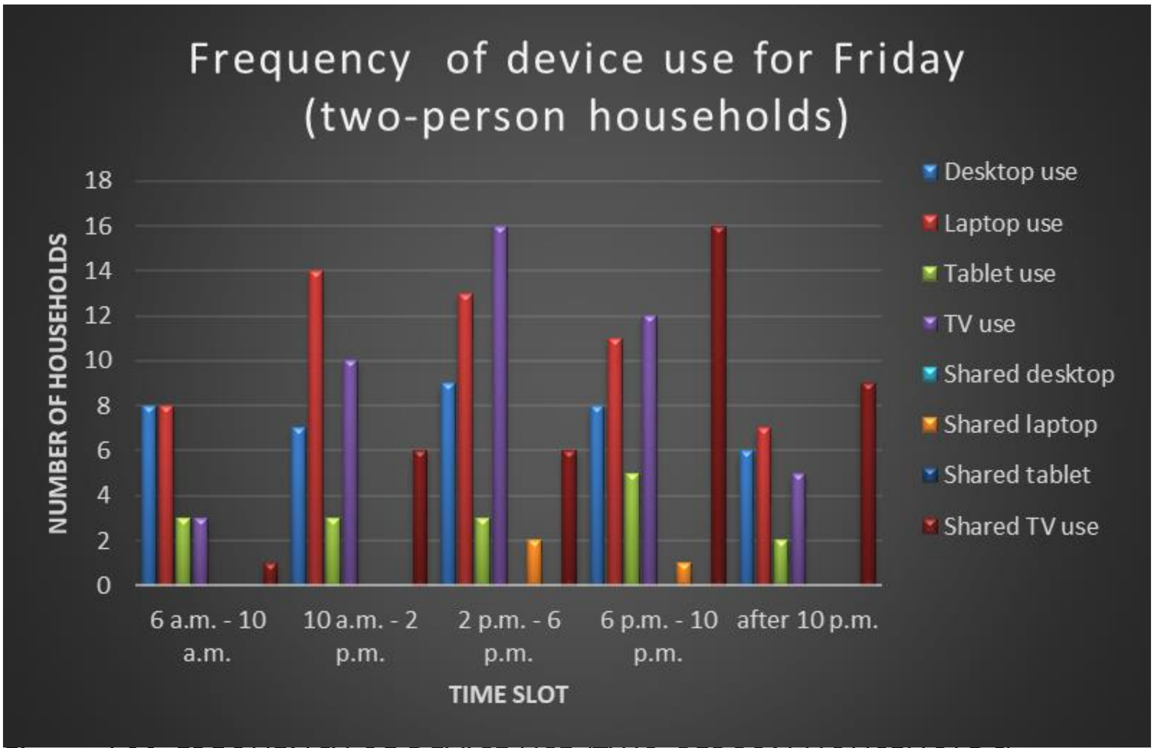

Figure 4.20: FREQUENCY OF DEVICE USE (TWO-PERSON HOUSEHOLDS)

On Friday, the intra-day index (Figure 4.12) suggested that about 51% (21 of 41) households reached their maximum at the 6 a.m. – 10 a.m. time slot. The pattern suggested a significant dip to about 17% (7 of 41) two-person households at the 10 a.m. – 2 p.m. and continued declining in synchronicity to about 2% (1 of 41) two-person households at the after 10 p.m. time slot.

When investigated through the week, Friday pattern of inter-day maximum index (as shown in Figure 4.13) suggested that there was a spread in the timing of the maximum inter-day index as about 2% (1 of 41) of the two-person households reached their maximum inter-day index at the 10 a.m. – 2 p.m. and the after 10 p.m. time slots respectively. The peak synchronicity of maximum inter-day demand was at the 2 p.m. – 6 p.m. time slot closely followed by the 6 a.m. – 10 a.m. time slot with about 7% (3 of 41) and about 5% (2 of 41) of the two-person households respectively.

The synchronicity of device use (as indicated in Figure 4.20) hold a peak at the 2 p.m. – 6 p.m. for the single use for (TV, laptop and desktop). The single tablet use peaked at the 6 p.m. – 10 p.m. time slot. At the 6 a.m. – 10 a.m. time slot, similar frequency values were recorded for single (tablet use and TV use) and single (desktop use and laptop use). This implies that the everyday lives of our cohort for these devices were similar for this time slot. For shared use, at least one household was watching TV with someone else throughout the day with a peak of synchronicity of shared TV use at the 6 p.m. – 10 p.m. time slot.

Saturday

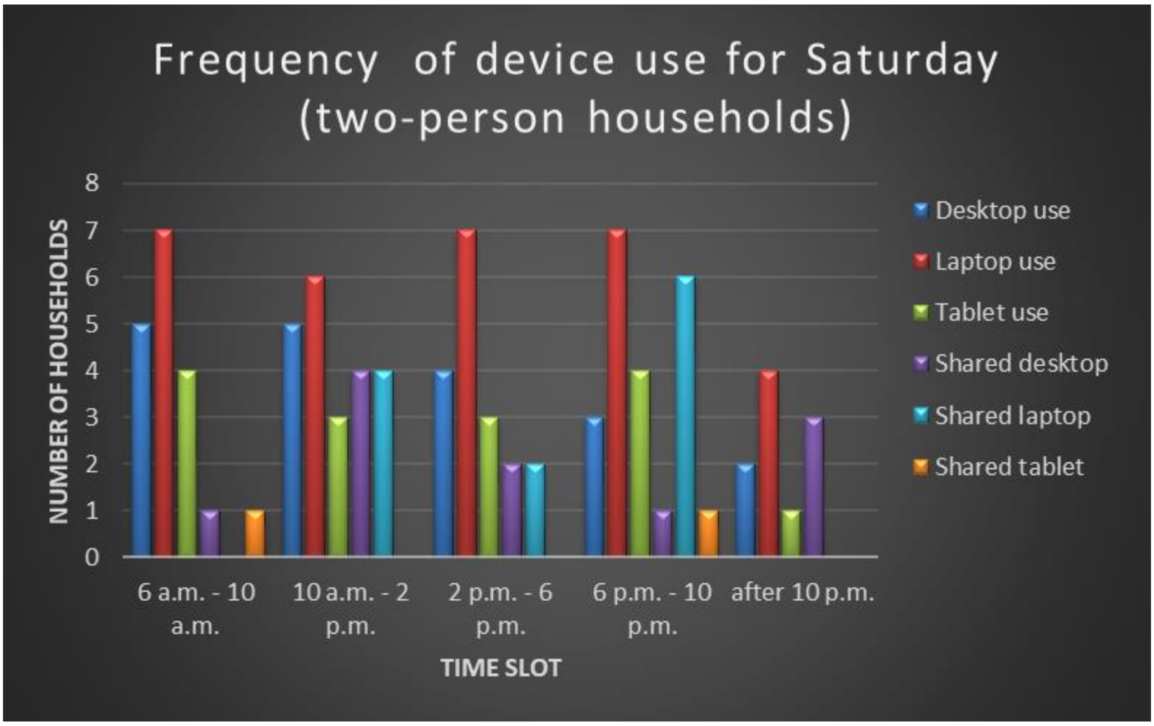

Figure 4.21: FREQUENCY OF DEVICE USE (TWO-PERSON HOUSEHOLDS)

On Saturday, the intra-day index (Figure 4.12) indicated that about 37% (15 of 41) of the households had their maximum intra-day index at 6 a.m. – 10 a.m. Other times during the day indicated a shared 10% (4 of 41) between two consecutive time slots (10 a.m. – 2 p.m. and the 2 p.m. – 6 p.m.) from where it rose in synchronicity to about 22% (9 of 41) at the 6 p.m. – 10 p.m. time slot. The after 10 p.m. also indicated that about 12% (5 of 41) of the two-person households were at their intra-day maximum intensity of demand.

When investigated across the week, (as indicated in Figure 4.13), Saturday indicated that about 2% (1 of 41) of the two-person households reached their maximum inter-day index for 4 of the 5 time slots with the exception having no household. In the context of everyday life, Saturday for the two-person households did not indicate that majority of the households were performing a combination of energy-relevant activities that led to their maximum inter-day demand. In other words, Saturday did not indicate any features of the weekend demand as it was a typical day for the cohort.

In Figure 4.21, I recorded that all the devices indicated single use by at least one household throughout Saturday. The TV, however, did not indicate any entry by the households. I also recorded the same frequency values across multiple time slots for the same device. Laptop single use also indicated same frequency values in the 6 a.m. – 10 a.m., 2 p.m. – 6 p.m. and the 6 p.m. – 10 p.m. time slots. Desktop shared use also indicated that it occurred in only one household at the 6 a.m. – 10 p.m. and 6 p.m. - 10 p.m. time slots. Similarly, shared tablet use occurred in one household at the same time slots as the share desktop use. These distinctions and similarities in the frequency value within and across devices indicate the variety of the patterns of shared and single use of devices that occurred in the cohort. There was no entry for TV use, which is a significant non-use finding in this study. It is worth noting that this is a surprising result and may have resulted from measurement errors.

Sunday

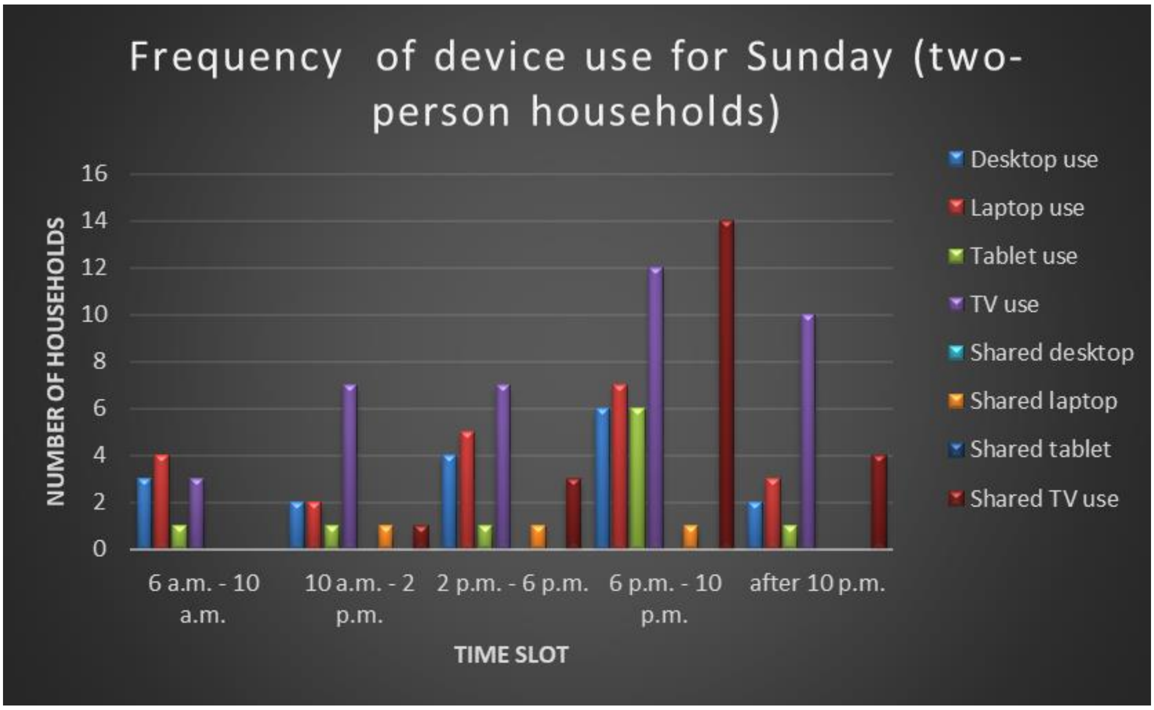

FIGURE 4.22: FREQUENCY OF DEVICE USE (TWO-PERSON HOUSEHOLDS)

Sunday, as shown in Figure 4.12, can be characterised by two peaks with the primary peak at the 6 a.m. – 10 a.m. time slot with about 39% (16 of 41) and the secondary peak with 27% (11 of 41) at the 2 p.m. – 6 p.m. of the two-person households. This rhythm implies that Sunday features a majority of the energy-intense activities during the morning for most of the households. In the context of the week, as shown in Figure 4.13, about 5% (2 of 41) of the two-person households had their maximum inter-day index at the 10 a.m. – 2 p.m. and 2 p.m. – 6 p.m. time slots each. The 6 p.m. – 10 p.m. and after 10 p.m. time slots had zero households.

