

## **EVERYDAY HOUSEHOLD PRACTICES AND ELECTRICITY USE: EARLY FINDINGS FROM A MIXED-METHOD APPROACH TO ASSESSING DEMAND FLEXIBILITY**

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### **Abstract**

*In managing the high electrical energy demand during the peak early evening hours in UK domestic buildings it is critical to understand how household practices are coordinated in relation to resources used. In this paper an interdisciplinary group of researchers from sociology, environmental science, engineering and health present an account of their methodological approach and the reasoning behind it, along with some evidence of the impact different household everyday activities and routines have on electricity demand. It presents an innovative methodological approach that brings together Time-use and Energy-use research in households by combining social science and engineering tools and techniques in data collection and analysis. Established methods of self-report Time Use dairies and structured questionnaires were combined with innovative high-resolution electricity meters, automated Wearable cameras, and wrist-worn accelerometers capturing both qualitative and quantitative data. Electricity use was explored in this study through the lens of the temporal sequence of everyday activities that occur at home - often synchronised with other activities (or events) - and involving a number of appliances. The analysis of different variants related to time, space, sequence and intensity of activities showed how the extended routines involved in practices like food preparation, eating, personal/family care, household upkeep and resting/leisure time, might be flexible in time to adapt to electricity network requirements. Insights from this study provide indicators of the flexibility (or inflexibility)*

*everyday household practices have which can be scaled-up and explored in larger datasets.*

## 1. INTRODUCTION

Domestic sector is responsible for around 29% of Europe's electricity demand [1], while the UK's electricity consumption from households electricity use in 2003 represented the 35% of total consumption rising 1% every year since 1970 [2, 3]. In different national contexts the undergoing significant changes in energy systems and the transitions of electricity network towards renewable energy sources for electricity generation bring new challenging balances between supply and demand. Households use over half of the UK's electricity during the 'winter peak' between 6 to 7pm. Knowing the activities before and after the electricity peak demand period can help to reduce it, encouraging a shift to flexible loads and integrating more efficiently renewables. However, there is still an inadequacy of a good understanding of households' electricity consumption and load profiles. This is highlighted by the growing interest of research in energy demand studies towards how energy use is constituted socially and materially. Peak demand is an interdisciplinary problem and as Powell's [4] argues, electricity 'load' cannot be seen solely as an isolated physical phenomenon measured in voltage energy services, but also as a social one consisted of activities and social practices (e.g. cooking, laundry, dining etc.), as these compose the early evening peak demand loads.

Previous interdisciplinary studies [4] used part of a large and multi-faceted data set to explore qualitatively the 'peak flexibility' opportunities and implications for electricity demand in houses by contrasting performances of practice in cooking, dining, laundry and washing in the peak demand hours. In recent studies Wilson [5] developed a multi-step methodology, using time-use studies' profile data in a smaller number of houses and linking activity-centric research to energy-related research, to provide activity-related energy feedback to households with smart meters. While the *Meter* project adopts some of the methods discussed here at scale by conduction simultaneous collection of time-use and residential load profiles from several hundred UK households [6].

## 2. INTERDISCIPLINARY APPROACH

The interdisciplinary approach presented in this paper developed by a group of researchers from sociology, environmental science, engineering and health to broadening the current polarisation among engineering, economic and social science approaches and to provide different perspectives on the underlying factors involved in peoples activities and electricity use. The study's challenge was to bring together established methods from time-use studies and energy-use research combining novel mixed-methods tools and techniques from different disciplines to understand how everyday household practices are coordinated in relationship to electricity use. As Hitchings [3] suggests, investigating peoples' everyday practices requires to bring alternative methods that enrich the traditional methods of interviews.