The frequency values as shown in Figure 4.22 indicated that at least one household was using the investigated devices (single use) throughout the day. The single tablet use indicated that one household was using it throughout the day except for the 6 p.m. – 10 p.m. time where use synchronicity increased. Similar frequency values were recorded across devices in different time slots. The single TV use at the 10 a.m. – 2 p.m. and 2 p.m. – 6 p.m. time slots were the same with the single laptop use at the 6 p.m. – 10 p.m. time slot. These suggest that similar numbers of two-person households in our cohort were engaging in these activities at different times for two different activities. The shared TV use had a rhythm of the gradual increase in synchronicity of use from one household at the 6 a.m. – 10 a.m. time slot and rose subsequently to a peak at the 2 p.m. – 6 p.m. time slot.

Chapter 5 : Discussion

5.0 Chapter summary

This Chapter entails the discussion of the findings presented in Chapter 4 in line with the objectives of this thesis. It begins as an introduction in Section 5.1 and in Section 5.2, I discuss the findings sub-headed with the set objectives.

5.1 Introduction

This research acknowledged the plethora of approaches to the investigation of the everyday life of older people with(out) a focus on their energy demand in Chapter 2. However, the focus on the time of the day when activities took place, how they were concentrated or sparse is not widely addressed in the literature on older people. This study fills this gap based on the projected and implied importance of older people from census and energy literature respectively. As indicated in Chapter 3, this study's sample population was older people who live in Reading, UK.

The aim was to investigate whether the rhythms and timing of practices of older people are significantly different through the days during the week. I analysed the synchronicity of similar device uses and the synchronicity of cumulative electricity demand by indexing the readings (as explained in Section 3.1).

5.1.1 General findings

The findings indicate that solo living (single households) generally had a lower kWh reading than the two-person households (as shown in Figure 5.1). These results suggest a strong role of occupancy in energy demand (single or two-person) as these two categories were very distinct in their device use pattern. It also indicated that there were some "unusual days" (days in which households reached their maximum intensity of demand) that applied to all the households but occurred at different time slots on different days. In other words, the single households were less routinised than the two-person households in their rhythm of demand and device use.

In addition, the results highlighted that Monday through Friday, demand was difficult to generalise or label as "weekday" because the routines and practices within those days varied significantly. In the single households, for example, as indicated in Figure 4.2, the maximum inter-day index occurred on Monday and Thursday through Sunday. For two-person households, as shown in Figure 4.13, the "unusual days" seemed to occur more on Monday through Wednesday with fewer households at their maximum inter-day index on other days. Table 5.1 below summarises the findings for this study and their contribution to knowledge. The following key contributions can be inferred. First, single and two-person older households are very distinct in their kWh readings, pattern of activities, pattern of intra and inter-day intensities of demand and peak demand distribution characteristics. Second, the incidence of "coming together" of practices was not conclusive. Thus, speaking to the diversity of this cohort and suggesting a caution on implying homogeneity in their use characteristics. There were, however, days and time slots where the intensity of demand and devise use declined considerably by both groups. These occurred in the after 10 p.m. time slot. These were expected. Furthermore, the 6 p.m. – 10 p.m. time slot indicated a peak in some instances for device use. Third, unusual days were spread across the week. Thus, the ordering of their week which reflects their device use pattern suggested that they had more control over their time. In other words, the "weekend" demand occurred at nearly all the days during the week. Saturday was distinct in the case of two-person households for disuse of appliances in general and comparatively significant decline in appliance use for the single households. Although, this was not reflected in their load profile. An implication of this is that the unusual days may occur for the devices and the load profile separately depending upon the set of devices investigated. These also suggest that although, the practice of watching TV declined on Saturday, this was replaced by other energy-relevant practices that almost replaced these audio-visual devices and did not indicate a significant difference in the average meter reading of the households.

It is noteworthy for mention that of all the selected appliances, only TV watching was associated with a shared use in single households. Although, Yates (2016) concluded that sharing was significant in multiple occupancy homes, the results still suggested a significant individual use for the selected devices. A detailed explanation of the results in Chapter 4 is below.

As implied in Yohanis et al. (2008); Abrahamse and Steg (2009); Yohanis et al., (2008); McLoughlin et al. (2012) age of the occupants has a significant role in the load factor and demand in the household. This study did not investigate the role of age in characterising energy demand of older people but investigated patterns of demand of older people within the day and the week. The results in 4.2.2 and 4.3.2 broken down to each day during the week showed significant variation inter and intra-day.

TABLE 5:1: A SUMMARY OF THE HIGHLIGHTS OF THE FINDINGS AND THEIR CONTRIBUTION TO THE LITERATURE

Findings	Brief evidence in the literature and the contribution of findings to the literature.
The rhythm of consumption largely related to the household category (single or two-person) as they were distinct from each other (see Figure 5.1 for the average kWh meter readings).	This finding's contribution to literature reaffirms that single and two-person households are distinct in their rhythm and energy consumption volume. For example, the single households' average kWh readings are lower than the two-person households (Figure 5.1). These finding echoes earlier studies like Wallis et al. (2016) where they indicated that the differences in demand pattern can largely be explained by the typology of the household. Brandon and Lewis (1999); McLoughlin et al. (2012) also indicated that household size is a significant

	explanatory variable for energy demand.
The intra-day intensity of demand across the two groups had a significant variation in results across the week.	The contribution of this finding highlights the peculiarity of each day of the week and the distinction between the two groups. For example, the intra-day variation is found to be stronger for single households than two-person households across the week. This finding's contribution to literature is that the peculiarity of the day of the week is more significant when examining single older households than two-person older households. This finding partly echoes (Wallis et al., 2016) where they indicated that the same activities had different levels of intensities across households, although they did not categorise the households based on single and two-person households and do not specifically refer to older households. Furthermore, the high

	intra-day variation emphasises the importance of the combination of timing and intensity of demand as emphasised in Torriti et al. (2015). The variations suggested that, for example, in the two-person households, there was more predictability of maximum intensity of demand at the 6 a.m. – 10 a.m. time slot. The contribution to literature is that the timings of the highest intra-day index for two-person households are comparatively predictable to be the 6 a.m. – 10 a.m. time slot. This result is important for "energy balancing" as it reiterated the importance of the characteristics of the household.
The 7-day cycle provided significant variation in terms of patterns and intensity of demand.	The contribution of this finding highlights the importance of data collection spanning at least a 7-day consecutive period. The commonly used random selection of days would be unable to capture the variations

	that characterised each day. This contribution was also indicated in Walker (2014) where the importance of the week in the rhythm of demand was reiterated. The 7-day duration enabled me to identify the "dovetailed" activities within a week and highlighted their most energy-intense time slots. The contribution of this indicates that the time slots of highest intra-day intensity did not always coincide with peak device use in the two-person households, for example, for the selected devices. This may have been caused by multiple factors such as use and charging the device not coinciding and also use when other energy-intense activities were going on. In addition, it could be because of the consumption of the selected devices not being a major contributor to the peculiar "peak" periods in the household but

	contributors to demand at multiple time slots.
The diurnal intensity of demand indicated how their day was ordered. The ordering of the day provided mixed findings as maximum intensities differed across single or two-person and secondary intensities varied for the whole cohort.	This finding, although unexpected reiterates the importance of examining the processes that lead-up to the use of the selected devices which Shove et al. (2009) suggested might shed light on the results. This finding also enables me to suggest that for further studies, researchers may investigate these processes to provide a more holistic explanation for the potentially mixed results which this study was unable to do.
There was a positive relationship between the occupants and the kWh meter readings of the households.	As mentioned earlier, this finding suggests that it is expected that two-person households would have a higher kWh reading than single households. This was partly echoed in Jones et al. (2015) where they indicated that more people in a household would lead to more kWh

	demand. Although, they did not categorise more to mean an additional person only, on the surface of it, "more" is the case in two-person households in comparison to single households. The contribution to literature of this finding is the partial reaffirmation of but "more" may need to be qualified further.
Peak demand results were mixed with temporal variations across the days of the week and the time slots of the day.	This finding reaffirms that older households are not a homogenous group, they have many similar attributes. It also suggests that they should be characterised in the context of energy demand by the characteristics of their demand in addition to their socio-demographic characterisation. This finding reaffirms Thøgersen (2017) where it was stated that households have unique lifestyles. The kWh readings of the households indicated the choices of the households to leave them on standby,

	to share the use of device among other lifestyle choices by the households. My results concur with Browning (2012) where they indicated that contrasting results are feasible thus generalisation was difficult to assume or conclude as implied by Gershuny and O'Sullivan (2017). Secondly, a reoccurring pattern as implied in De Silva et al. (2011); Friis and Haunstrup (2016) was difficult to arrive at as variation was significant in this study's cohort. However, in terms of maximum intra-day intensity, the two-person households indicated significant levels of routine.
Certain days of the week were uniquely low in demand intensity within the groups, their inter-household peaks were more varied. In other words, the households had less	This finding was unexpected in the context of the available literature. This finding suggests that some days of the week are peculiar for non-use. The contribution of this lies in demand balancing over a period of one week and during a day to assess when

variation in troughs than in their peaks.	demand could be shifted to reduce their peak demand. Also, for social rhythms, this finding suggests that “coming together” is not limited to use and disuse is also subject to “coming together”. This contradicts previous findings like Walker (2014) that argued for “social rhythms” which implied that consumption would be alike. The cohort indicated “synchronised” troughs in demand when I compared both groups. This temporal pattern did not, however, conform to a weekend pattern. The two groups were asynchronous intra-day in the intra-day peak demand (such as the morning and evening peaks).
The device use can be characterised as largely single use even among the two-person households.	This was not an expected outcome. The contribution of this finding indicates that for the cohort, sharing was not prominent in device use despite two-person occupancy. This is a major policy opportunity such that in

	addition to demand reduction and shifting, policy can also encourage sharing of device use as part of demand-side management. This is feasible as a previous study by Walker (2014) indicated that "social synchronisation" which implies that the same things are happening across temporal and physical spaces. This can be harnessed to the fullest. My findings also contrasted those in Browning (2012) that suggested that synchronised use was more prevalent in two-person households.
The day of the week was not significant in explaining the nature of demand.	In the context of a weekday to mean Monday through Friday, the findings of this study suggest the demand of the households did not indicate any significant rhythm of kWh readings that suggested that these days as a group stood out. Rather what the results indicate was a wide spread of readings that had troughs, spread

	through the week. This is contrary to the findings in Walker (2014) among others that describe a "typical" weekday with a morning and evening peak. The cohort had mixed results as they peaked in their consumption outside the "typical" days and times attributed to peak demand. The findings reaffirmed the emphasis of Naus (2016) on the understanding of the heterogeneity of practices and Powells (2014) suggesting significant variability in performance of practices. With these in mind, the results of this study confirmed the significant variability that occurred intra and inter-day. Hence, one day or a few days I deduce did not suffice in explaining the cohort's demand. Studies like Fischer et al. (2015) singled out Saturday and Sunday as being distinct from each other. These contrasting findings make the case for

	collecting time use data daily for a minimum of consecutive days as each day revealed unique rhythm from my findings.