Therefore, self-report time-use dairies, structured questionnaires and reconstruction interviews combined with electricity meters, automated wearable cameras, and wrist-worn accelerometers. Established methods used in previous time-use studies [7, 8], used self-reported time diaries to capture the time spend on activities in large national (e.g. UK's Office of National Statistics, ONS 2000/01 and 2005 Time-use survey collected respectively 21,000 and 5,000 diary days) and international sample sizes, and coded using the Harmonised European Time-Use Surveys

(HETUS) to allow comparisons between European member states. Common methods in energy-use studies for exploring everyday practices and collecting additional socio-demographic, economic and technical information were used to structured questionnaires, as well as to the semi-structured interviews re-constructing activities of the day with the participant [3, 4, 9-11]. In the building energy research area, Spataru and Gauthier [12] used wearable SenseCam sensors to collect occupancy data in households, monitor participants’ thermal comfort and system controls in relation to energy use. One of the challenges in this area in monitoring electricity use is the constraints in data resolution, cost of sensors and ease of installation by the householder. In research areas like health and travel studies combination or stand-alone methods of wearable sensors like cameras and accelerometers are well explored. Such methods used for instance to detect occupants’ presence and motion indoor (in residential or working environment) and outdoor contexts (local environment, urban facilities and services) or the levels of physical (in)activity and relationships with quality of life, health and wellbeing [13-15]. The value of combining device-based and traditional self-reporting methods is a tentative of evidence based research to close the gaps in small samples of previous self-report methods [16]. Studies from different discipline areas [12, 13, 15, 17], found that the use of wearable devices and sensors helped understand, conceptualise and map location, motion, activity providing the exact time period in which people are engaged with specific behaviours and practices. However, when such methods are used to monitor occupants in homes issues associated to privacy reasons may often constrain implementation and outputs’ resolution.

Example of the relationships between household practices and electricity use in food preparation as explored from the interdisciplinary group of researchers in this study is illustrated in Table 1 below.

<b>Interdisciplinary research approach</b>	<b>Example of relationships explored</b>
<b>Environmental science and engineering</b> <i>(Lower Carbon Futures, ECI)</i>	Sequence of evening cooking practices and use of lighting
<b>Sociology</b> <i>(CTUR, Department of Sociology)</i>	Gender relations in households and time use of cooking appliances
<b>Health</b> <i>(Department of Public Health)</i>	Physical activity rate in food preparation and eating, wellbeing, health habits and use of appliances

Table 1: The study’s interdisciplinary approach and relationships explored in the empirical evidence data.

### 2.1. Data collection methods and techniques

Four case studies, as part of the Energy -24 collecting New time Use Resources (CNTUR), are used in this paper to illustrate the interdisciplinary approach developed for data collection and analysis. The socio-demographic characteristics for these cases include single occupied houses with female occupants between the age of 28 and 64 living to similar size dwellings (2 and 3 bedroom houses) and with full time employment patterns (38-55 hours/week).

Different types of data collected from different sources provided different levels of resolution of

qualitative and quantitative real-time data. As shown in **Erro! A origem da referência não foi encontrada.**, this comprises self-report time-use dairies, structured questionnaires and reconstruction interviews combined with electricity meters, automated wearable cameras, and wrist-worn accelerometers.

Quantitative data include real-time data of household electricity use using an innovative high resolution electricity meter (*e-meter*) developed by low-cost configured smart-phones (Layberry, 2014, Grunewald and Layberry, 2015) that collects electricity readings every second for one day (24hours). The quantitative data from the wrist-worn accelerometer (Axivity watch) provides recordings for 48 hours of the intensity in a participant’s physical activity (PA)<sup>1</sup> from fine movements like writing, eating, resting to mild and moderate activities such as cooking, tidying, walking and cycling.