5.2 Addressing research objectives

In this Section, I divide the description and explanation of the results in chapter 4 based on the research questions. Under each research question, I discussed what (older) people did with an emphasis on the time slots with the most significant results.

5.2.1 To deduce the rhythm of practices related to the electricity demand of older people

My investigation into the literature suggested that the question of the rhythm of electricity demand is one that has gained considerable attention from research directly and indirectly in recent times. Multiple studies have observed time use, energy demand (intensities) and developed significant solutions and models that contribute to the understanding and management of rhythms. I concluded from the literature that it is the rhythms (i.e. the temporality and duration of people's practices) that constitute peak demand and rhythms of electricity demand provide insight as to "what people do." Rhythms of electricity demand have been studied using different variables and lenses in the literature, such as the number of occupants (Wallis et al., 2016), the practices in the households (Shove et al., 2014), the (socio-demographic) characteristics of the households (Brounen et al., 2012), and price of energy.

In this thesis, I investigated the intersection between rhythms and households' characteristics with specific emphasis on time use and older people. Findings by Wallis et al. (2016) partly informed the separation of the cohort into single and two-person households. This enabled me to investigate their practices and ordering of the day which resulted in their rhythms. The results as indicated in Figure 5.1 (below) for example, seem to confirm the findings of Wallis et al. (2016) that implied that there was a distinction between single and two-person households. From the average kWh readings in Figure 5.1, the two-person households had a higher reading at all the time slots throughout the week. On Monday, for example, the two household categories are so distinct in their electricity demand rhythm that the lowest average kWh reading which was at the after 10 p.m. time slot for the two-person households was almost the same as the highest average kWh readings for the single households. In Figure 5.1, another distinction between the rhythms of the two groups is the seeming spikes at the 6 a.m. – 10 a.m. time slots through the week for the two-person households which is not replicated by the single households. This rhythm of demand suggests that the single households are considerably less routinized than two-person households. This consistency in rhythm of demand was amplified in their intra-day index as indicated in Figure 4.1 and Figure 4.11 for single and two-person households respectively where there was a spread for single households in their maximum intra-day index, and the two-person households seemed to have a "coming together" at the 6 a.m. – 10 a.m. time slot.

I argue that the strong disparity between the two groups is a result of the internal mechanisms of co-living that structures some activities around time slots or days. This was highlighted by Shove et al. (2009) where it was indicated that a focus on performance omits the underlining processes in a household.

There are, however, similarities between the groups as Figure 5.1 suggests that the after 10 p.m., time slot indicated the lowest average kWh reading for each day. Furthermore, the 6 p.m. – 10 p.m. indicated one of the peaks for both groups through the week. From the pattern of average meter readings indicated in Figure 5.1, I can deduce the following two main sets of findings.

Firstly, the average single household standby and/or lowest average meter reading is approximately 0.5kWh and this takes place at the after 10 p.m. time slot only. For two-person households, their standby and or lowest average meter reading ranges between approximately 0.8kWh – 1kWh which also occurs at the after 10 p.m. time slot.

Second, as alluded to in Section 2.4.4, a day can be characterised by two peaks (morning and evening). Expectedly, the 6 a.m. – 10 a.m. time slot can be characterised by a spike in average readings as they were at their trough in the preceding time slot. This rise in demand is, however, different for both groups as the 6 a.m. – 10 a.m. time slot had higher peaks for two-person households and plays a more prominent role in the rhythm of the two-person households. For example, Tuesday through Thursday indicated that the 6 a.m. – 10 a.m. time slot had the highest average kWh reading for those days in two-person households. The rhythm of demand for single households can be generalised with an expected highest average reading at the 6 p.m. – 10 p.m. while it occurs earlier for the two-person households as earlier mentioned. The main contribution to knowledge lies in the indication that the time slot of the day of the highest average demand for both groups differs from 6 a.m. – 10 a.m. and 6 p.m. – 10 p.m. for two-person and single households respectively. This has implications on demand balancing as the attributes of the household now not only play a role in the volume of demand but also the timing of average peak demand.

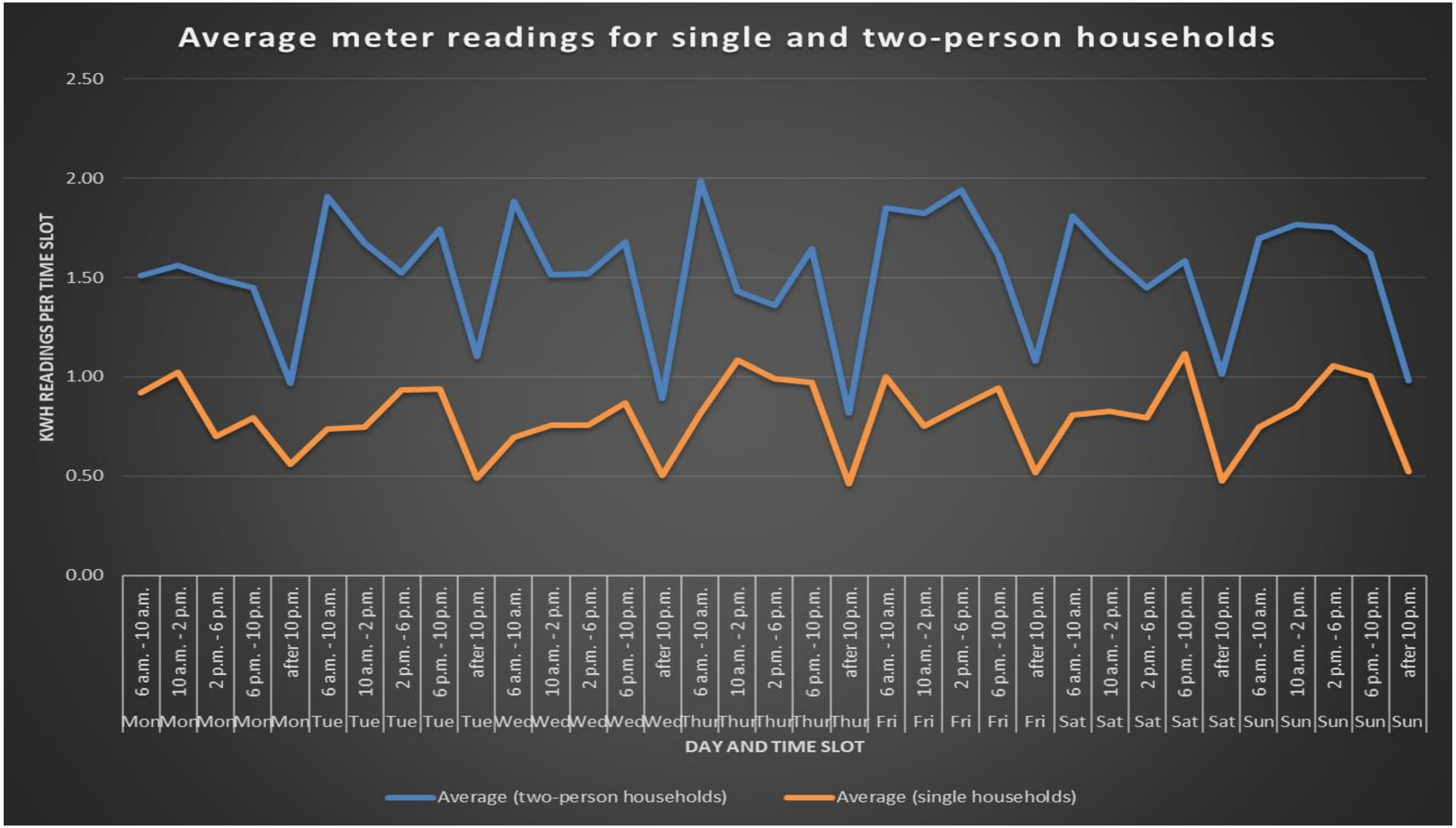

FIGURE 5.1: AVERAGE kWh READINGS

5.2.2 To investigate the variation of diurnal activity patterns

What happens during the day, whether it is a weekday, weekend or holiday is of prime interest to time use and energy researchers. Some activities like watching TV and laptop use are characterised by interruptions and repetitions. For example, it is not uncommon for households to interrupt TV watching with a toilet break or a cup of tea or any other activity. In other words, these activities are both dove-tailed and cyclical as explained in Section 2.4. These imply that indication of use at best can be an estimate, and actual use can and is expected to vary quite a lot in the span of a day and within the time slots. However, the literature presents a mixed position on variation. For example, Walker (2014) described the phenomena of the "typical" weekday and Powells (2014) suggested that the variability of performance of practices is context and temporality-dependent. Walker (2014) implied that there should be some level of stability in the performance of practices to qualify it to be typical and Powells et al. (2014) do not completely contradict this, they implied that variability may or may not occur thus avoiding the characterisation of a "typical" weekday. The typical weekday I argue stems from the social structures of "9-5" work pattern that orders the day of the society (Zerubavel, 1989). For example, this work pattern demands the residents to be at work at 11:30 a.m. on a Monday and off-work or at home at 9 p.m. on a Tuesday on what is widely accepted as a weekday or working day. Whether a day is "typical" or "unusual" has direct implications for the pattern of performance of domestic practices. I investigated the diurnal variation of device and electricity use of the older cohort who do not necessarily conform to the "9-

5" work structure and have more control over their "everyday life" which has been attributed by Thøgersen (2017) as being principally responsible for variation.