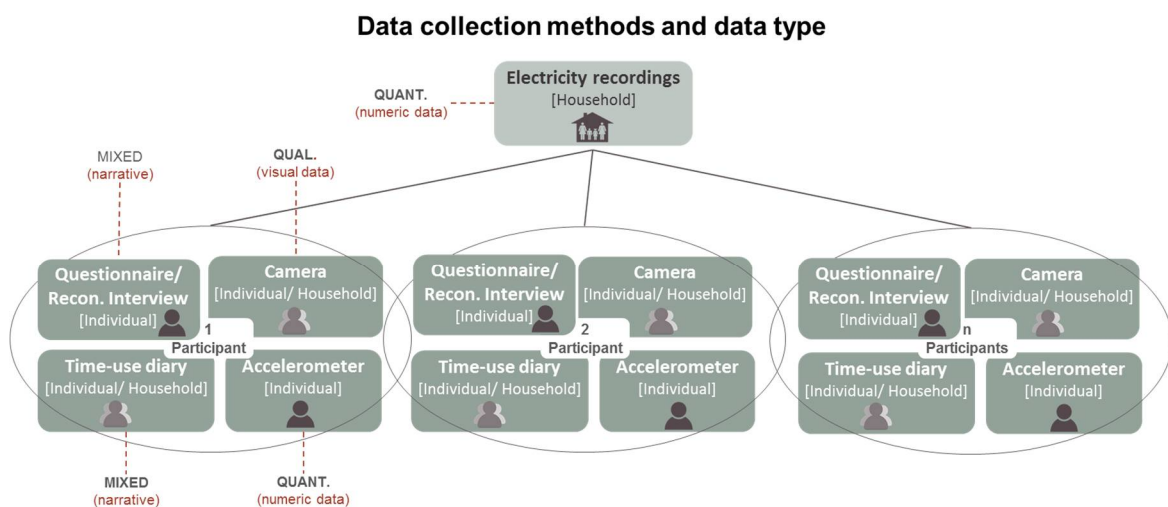


Figure 1: Different data collection methods and data type.

Qualitative data from automated wearable cameras (Autographer) provides additional visual recordings of a participant’s indoor and outdoor activities for a day as well as other socio-technical information of the context in which the activity occurs (e.g. artificial lights use or type and number of appliances, family care routines, etc.). Interview transcripts with participants’ narrative from viewing and reconstructing the events of their study day from images is used in validating qualitative data collected from other methods. Mixed qualitative and quantitative data is captured from time-use diaries to provide: the sequence of a participant’s activities (who does what and when?) during weekdays; information on joined activities with other members within the household; activities duration, location, and routines related to electricity use and usage of appliances; followed by their subjective rating of activity enjoyment. The combination of visual material and diaries information provides an insight on how the main and secondary activities

<sup>1</sup> The term PA is used to describe various aspects of an individual’s daily behaviours (sports, occupation), activities (walking, running, swimming) and bodily movements. 15. Troiano, R.P., et al., *Evolution of accelerometer methods for physical activity research*. British journal of sports medicine, 2014. **48**(13): p. 1019-1023.,

occur. Structured questionnaire collects information about the household from four distinct areas helping understand the social and physical environment and background context of everyday practices:

- socio-demographic information of the focusing on household occupancy factors (number of occupants and occupancy patterns);
- technical information about the building, ownership status, electric forms of heating, appliances and transportation mode providing information on both purchase and usage factors for instance by asking about the types of artificial lights and lighting practices or number of appliance and frequency of use;
- socio-demographic and economic information with questions on employment status, household income and electricity payment and;
- finally some personal information about occupants health, intensity of their everyday routines, and their physical characteristics that provide factors related to activities and energy use practices.