The results as indicated in 4.2.2 and 4.3.2 suggested that through any day during the week, there was no particular ordering of the activities but there seemed to be a "coming together" of activities at mainly the 6 p.m. – 10 p.m. time slots during the day. The results can generally be described as partly concurring with Torriti and Hanna (2014) who suggested that households without children had an unpredictable demand. All the households in my sample lived without children. The significant variation in electricity demand patterns across households within and across the categories as indicated in 4.2.2 and 4.3.2 suggests that the device use within the households can in some instances, be described as "unpredictable." For example, Figure 4.7 indicated a rise to 12 households in TV use at the 2 p.m. – 6 p.m. time from the previous and subsequent frequency of TV use of 6 and 2 respectively. This rise and drop in occurrence indicates some unpredictability in TV use among single households.

Diurnal activity patterns (device use) variation was captured using a diary (as explained in Chapter 3) where the households indicated their (shared) use of selected devices. It is noteworthy for mention that as explained in Chapter 2, practices may reflect significantly in the kWh readings of the household as indicated in Friis and Haunstrup (2016). In this work, the devices under study for (shared) use may not reflect significantly in the kWh meter reading at the time of use for at least three reasons. First, some can be battery-powered thus their use and kWh readings may not coincide. Second, their use can often be "standby" which reflects in kWh readings but does not suggest active use. Third, I relied on the diary entries of the households to indicate the variation of use of these appliances as using the kWh in Figure 5.1 (above) is not a reliable indicator of the performance of the selected practices. For example, the findings indicated in Figure 4.7 suggest that there was a rise in device use by single households at the 2 p.m. – 6 p.m., but Figure 5.1 does not reflect a rise in average demand by the households. Although as mentioned in 3.1, these devices contribute to peak demand, their contribution can be delayed to when they are being charged as a rise as the number of households using the selected devices did not reflect in the average demand of the households.

For desktop use (see Figure 5.2) the diurnal variation for both categories of households seemed to follow the trend of decline from the 6 a.m. – 10 a.m. and have a secondary peak at the 6 p.m. – 10 p.m. time slot through the week. On Monday, Figure 4.15 suggests that there was a stable frequency of use as it ranged between 3-5 households through the day. Similarly, the use for two-person households ranged between 1-6 households. On Tuesday, Figure 4.6 suggests that it was used by a range of between 3-8 households through the day to a peak in the rhythm of users at the 6 p.m. – 10 p.m. time slot. The two-person households' use peaked at the 6 a.m. – 10 a.m. time slot with a decline in frequency of users through the day. For both groups as indicated in Figure 5.2, there was at least one household using their desktop through the week.

The laptop use for the single households seemed to have a diurnal fluctuation of between 2-4 households, 0-3 households and 0-2 households for Monday through Wednesday (Figure 5.3). In other words, a maximum of about 22% of the single households was using their laptop on Monday and Saturday at the 6 a.m. – 10 a.m. time slot only. For the two-person households, the diurnal variation of use (Figure 5.3) suggests that there were two peaks of uses during the day through the week at 2 p.m. – 6 p.m. and 6 p.m. – 10 p.m. The most significant diurnal variation occurred on Tuesday from 7-18 households between the 2 p.m. – 6 p.m. time slot and the preceding time slot. Monday and Saturday followed a similar diurnal pattern of peaks while Sunday was distinct from other days with two peaks at the 6 a.m. – 10 a.m. and 6 p.m. – 10 p.m. time slots.

For tablet use as indicated in Figure 5.4, the single household diurnal variation of use suggests that there were at least two peaks daily with Thursday being distinct with 3 peaks of use. The two-person households seemed to follow a similar diurnal variation of use with the single households as Thursday also stood out with three peaks of use. The two groups started use at the 10 a.m. – 2 p.m. on most days and peaked at the 6 p.m. – 10 p.m. time slot. Wednesday and Thursday had most variations in the frequency of use as two-person and single households use peaked for the week on Wednesday with 4 and 9 households respectively. Tablets seemed to be in use by both groups at the after 10 p.m. time slot by some of the households as only Friday recorded a null entry for single households.

As indicated in Figure 5.5, the diurnal variation on the TV use suggests a peak at the 6 p.m. – 10 p.m. time slot for both groups. TV use featured prominently in the diurnal activities of the cohort as there were at least three households using it at all the time slots except Saturday where the two-person households indicated a null entry. The main contribution to knowledge this finding indicates is that the device use habits are distinct between the groups, although Saturday and Sunday are expected to have comparatively less use of the selected devices. This has implications for policies on demand balancing as the data suggests that these devices play a lesser role in peak demand. This means the contribution to peak demand suggested in the literature is potentially the day during the week and not a blanket participation as the previous literature suggests.

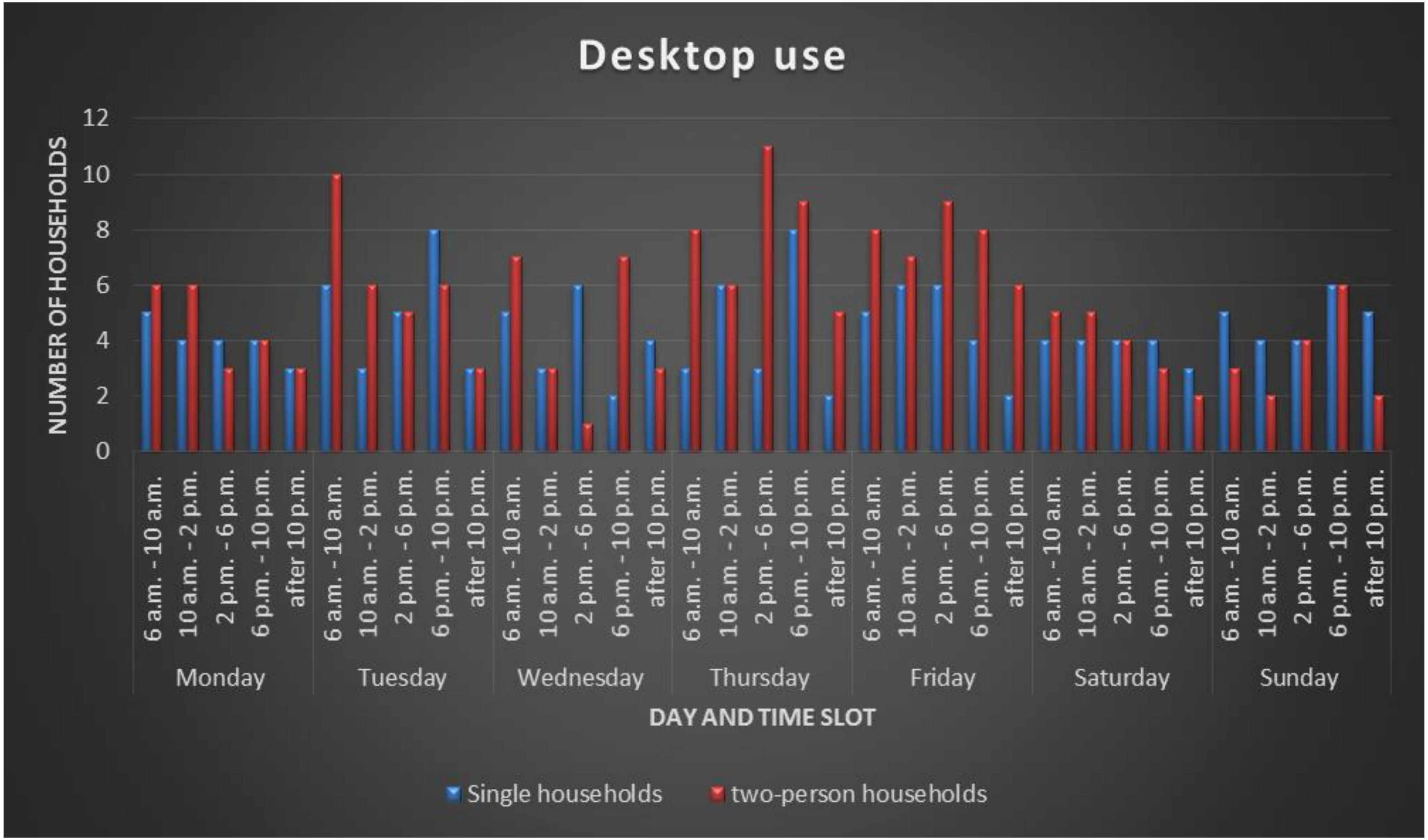

FIGURE 5.2: DESKTOP SHARED AND INDIVIDUAL USE

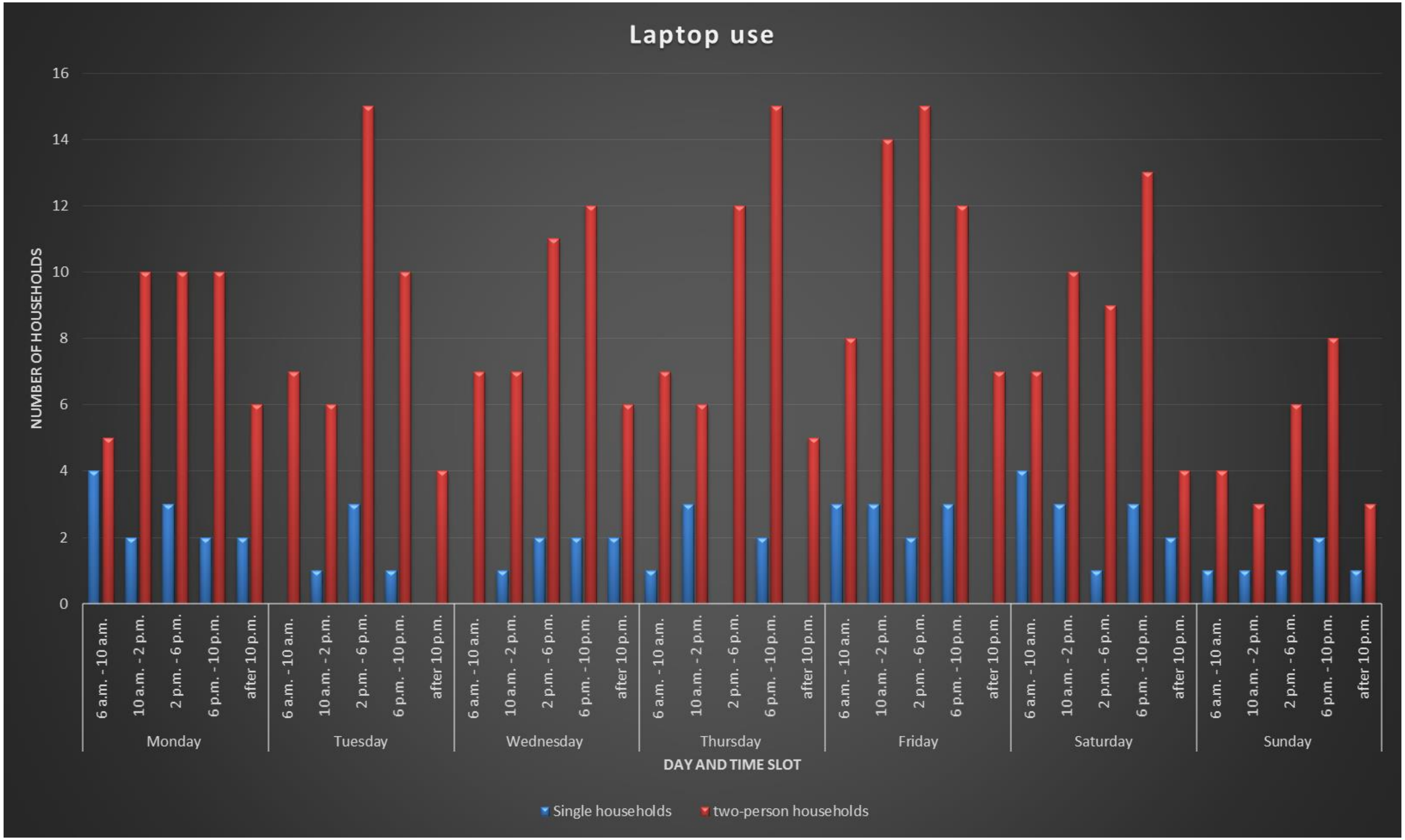

FIGURE 5.3: LAPTOP SHARED AND INDIVIDUAL USE

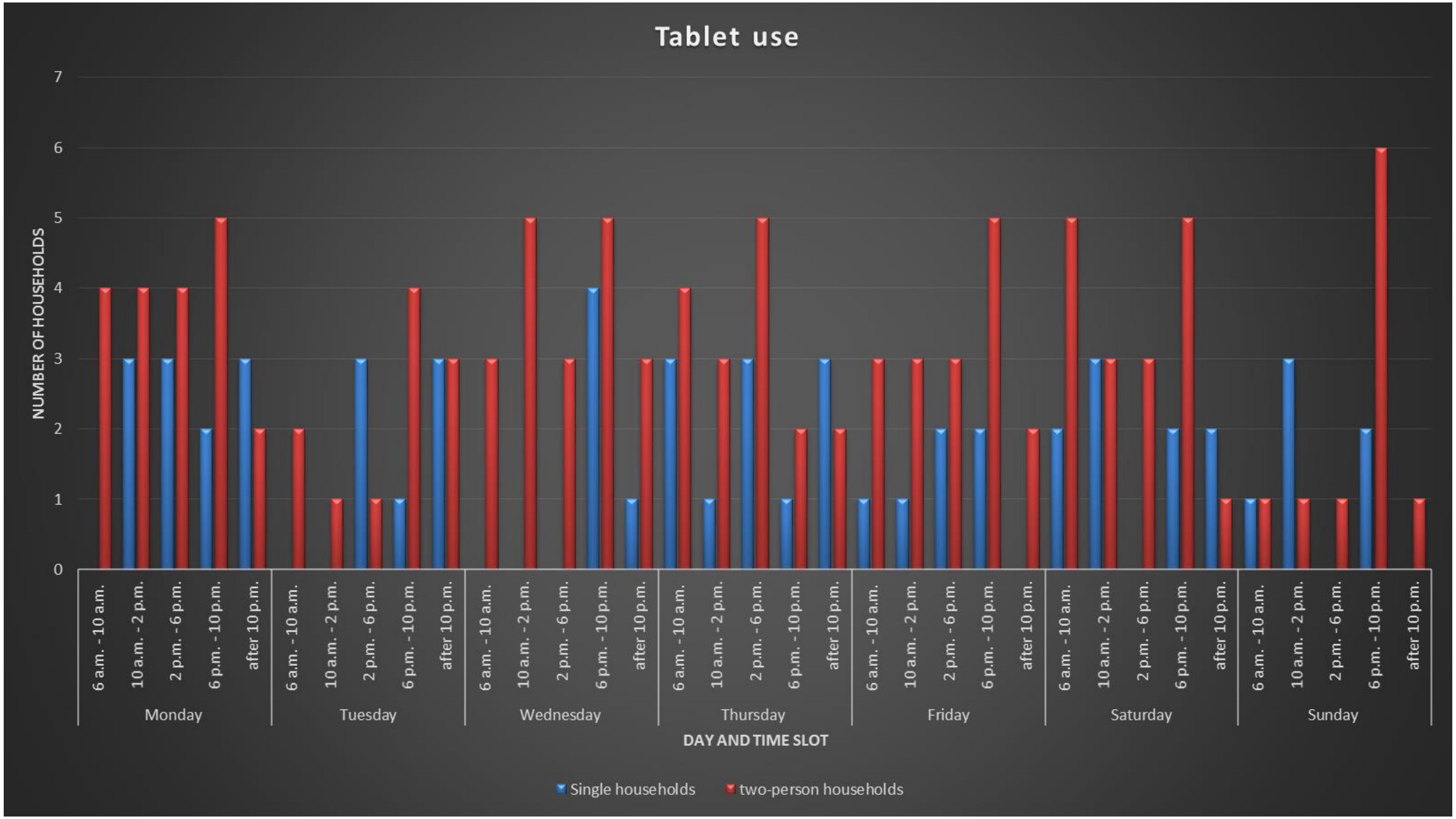

FIGURE 5.4: TABLET SHARED AND INDIVIDUAL USE

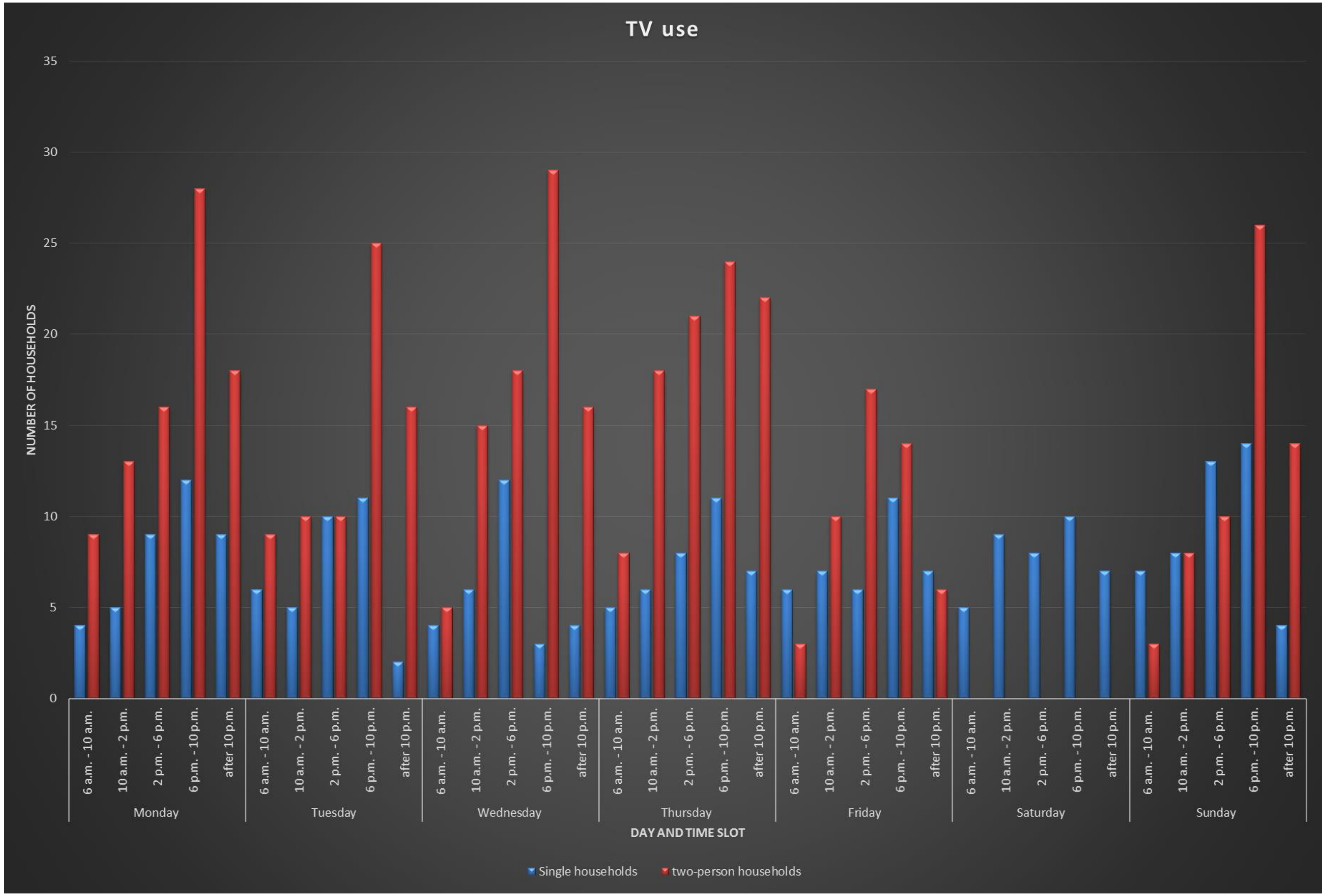

FIGURE 5.5: TV SHARED AND INDIVIDUAL USE

5.2.3 An investigation of the weekly variation of activities through their inter-day intensity of demand

Earlier, I investigated the diurnal variation of selected activities (device uses) based on their diary entries. I also investigated the varying intensity of demand using the indexed meter readings' intra-day and inter-day to deduce the agglomeration of kWh relevant uses. This enabled me to infer the variation of the collective performance of practices during the day and during the week. This was partly to identify the notion of rhythm and sequence suggested in Hahn et al., (2009) and Jalas and Juntunen, (2015). Furthermore, they placed emphasis on the importance of identifying the variation of the intensity of demand as it explained the variation between households, especially when they have similar device use patterns. In Figure 4.2 and Figure 4.12, I indicated the pattern of maximum inter-day index for the single and two-person households respectively. These were the time slots when the households reached their maximum inter-day similar device use patterns. In Figure 4.2 and Figure 4.12, I indicated the pattern of maximum inter-day index for the single and two-person households respectively. These were the time slots when the households reached their maximum inter-day index for the week. In Figure 5.6, I illustrate that no single households reached their maximum inter-day index from Monday after 10 p.m. time slot through Thursday 6 a.m. – 10 a.m. In other words, the pattern of "coming together" of energy-relevant activities implies that these time slots and particularly the whole of Tuesday can be characterised as a "typical day" as no combination of activities culminated in the maximum inter-day index for the households. The peak of unusual days seemed to occur on Thursday through Sunday with Sunday (6 p.m. – 10 p.m.) having the highest percentage of single households at their highest inter-day index. There seemed to be a wide variation in the inter-day indexes across the single households as Figure 4.2 on the surface of it suggests that Tuesday did not have any characteristically unique pattern of the average inter-day index. Tuesday had a slightly higher average inter-day index than Thursday at the 2 p.m. – 6 p.m. time slot, and the latter had households that reached their maximum inter-day index.