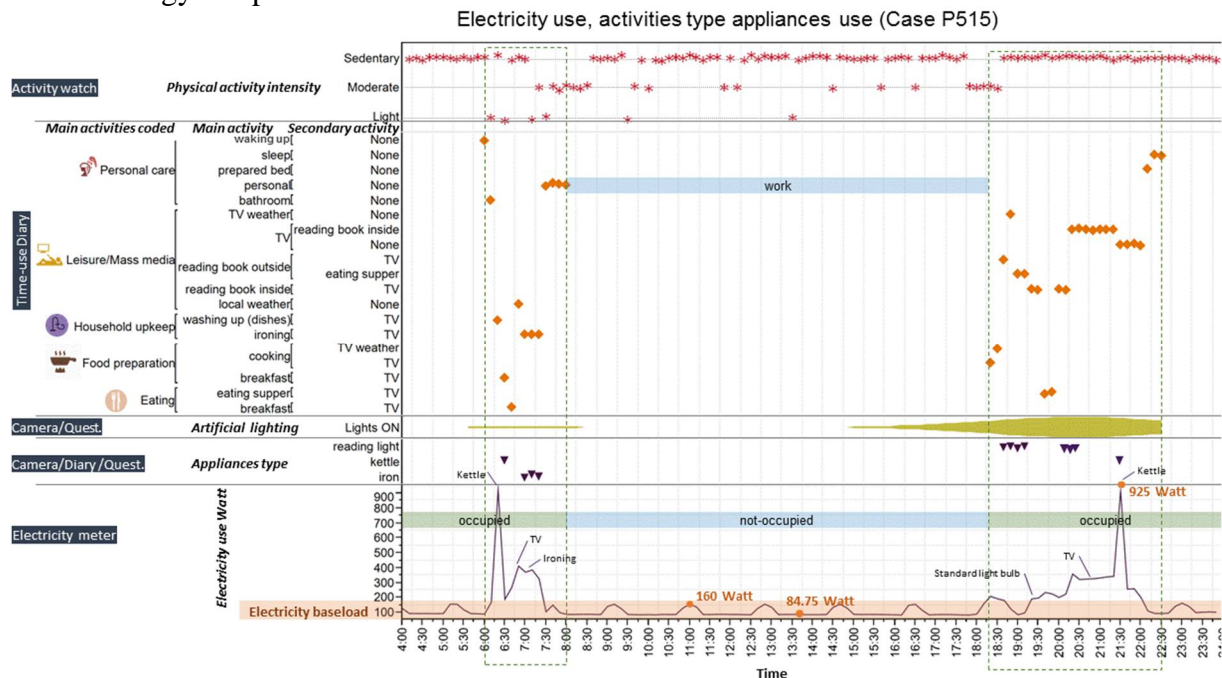


Figure 2: Example of analysis and data resolution using different methods and data sources.

The interdisciplinary approach in this study using multi-source data collection methods allowed cross-check of events on different recordings outputs maximising data validity and providing in-depth insights into personal and household activities related to electricity use (Figure 2). The specific methods selected complement each other to build a ‘thick’ picture of individual and household activity and to enable in-depth analysis of the extent to which different household everyday activities and routines can fit in the notion of flexible electricity demand. The novel methods suggested here combined different devices and techniques in data collection to overcome previous limitations and bias of self-report recordings of states, intentions and behaviours.

Confirming from images where the occupant is, and what the occupant does at a 1 minute-resolution this complements diaries and questionnaires information, which are a subjective recording of self-report perception of states and activities, and helps researchers to contextualise their assessment. For instance in the time-use diary evening food preparation is commonly recorded as ‘cooking dinner’ or ‘make dinner’ which may provide the type of activity, nonetheless does not give any information on other elements within this activity related to electricity use. In this, visual data from the wearable camera is not just a cross-check of the diary and questionnaire inputs, but puts the practice of food preparation in context confirming the exact time, sequence, location and occupancy characteristics, participation of other household members in the main and secondary activity, while it also provides evidence on the usage and type of appliances and lighting. The activity watch by measuring the physical activity (PA) confirms the time spent in specific states and sequence of the activities recorded with the other devices and techniques. The outputs derived from this help assess activity rate quantifying the intensity of physical activity *Sedentary* (<1.5 MET, like sleeping, watching the TV or computing), *Light* (1.5< and <3.99 MET, like cooking, eating, showering), *Moderate* (4.0< and <6.99, like housekeeping, walking) and *Vigorous* (7.0<MET, like exercising, cycling, running) measured in MET (Metabolic Equivalent of Task units). This output is particularly useful to enable activity recognition and explore relationships between electrical and physical intensity of a participant’s daily routines within the household.

## **2.2. Analysis of energy related activities**

In previous studies Bates et al. [18], explored energy consumption in the wider setting of services framing the context of their associated practices, expectations, energies, infrastructure and appliances by focusing on specific activities related to entertainment and IT, lighting, and food preparation and storage (i.e. cooking and refrigeration). Recent studies [5] following similar approaches explored a set of 16 activities that characterise everyday life at home grouped into 4 categories (i.e. Daily Routines, Interacting, Computing & Leisure, and Other Activities) looking on their association with energy end-use technologies. While there is an extended body of domestic energy research employing practice theory perspectives on heating, lighting, cooking, laundry, bathing as causes of energy use [9, 19-21], there is little combined with time-use studies using empirical practice-based data.

Activities involved during electricity peaks need to be understood in the context of social practices in order to understand how forms of flexibility and electricity shifts can be composed. The qualitative data has been analysed with NVivo software using HETUS thematic codes in coding activities and technologies within different clusters (e.g. occupancy cluster employment type, household composition etc.). While by employing theories of practice variants and relationships within electrically intensive everyday practices have been interpreted. As Powells et al. [4] suggest, theories of practice in time-use explorations can contribute not only in a better understanding of the factors related in peak demands activities but also explain ‘how and why social co-ordination in time and space around electricity use emerges and persists’. A simplification of Gram-Hanssen [20, 22], approach of the key elements of practice theory (Know-how and embodied habits, Institutional knowledge, Engagements, and Technologies) to three

elements categories stuff (materials), images (meanings) and skills (competences) suggested by Kuijer [23], employed in Higginson et al. [24] experimental study to visualise relationships between practices. In this approach different performances of practice can use different combinations and interconnections of these three elements (stuff, image and skill) and not just seen as single and homogenous within a practice [24].

This latter approach implemented in this study to organise the data from different collection methods and facilitate communication of theoretical associations and interpretations of practices to the interdisciplinary group of researchers. An example of analysis of morning activities using social practice theory is illustrated in Figure 3 below.

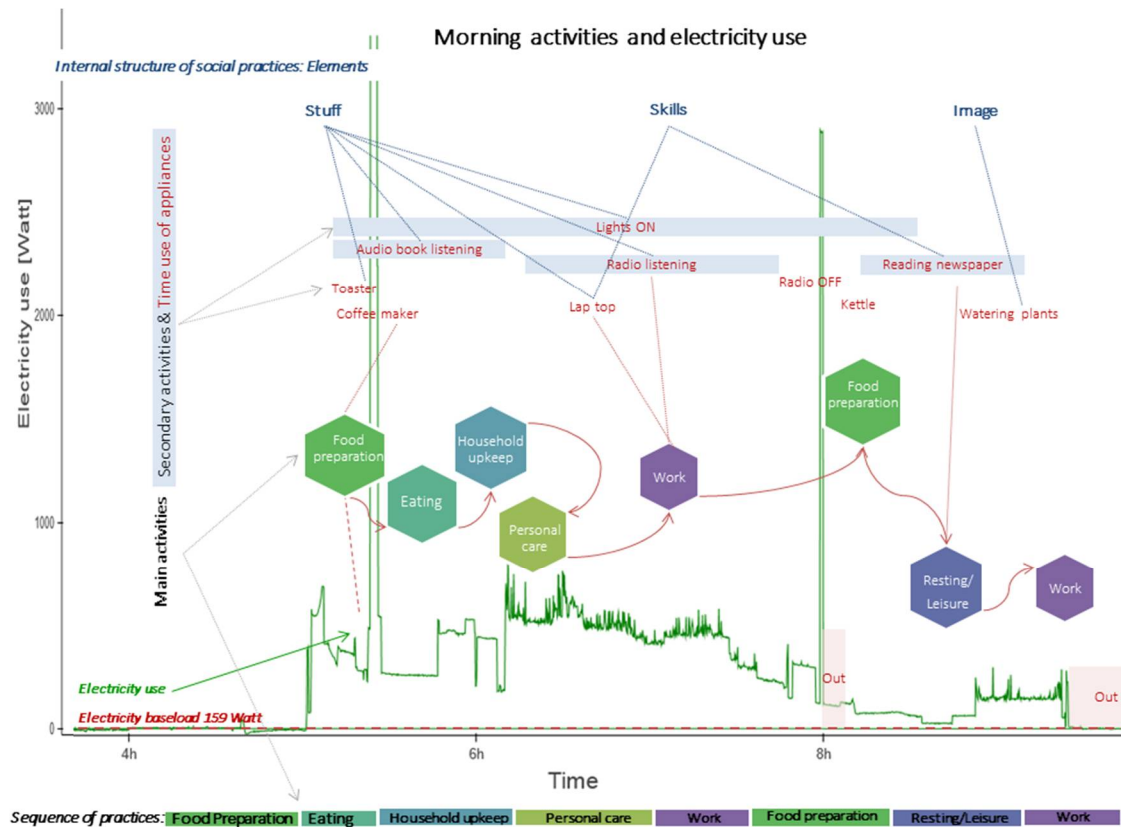


Figure 3: Example of analysis of morning activities as interpreted by social practice theory.