The two-person households' variation of activities indicated that a majority of the cohort reached their maximum inter-day index on Tuesday through Thursday (Figure 5.6). Monday, Saturday and Sunday had the lowest cumulative percentage of households at their maximum inter-day index. These were the unusual days for most of the couple households. It is difficult to explain this result, but it might be related to how their day was structured and whether these days of the week had any significant activity that led to it. The main contribution to knowledge here is that the day of the week that households use more energy than normal varies between households significantly. Although, in the case of the single households, the intensity of demand suggested that Tuesday and Wednesday were "normal" days and other days of the week for both groups had a spread of households at their inter-day index. Furthermore, interestingly, despite the 6 a.m.- 10 a.m. time slot featuring prominently in the two-person households' intra-day index, it did not feature prominently in the inter-day index. This perhaps suggests that the practices that led to the 6 a.m. – 10 a.m. time slots being the maximum intra-day index were more routine and more or another combination of activities led to the inter-day index that occurred for a majority of the two-person households. This also implies that the highest and consistent time slot for the intra-day index does not necessarily represent what the week looks like when viewed consecutively. This also indicates what might have been missed by earlier studies that selected days randomly for time use surveys, and these disparities in results would have been missed.

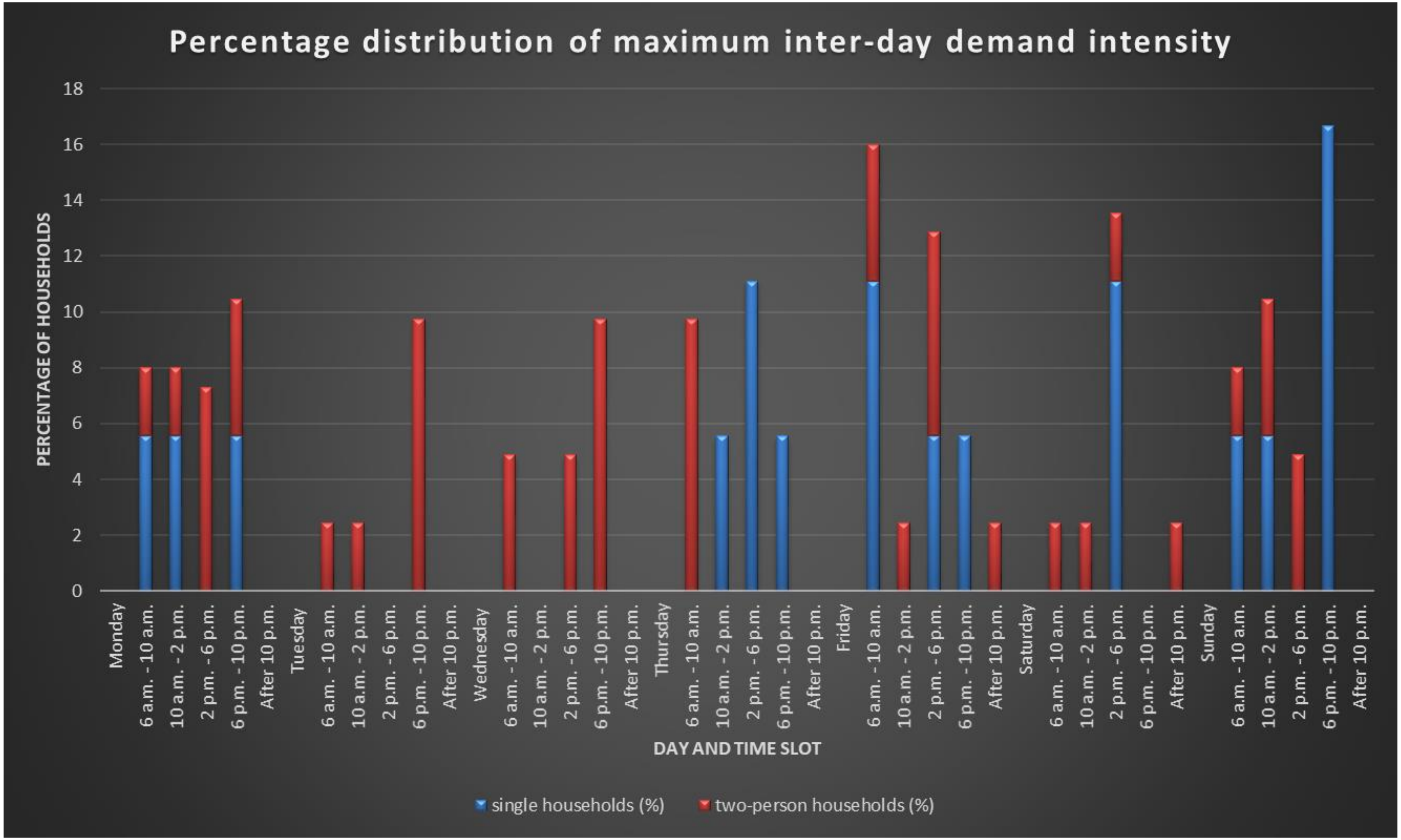

FIGURE 5.6: DISTRIBUTION OF MAXIMUM INTER-DAY INDEX

5.2.4 An investigation of the similarities in device use synchronicity and electricity demand intensity between single and two-person older people's households

The inter-day intensity of demand is a way of measuring how demand varied across different days. As indicated in Figure 32 above, the two-person and single households performed practices at very different temporalities that resulted in their inter-day intensities of demand. I investigated the variation in the differences between the two groups in their kWh meter readings, intra-day and inter-day index readings. The reader can refer to Figure 5.1 for the average meter readings, Figure 4.2 and Figure 4.12 for the inter-day indexes for single and couple households respectively and Figure 4.1 and Figure 4.11 for the intra-day index for single and couple households respectively. The results indicated in these Figures may be influenced by a myriad of factors; and particularly by the structure of the day. It is important to reiterate here that the recruitment process ensured that nothing special or unusual was planned or occurred during the period of data collection, hence I can reasonably assume that the respondents' device use and energy-intensity indexes are typical. Some devices such as the TV seemed to indicate synchronicity of disuse on Saturday and Sunday as their use was significantly lower than other days. Can this disuse be attributed to the weekend? It is difficult to tell as this study only investigated the "what" and "when" of the device and not the "why." That notwithstanding, the relative spread in the peak synchronicity of device use as indicated in the time slots do not support previous studies that implicitly or otherwise suggest a dual daily peak of morning and evening. The relative lack of structure of the households in this study indicates or may suggest that this cohort has fewer fixities in terms of practice ordering and potentially some level of control over their device use. The main contribution to knowledge here suggests that there is significant variation the pattern of activities, and all the selected devices featured during the time slots with the highest intensities of demand. The frequency of use of devices indicated in Figure 33 and Figure 35 however, gives an indication of how often the households engaged with other devices that potentially contribute to peak demand and for some, their use in conjunction with the other devices that are used daily may lead to the highest inter-day intensity.

Chapter 6 : Conclusion, limitations and suggestions for further study

6.0 Chapter summary

In this Chapter, I identify the conclusions that I drew from each research objective in Section 6.2. In Section 6.3, I highlighted the implications of my findings for energy providers, policy-makers, researchers, older people and manufacturers. In section 6.4, I itemise the limitations that characterise this type of research in general and specifically limitations and assumptions in this research. I put forward suggestions for further studies in Section 6.5.

6.1 Introduction

Electricity demand research can be characterised as a cut diamond with many valid sides each with limited applicability and yet invaluable to achieving the widely accepted goal of a low-carbon future. This multiplicity of perspectives necessitates complementary and often conflicting methods and objectives. Most energy (electricity) demand studies either focus on the animate actors such as the consumers, policy-makers and industrial users or inanimate aspects of energy demand by focusing on the buildings, weather and appliances inter alia. I attempted to investigate the two main actors: people, in my case, older people and machines. These "interact" as energy (electricity) demand only occurs after the interaction between "man and machine." The evidence suggests that single and two-person households have very different structures to their days. Thus, my conclusions highlight and break down these differences. The research findings are associated with higher uncertainty around generalisations over older people as a category of electricity end-users, but lower uncertainty around the differences between older people living alone and those living with another person. There were instances of "coming together" of (dis)use by the cohort, and the conclusions would be based on the demand attributes investigated in this research (intensity, timing, synchronicity and intensity of activities and demand).

6.2 Conclusions of the study based on the objectives of this study

Below, I itemise the conclusions that I draw from each objective of the study in the context of a day and a week:

To deduce the rhythm of practices related to the electricity demand of older people

As indicated in 5.2.1, the meter readings of the single and couple households were varied thus, I would be deducing their rhythm of demand based on their average meter readings as shown in Figure 5.1. What is, however, interesting is that despite considerably fewer selected devices participating in the demand on Saturday and Sunday, there seems not to be any significant difference to the rhythm of average demand by the household on these two days. This is especially the case in the peak average demand that was similar to any other day (Figure 5.1). This suggests that although the TV, for example, played less of a role, other devices perhaps contributed to the load profile on these two days. Perhaps there are separate unusual days for the selected devices which may not coincide with the overall unusual demand from the household. My conclusions would be based on the peaks and trough and the time slots where they occur. The rhythm of electricity demand suggests that a trough was reached at the after 10 p.m. time slot throughout the week. This means the subsequent time slots, the 6 a.m. – 10 a.m. time slots would always indicate a rise in demand. For the single households, the rhythm of average meter readings suggests that there are multiple peaks during the day with the highest peak at the 6 p.m. – 10 p.m. time slot with a typical reading of about 1kWh while at the troughs, the average reading was about 0.5kWh. For the two-person households, the average peaks were about 1.9kWh. The time slot where the average highest reading occurred for the two-person households was more widely spread out with a combination of the 6 a.m. – 10 a.m., 6 p.m. – 10 p.m. and in one case on Friday at the 2 p.m. – 6 p.m. (see Figure 5.1). The results in Figure 5.1 seem obvious and self-explanatory in terms of the meter readings, but they do not indicate any significant distinction across the days as they followed similar patterns of variation. The results suggest a stable reading for the average peaks and troughs for both groups. In addition, I can cautiously conclude from the demand rhythm that the time slot of the day was a greater explanatory factor for the average readings than the day during the week for the cohort. If the time during the day is more critical, what older people do at different times during the day is vital to explaining and potentially predicting energy demand characteristics. In other words, it can be deduced that variation is expected to be strong by single households' intra and inter-day while the most significant variations for two-person households can be expected to occur intra-day.

To investigate the variation of diurnal activity patterns of older people.

In the context of the day, device use practices, especially for TV can be expected to occur in more time slots in single households than in two-person households as shown in Figure 5.5 where two-person households indicated a null entry for Saturday, for example. The rhythm of practices for the TV and desktop suggested that they are both used all day with an expected peak during the 6 p.m. – 10 p.m.

time slot (Figure 5.2 and Figure 5.4 respectively). Tablet and laptop use tend to start at the 10 a.m. – 2 p.m. time slot and are expected to end at the 6 p.m. – 10 p.m. time slot (Figure 5.4 and Figure 5.3 respectively). Shared use in single households only occurred for desktop and TV use (Figure 4.5, Figure 4.6, Figure 4.7, Figure 4.9 and Figure 4.11) for shared TV use and Figure 4.10 for shared desktop use). I can deduce that based on my cohort, single older people can be characterised by sharing fewer device uses on Saturday and Sunday than on other days even though device use is significantly lower on these two days. I can conclude that, the patterns of activities of the cohort were varied during the day. However, these results do not indicate clear trends of peaks and troughs of average kWh demand as their was significant intra and inter-household variation. This may be partly attributed to the potential mismatch between their use and meter readings as indicated in 5.2.2.