For the purposes of this study, although data collection included both in-home and outdoor activities, these were reduced to mainly indoor activities as are directly related to a household's end-use electricity consumption. Therefore, the empirical investigation focussed on the sequence and duration of a set of daily activities that are most electrically intensive<sup>2</sup>. The sequence explored what primary (main activity) and secondary activities (activities occurring simultaneously) are

<sup>2</sup> The study uses the approach presented by Powells et al. (2014, p.48, Table 2) for each of the appliances reported or recorded to be used in certain activities for the total electrical load (kW) and load band definition (very low = <0.99 kW, low = 0.1–0.2.99, middle = 0.3–0.99 kW, high = 1–2.49 kW, very high = >2.5 kW).

involved on specific six social practices like: food preparation, eating, personal/family care, household upkeep, home employment work and resting/leisure time<sup>3</sup>. In this for instance in household upkeep practices laundry and washing dishes were explored when laundry and dish washing appliances are used or in food preparation on the type and number of electrical appliances used. In households with more than one occupant, activities and their co-ordination within a performance of practice is distinguished in terms of shared and individual activities. Similarly ICT technologies (i.e. plugin or not) distinguished to those that are used in a single activity (e.g. oven and cooking) and those for multiple activities (e.g. multi-tasking lap-top for watching TV, listening music, work and socialising). While in multiple occupancy houses energy services (i.e. electrical heating and lighting) and co-ownership of technologies were also assessed (e.g. appliance integral use by a single user or by multiple users/occupants in the household likes TV or kitchen appliances). Time length (duration) has also explored how practices are coordinated in terms of temporality of activities looking whether these are repetitive routines (food preparation and audio book listening) or non-repetitive, temporary and unique daily events (prepare tea for guests).

Knowing the daily occupancy of the household is important not only to the base load calculation but also in creating daily profiles in which a participant's registered or unregistered activity or inactivity can improve the understanding of how electricity is being used in the household throughout the day. However, occupancy cannot solely explain household's electricity baseload. As found in previous studies [25], defining base-load for each household is important first because depicts the lower electricity demand provided by the network and secondly how much of this load can be met by a generation system (e.g. cases in the sample with PV installed). For the purposes of this study the base load for each household is considered the average of the lowest hourly consumption of the time that the house is not occupied or occupants are inactive (e.g. asleep) and all appliances are switched off or in standby mode. This also allows extracting from the electricity meter readings human base load that gives an estimation of the human activities taking place on the peak demand hours and that is cross-checked with the accelerometer data indicating the level of a participant's activity in relation to appliances use.

The electricity base-load for each household (lowest consumption) was considered the hours of the day that the house was not occupied. This includes appliances that are always on stand by and those appliances that are continuously in operation (e.g. wireless routers, refrigerators, aquarium, security systems, etc.). However the lowest consumption excludes the appliances that were programmed to automatically function only for one time when the house is not occupied (e.g. washing machine, dishwasher, etc.). From the data provided from the participant's diary and images (wearable camera) daily activities found also to involve automatic operation of programmed appliances, like washing machine or dishwasher that are in use when the house is not occupied. This allows identifying the number of routinely or not energy related operations, except from the stand-by, that are selectively happening in house when people are not there. For instance flexibility is explored within more solitary tasks and less heavily socialised household activities like laundry and dishwashing [4, 26, 27], to provide evidence based indicators towards selective

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<sup>3</sup> The set of activities emerged from the sample used the activity code list of the UK Harmonised European Time-use Study (HETUS) Guidelines 2014 (Centre for Time Use Research 2014 based on ONS (2000)).

automation of daily practices. Studies like Grunewald [28], suggest that even in cases where automation is thought to take full agency of response management, ‘practice led’ mechanisms of daily practices are deeply affected by practitioners and less by ‘appliance led’ flexible options. In this respect observations from this study are of importance to technical and economic understanding of the possibilities to shifting selective practices towards ‘active demand options’ [26].