An investigation of the weekly variation of activities through their inter-day intensity of demand of older people

In the context of the week, our results did not suggest any pattern that indicated that any day had experienced a significantly higher number of activities compared with other days during the week. The variation occurred in non-use as notably none of our two-person households reported watching TV on Saturday. Furthermore, Tuesday and Wednesday for the single households indicated that no household had their maximum inter-day intensity. From these, I can conclude that older people's synchronicity pf activities was spread across the week, but their troughs of energy-relevant practices are more synchronised. The investigation of non- performance of activities was however outside the scope of this study. During the week, older people are expected to use their washing machine and the microwave at least once a week and once a day respectively. The inter-day intensity of demand suggested that there was considerable variation resulting in the spread in the maximum inter-day intensity across the week. The results here suggested a weak link between the unusual day and their demand. The spread of the inter-day index across the week by both groups suggests that the unusual day could have fallen on any day during the week. The results also do not support previous work that suggests a “weekend” demand. This cohort exhibited what may be described as a “weekend disuse” if the definition of a weekend is Saturday and Sunday for the two-person households. A situation where there was a considerably lower demand for the selected activities and there was a null response on Saturday for TV use in two-person households. The inter-day index for the single households also did not support the weekend demand as there was no distinct level of activity or frequency of households that reached their maximum inter-day index on Saturday and Sunday. I can conclude that it, the control over the ordering of the week can be attributed to be responsible for the spread.

An investigation of the similarities in device use synchronicity and electricity demand intensity between single and two-person older people’s households.

As mentioned earlier, our results suggest that single and two-person households are very dissimilar in their demand patterns. The dissimilarities have been addressed in earlier Sub-Sections in 6.2 (above). I can, however, conclude for both groups that the peak synchronicity of device use for the investigated devices is at the 6 p.m. – 10 p.m. time slot for the (shared) TV use, whereas other device uses have varying peaks between the 10 a.m. – 2 p.m. and the 2 p.m. – 6 p.m. time slots. The intensity of demand was largely dissimilar as 6 a.m. – 10 a.m. featured prominently as the maximum intra-day index for the two-person households while the 6 p.m. – 10 p.m. featured more for the single households. The weekend intensity of demand did not indicate any significant difference from the weekday for both groups. Other similarities between both groups were highlighted in preceding sub-Sections that examined the objectives of this research in Section 6.2.

6.3 Implications of findings

I identified the following implications of findings and organised them based on the sphere of relevance: policy-makers, researchers, older people, manufacturers of devices and others.

Policymakers and energy aggregators

Before this study, the literature on older people had described an ageing population with peculiar attributes. I argued that as a potential consequence of these, practices are changing inevitably with the increased use of existing and emergent technologies and device characteristics/ functions and capacities. Technologies like recording live TV allow residents to record programs and watch at different times and "binge watch." This increasingly performed practice of binge-watching means that structure can increasingly be displaced in the practice of watching TV. For instance, households can wait until the family to be around for them to enjoy an entire season of their favourite TV show instead of watching it only at the time when it was broadcasted. They can also not miss out on the day's happenings on TV and decide to watch when they are home. These have significant implications for policy-makers as understanding device use by an increasingly older population has implications for demand flexibility. Flexibility of energy demand is increasingly important for policy-makers. The value of the technical potential of the flexibility market was estimated to be around £8 billion per year by the National Infrastructure Commission (Strbac et al., 2016). A significant volume of residential electricity demand during evening peaks is associated with TV watching. The results from this study suggest that TV use is characterised by prolonged use and on some days, distinctively less use. Although this study did not investigate why Saturdays, and Sundays for both categories are associated with less TV watching. The implication of this lies in that their time use and time of use is increasingly controlled by the households as they are increasingly not necessarily bound by work or timing of TV programming. The implication for policy and future study would be to decipher how much of the extensive TV time is “bound” by programming and why they watched at those times. This would give an insight into if they are willing to shift or even disuse the TV at certain times or even choose another device entirely. For example, all the households had internet access, and most of the households had a computer, desktop, tablet or laptop. These are potential complements to the TV as these devices increasingly become multi-functional. Hence, the gaps in TV use may have been because of migration between devices and do not necessarily mean the practice of watching TV was halted. This was not investigated for this study as I asked households to indicate when they used the selected devices but the practice itself might have endured outside the period the TV as a device was in use.

Another policy relevance of the results indicated in 4.2.2 and 4.3.2 is with regards to pricing. Knowledge about when older people are awake and about some of the activities they are engaged in means that pricing can be designed to nudge them. For example, single older households tend to be awake later than two-person households. This assumption is based on when they indicated interaction with the selected devices and their intra-day intensity of demand. The reader can refer to Figure 5.5 for TV use, Figure 5.3 for laptop use and the intra-day index for single and two-person households in Figure 4.1 and Figure 4.12 respectively. Campaigns to carry out washing (dishes and laundry) at off-peak times can potentially be more successful with single older households because the findings for this study suggest that they have higher intra-day variation, for instance, and potentially more ownership of the ordering of their day compared with two-person households.

The load profiles (intensity of demand) of the households are also relevant to policymakers as they would expect single households to consume less on average (about 1kWh/time slot on average) than two-person households (about 1.5kWh/time slot on average) as in Figure 5.1. These figures and the pattern of maximum intensities of demand and synchronicity of use are indispensable to energy projection planning and can inform an infrastructure provision. I recognise that these figures are not from a nationally representative sample, but they provide guidance on the capacity of supply required to neighbourhoods highly populated with older people.

The load profiles are also significant for the emerging segment of demand-side response aggregators. Energy aggregators would find these results useful as they can better understand patterns and make business decisions when siting their services in areas where older people predominantly live. The timing and intensity of demand also help energy aggregators understand when, and how long they can harness energy from localities largely populated by older people. The implication of identifying the load profile of this cohort directly affects demand balancing as they should project for and accommodate the peaks and troughs of this increasingly growing age group. The cohort is expected to peak multiple times during the day (Figure 5.1) and the supply, and the demand-side management policies may be targeted towards reducing the frequency of peaks or their intensity of demand.

Local Authorities and Housing Authorities

When considering neighbourhoods, these results indicate the trajectory of device use, and the load profiles can guide Local Authorities and Housing Authorities on the capacity of transformers, for example, and energy generation projections for public housing occupied by older people. Local incentives and taxation can be developed based on some of the types of data and methodologies developed in this study. For example, levies such as parking can be adjusted or timed towards when older people are using those facilities (i.e. not at home). Although the results indicated in Figure 5.2, Figure 5.3, Figure 5.4 and Figure 5.5 suggest that the use pattern and rhythms are varied, simulations could be derived to indicate time slots when older people are least likely to be home. This user-referenced and user-sensitive approach would enhance inclusivity of pricing and potentially make neighbourhoods' increasingly older people friendly. Although, its application largely depends on availability of the data and participation of the households. One of the implications of the findings of this study could include local authorities tailoring advocacy for fewer energy-intense activities or nudging the demand of their residents to reduce the carbon footprint of their community.

Researchers

Throughout this study, I highlighted the relevance in this study to research on domestic time use and domestic energy research in general. Here, I highlight three areas to which this study is relevant to researchers;

a. This study highlighted the need to revisit the design of the methodology for domestic time use and energy research. The findings suggest that the current widely used approach needs to be revisited for two reasons. Firstly, randomly selecting a day or days for domestic time use or energy demand research does not capture activities that may occur on non-collection days. In addition, non(performance) of practices cannot be generalised to depict their everyday life as the duration of collection of less than a week may be insufficient to draw that conclusion. This study showed that consecutive days may have comparatively minimal activity (e.g. Tuesday and Wednesday for the single households where no household reached their maximum inter-day intensity). In the case of the two-person households where no household watched TV on Saturday, randomly selecting these days for these two groups would have yielded a skewed and misleading conclusion about their everyday life. Secondly, collecting time use or energy data should not be based on the separation between weekday and weekend. Widely available time use data assume that days Monday to Friday are distinct from Saturday and Sunday or with variations in other sources that suggest stratifying days into 3-4 categories. I have mentioned throughout this study that this separation in data collection is not applicable to the older cohort as it assumes a working week which does not apply to a majority of this cohort. For the rest of the population, I also propose that this approach leads to misleading results due to the increasing trend of work from home. Households (including those with young children), can increasingly choose fewer hours, shift work and or work at the weekend. This study revealed that time use data should be collected every day of the week if the everyday practices of households are to be fully and accurately appraised. I did not experience significant levels of respondents' fatigue, which is often put forward as a reason for the two day diaries rather than seven days. Although seven-day diaries require significantly higher levels of effort in collection and recruitment and time if the metering devices are limited as was the case in my study.

b. This study also highlighted some of the challenges of collecting time use data. I recommend that researchers should adopt meters that have local storage for domestic time use and energy research. Remote collection of data -I learnt from the field- is not fit-for-purpose. Challenges such as health and safety, accidental switching-off, poor signal and non-availability of broadband are factors that I make a case for to adopt local storage of data. Overcoming these challenges, I argue would make for a smoother and more successful data collection.

c. This study also revealed that older single and two-person household consumed differently, and their pattern of use similarity is negligible. This is important for researchers as available data on time use of older people do not necessarily subdivide them on this basis (being single or two-person households). The results in Figure 5.1, for example, suggest that they may be investigated with greater emphasis on this to provide a more accurate representation of their everyday life as their meter readings were very dissimilar. Furthermore, evidence exists that single households have a less predictable pattern of demand than households with children, for example.

Older people

This study contributes toward older people's own understanding of domestic energy demand in three ways:

a. The knowledge of their pattern of device use enables them to make more empirically-based demand-side management decisions. Decisions such as demand shifting and automation can only be known if their demand fits characteristics such as being flexible or a programmable device. Device use patterns can be found in 4.2.2 and 4.3.2.

b. This research makes electricity demand less invisible as older people can make empirically-based decisions knowing the pattern of their intensity of demand. Invisibility of demand is one of the widely-acknowledged factors that have hindered interest or participation in cost-saving or energy-saving behaviours.

c. Research of this type enables older people to understand their demand. For example, the results in Figure 5.1 suggested their pattern of average demand, and older households can use this load profile as a benchmark to see how they can manage their demand. Thus, they can make empirical decisions on potentially cost-saving retrofits like double glazing and improved insulation or natural lighting as their late-night TV or computer habits are accompanied by heating for thermal comfort. Potential greening of their energy to save cost or generate income such as the installation of ground-source heat pumps, photo-voltaic and solar-thermal systems. Knowing their demand pattern and intensity and the nature of activities they perform allows them to objectively decide the systems that have the highest return on investment (if they are motivated by monetary incentives) or highest generation capacity (if they are motivated by green(er) energy considering the current relatively high initial cost of installation of these systems.