### **3. SOCIAL PRACTICES, ACTIVITIES AND ELECTRICAL INTENSITIES,**

In the following analysis we draw on the implementation side of study’s approach discussing some preliminary observations of electrical intensive morning and evening practices drawn out from the CNTUR sample for the specific cluster of single occupied houses (Figure 4). Daily practices, activities, technologies, and location where activities occur in relation to direct and indirect electricity loads and electrical intensity of appliances are illustrated in Figure 5 below.

Morning practices (occurring from 6:00 to 9:00am) are generally consistent, with interchangeable variations to the sequence personal care, breakfast preparation, leisure occur and are co-ordinated with ICTs use and household upkeep activities. Seasonal variations related to indoor daylight levels (e.g. increased daylight levels during the equinoxes) found not to affect artificial lighting demand especially in personal care practices in which lights were on in all cases. This suggests that particular practices of personal care perform independently from environmental conditions of time and space. Participants’ active day time begins with personal care that has the longer duration (10-90min) of morning performances and consists of main activities and instantaneous events like getting-up, showering and bathroom use and getting dressed. In some cases personal care co-occurs with secondary activities or events, varying in time length, like listening to music, checking mobile phone or drinking/eating breakfast. The most common secondary activity however, is the use of ICTs involving TV watching or socialising via social media and listening to music using smartphone, tablet or laptop.

The visual material from wearable cameras allows distinguishing plug-in technologies to interpreter electrically associated loads in the e-meter electricity measurements and cross-checks with the diary information and questionnaire. The duration of such secondary activities tend to last longer from instantaneous usage of kettle, toaster or microwave involved in main activities like food preparation. Visual data confirmed that various forms of breakfast preparation involve instantaneous events of cooking (shorter than the 10min recorded in the diaries) and of high electrical load (use of kettle, toaster and microwave = 1–2.49 kW) explaining the high peaks in the electricity recordings (e.g. Case P515, Figure 2). Main activities like personal care found less electrically intensive compared to co-occurring activities. While, in household upkeep combinations of ironing (medium electrical load) with TV watching and radio listening are also found to be electrically intensive and perform for shorter time during morning occupancy compared to evenings. Changing the time of a practice in multi-occupied houses requires higher coordination and sharing ‘pulse’ of time and space between linked activities and family members [4, 28]. In single occupied houses however time shifting practices like in house upkeep from evening occupancy peak demand hours to morning can be dependent from more flexible structures as it relies solely on the time capacity and ‘behavioural flexibility’ (willingness) of the practitioner

to make a sacrifice (waking earlier or share differently among other morning activities time).