Manufacturers of devices and advertisers

I identified 4 potential uses of this study:

a. This study is beneficial to manufacturers and installers of solar photo-voltaic and solar-thermal systems. As mentioned earlier, the data indicated in Figure 5.1 suggests that single and two-person older households daily consume an average of about 1kWh and 1.5kWh respectively (per time slot) (see Figure 5.1). This data is relevant in understanding the demand requirements of older households, hence installers can advise their older clients appropriately on the capacity of green energy systems they can install.

b. The data on the time use and synchronicity of computer use of our cohort is valuable to advertisers. They can target online advert based on the timings of highest synchronicity to optimise the consumption by their target audience (older people) which supports existing search engine optimisation algorithms (Figure 5.2).

c. Our results can also support data broadband use intensity by older people. Broadband providers can tailor their packages or their bandwidth to support hotspots (timing) of computer use.

d. Broadband companies can also use data if the type produced in this thesis to understand use pattern and schedule maintenance to time slots that have the least synchronicity of device use. This would enable them to cause minimal disruption to their customers. Smaller arrangements such as old people's homes and retirement homes can use our data to schedule maintenance of broadband infrastructure to minimise discomfort to residents.

6.4 Limitations of the study

Like all research, limitations abound. I highlighted methodological and data-related limitations throughout this study and identify here the following 9 limitations to this research:

a. This study has a location bias as it was carried out in Reading, UK. Hence, its applicability to other locations may be limited. This is, however, the case with several non-nationally representative samples. This location bias also implies that this study's results may not be applicable to other countries. The location of the data collection presented two biases. First, the sample was not nationally representative. Thus, I cannot imply that practices and demand pattern observed can be inferred to other parts of the England. Second, due to the location bias, I cannot compare it to other countries as indicated in 2.4.1 where practices and by implication, load profiles are contrasted across countries. The literature review took the location bias into account and relied almost entirely on UK time use sources for critical investigation.

b. This study has a limited sample size of 59 older households in total. A larger sample would have given a broader evidence base. Hence, the data potentially has limited potential for generalisation.

c. I did not provide for the weather seasons of the year. I assumed that the timing and pattern of the selected activities were largely independent of the weather. This may skew the results. I collected data through all the seasons of the year to minimise the potential weather bias.

d. I did not consider further socio-demographic classifications in the analysis, such as gender, income, and "older old." The latter is among other widely used sub-classifications previous studies, which suggest, "older old" people do things differently. These differences are widely attributable to their frailness compared to other sub-classes hence inability to perform most energy-relevant practices unaided. All the respondents for this study self-identified as healthy enough to carry out their daily activities.

e. Theoretically, I acknowledge that this study adopted a functionalist use of practice theory by operationalising the relationship between practices and energy demand. I recognise that a deeper understanding of the rhythms would have been achievable if I applied a deeper approach into practices. The functionalist use of practice theory is justified by the empirical weight of this research. Very few studies quantitatively capture entire weeks of older people's everyday lives in relation to their energy demand. In other words, this study's contribution to the body of practice theory is stronger on empirical grounds than theoretical ones.

f. I acknowledge that my focus on "what people do" skips the following questions: "why do they do this and what do they not do?" and "why do they do what they do when they do it?". In other words, an explanation of the "why" behind the timing, intensity and synchronicity of demand is missing. Addressing these questions would provide a more comprehensive understanding of the "what," "why" and "when" of domestic practices.

g. Despite the methodological contribution to time use and domestic energy research, I acknowledge that my collection methods are subject to errors in the data, participant errors, entry errors and participant bias and measurement errors from the energy meters. One of such limitations is the non-classification of the kind of time (see 2.3) when the cohort used the selected devices. Also, theoretically and methodologically, I acknowledge that practices are subject to interruption by other competing practices (inclusive of multi-tasking). The use of duration makes comparison complex, and thus I simplified it by using time slots. This enabled me to establish the occurrence of the device uses as the rhythm of the kWh meter readings fluctuated.

h. The sample comprised exclusively home owners. Thus, the data does not capture older people who live in rented properties, in Council properties and other public housing. Ownership of a property may influence the pattern of practices and often the nature of practices. Watching TV, for example, in a communal space which characterises some older people's homes does not apply to this cohort.

i. Also, the division of the time slots were such that the after 10 p.m. time slot was longer than the rest. As a result, the results may be skewed. This is largely based on my assumption that they would be asleep in this time slot, thus I did not want to interrupt their routine.

6.5 Suggestions for further studies

As highlighted through this study, I acknowledge that this research is in many ways a first step in improving the understanding of domestic energy demand and energy-related practices in general. The following suggestions are put forward to further studies on this area.

a. Other studies may investigate further the relationship between older people's activities and electricity demand by including interviews. The interviews may investigate why older people demand energy the way they do. The "why" question would guide intervention and a deeper understanding into not just the doings but the behaviours and circumstances that maintain or can potentially halt these doings. In a practice framework, this type of analysis would shed light on meanings and not just practice performance. For example, the TV watching time of an older household may be temporarily distorted because of babysitting arrangements for grandchildren when their parents are away for work or holiday. Data collected at these times would suggest these as their pattern of demand, but these commitments were the causal factors. During data collection, in one of my friendly conversations, a two-person household revealed that they did not watch TV for two days the preceding week because they were "disciplining" their grandchildren who they believe are addicted to TV. I did not investigate this further as it is outside the scope of this research. These non-work commitments potentially distort the everyday life snapshot which this study intended to capture. Information from interviews as to what they would be willing to change, postpone or abandon in their demand is pertinent to understanding how best to approach older people and their needs in the context of domestic demand policies. Interviews can also be used to characterise the "potential" other uses that devices are used for. These give a deeper understanding as to the timing, frequency and duration of use of devices. Another example I encountered during data collection was that households kept the TV on even when they were not actively watching and often did not know what programs were running. During a casual conversation, they revealed different variants, of "I keep the TV on because it keeps me company." From my observation, this unusual function of "keeping one's company" was mainly the case in single households. This can perhaps partially explain the duration and pattern of TV watching. Other researchers may ask why the TV was kept on. This would give a deeper meaning and understanding to domestic energy demand.

b. It is beneficial for further studies to investigate the specific use of devices. This is increasingly important as devices shift from mono to multi-function. An example consists of people watching TV programs on their tablets, desktops and laptops. These would inevitably influence the timing and duration of watching TV in the context of their engagement with the specific device, i.e. the TV. They may also be online shopping or on social media on their devices. These can potentially influence their frequency of visits to friends and family and grocery shopping trips as older people increasingly adopt online shopping for their daily needs. In addition, the multifunction of devices means that the traditional uses of radios are gradually phased out, stereos, DVD players inter alia as older people increasingly adopt smart phones, tablets and smart TVs among other multi-function technologies.

c. Addressing the current paucity of data or the inclusion of data on older people when improved would allow for more reliable comparisons between socio-demographic groups. Insufficient data has led to significant reliance on secondary, simulated and synthetic data. Due to the projected changes in the timing and characteristics of demand, synthetic data without commensurate enhancement of primary data would potentially lead to losses and or increased costs for the stakeholders.

Appendix

Sample appliance use diary

Domestic electricity consumption of over 65's in the Approach

APPLIANCE TIME-OF-USE DIARY

BEFORE YOU START:

- Thank you for interest in this voluntary research of appliance use. It entails two parts: a diary (below) and a meter (to be installed at the live cable of your electricity meter) both for a period of one week.
- This survey has been approved by the University of Reading's Ethical Research Committee and operates in accordance with the Data Protection Act 1998 and you are free to withdraw at any point.
- In all instances, you will remain totally anonymous in the analysis and reporting of this survey. The survey data is stored in a secure location and is ONLY accessed by the researcher and will be disposed after two years.
- By completing this diary, you understand that you are giving consent for your responses to be utilised for the purpose of this research.
- For further questions/ clarifications, please contact Yusuf Ibraheem (y.a.ibraheem@pgr.reading.ac.uk/ 07711052479) or my supervisor Jacopo Torriti (j.torriti@reading.ac.uk).

SECTION 1: ABOUT YOUR HOME (PLEASE TICK ACCORDINGLY)

Gender	**Female □ Male □ Prefer not to say □**
Age Group	**65-69 □ 70-74 □ 75- 79 □ 80-84 □ 85-89 □ 90+ □**
Current occupation	**Management □ Clerical □Manual □Volunteering □Others □**
Previous occupation	**Management □ Clerical □Manual □Volunteering □Others □**
Co-occupant's Gender	**Female □ Male □ Prefer not to say □**
Age group of co-occupant (if any)	**≤ 65 □ 65-69 □ 70-74 □ 75- 79 □ 80-84 □ 85-89 □ 90+ □**
Co-occupant's current occupation	**Management □ Clerical □Manual □Volunteering □Others □**
Co-occupant's previous occupation	**Management □ Clerical □Manual □Volunteering □Others □**
Building type	**Detached □ Semi-detached □ Flat □ Bungalow □ Other □**
Tenure	**Owner □ Local authority □ Private rented □ Others □**

SECTION 2: YOUR APPLIANCES AND THEIR TIME **OF USE**

PLEASE TICK **[√]** IF THE DEVICE WAS USED **ALONE** OR CROSS **[x]** IF **WITH OTHERS**.

A. TELEVISION

	6am-10am	10am-2pm	2pm-6pm	6pm-10pm	After 10pm
MONDAY					
TUESDAY					
WEDNESDAY					
THURSDAY					
FRIDAY					
SATURDAY					
SUNDAY					

B. LAPTOP/ NETBOOK

PLEASE TICK **[√]** IF THE DEVICE WAS USED **ALONE** OR CROSS **[x]** IF **WITH OTHERS**.

	6am-10am	10am-2pm	2pm-6pm	6pm-10pm	After 10pm
MONDAY					
TUESDAY					
WEDNESDAY					
THURSDAY					
FRIDAY					
SATURDAY					
SUNDAY					

C. DESKTOP COMPUTER

PLEASE TICK **[√]** IF THE DEVICE WAS USED **ALONE** OR CROSS **[x]** IF **WITH OTHERS**.

	6am-10am	10am-2pm	2pm-6pm	6pm-10pm	After 10pm
MONDAY					
TUESDAY					
WEDNESDAY					
THURSDAY					
FRIDAY					
SATURDAY					
SUNDAY					

D. TABLET

PLEASE TICK **[√]** IF THE DEVICE WAS USED **ALONE** OR CROSS **[x]** IF **WITH OTHERS**.

	6am-10am	10am-2pm	2pm-6pm	6pm-10pm	After 10pm
MONDAY					
TUESDAY					
WEDNESDAY					
THURSDAY					
FRIDAY					
SATURDAY					
SUNDAY					

SECTION 4: YOUR APPLIANCES AND FREQUENCY OF THEIR USE

PLEASE TICK [√] ACCORDINGLY

Appliance	Once daily	Twice daily	More than twice daily	Once a week	Twice a week	More than twice a week	Every 2 weeks	Once a month	Less often
 **Dishwasher**									
 **Electric cooker/ hob**									
 **Kettle**									
 **Microwave**									
 **Oven**									
 **Radio**									
 **Toaster**									
 **Washing machine**									

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