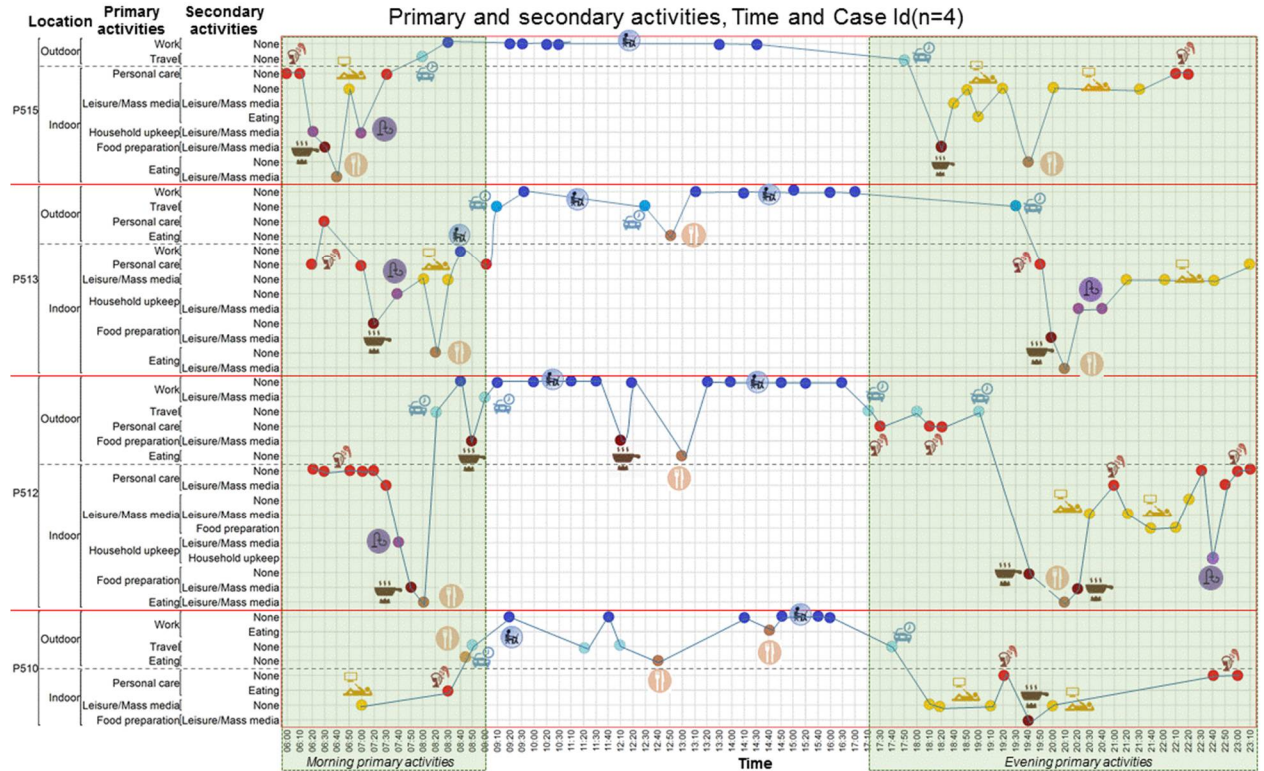


Figure 4: Sequence of primary and secondary activities in single occupied houses (n=4).

Evening occupancy (from 17:30 to 23:00pm) although it consists of similar interchangeable variations in terms of sequence of practices (e.g. between personal care, dinner preparation, leisure and housekeeping), compared to morning occupancy the duration of the same primary and secondary activities is longer. For instance evening leisure activities in all cases is considerably longer and synchronised with other activities that involve having the TV on and reading a book or eating. Among everyday practices in Powell’s et al. [4], evening meals was found the most inflexible practice constraint by social norms conventions and less open to effective peak demand shift interventions. Evening dinner preparation in the sample, varying in time length from 10 to 30min, has strong lifestyle dependencies in terms of preparation and is linked to social and health conventions, compared to breakfast. Cooking occurring at the peak demand hours (between 17:20 to 20:20 pm) and involving high electrically intensive appliances electric hob, kettle and microwave, found to perform in all cases in co-ordination with leisure activities like, watching TV and listening to the radio or socialising via mobile phone. Dining is performed as a primary activity in all cases except one, following always immediately after cooking performances and accompanied by TV and radio broadcasting secondary activities. In contrast, in short time food preparation practices involving microwaving preparation eating recorded as a secondary activity compressed in a 10min performance for both practices. The elements that form food preparation practices in different household contexts are associated

with certain times during the day (e.g. morning and evening cooking in full-time employment households), with certain ways of electrical intensity (e.g. lights on, electric oven cooking versus micro-wave pre-cooked meals), with certain ways of using resources (e.g. time in laundry or dishwasher routines in households with PVs) and also with certain health and dietary wellbeing practices (e.g. raw food diet versus cooked food or home prepared food versus ready or delivered). Social conventions in how food preparation and eating routines are performed in single occupied households vary in terms of time space and social commitments compared to families with children in which time performances are under certain less flexible time routines (e.g. eat, bath time, story/play time and sleep time) that constrain practices time and space flexibility. We recognise that configuring the flexibility of certain practices in response to peak demand loads, needs to consider flexible long term mechanisms for social and personal life changes (e.g. household composition changes from birth of a child, employment status changes homeworking incentives, diet changes due to age or health issues, etc.). Which supports that in demand side ‘flexibility is a dynamic property, which can only be observed through time and in conditions of change’ [28].

Categories of daily practices <sup>5</sup>	Activity Type	Time	Technologies involved		Location <sup>6</sup> (Indoor or Outdoor)	Direct or Indirect elect. load	Elec. intensity <sup>7</sup> <sub>8</sub>	Flexible or Fixed
Personal care	Wash and dress	10-90min	X X X	Hair drier Elec. toothbrush Elec. shower	Bedroom/ Bathroom	Direct/ Indirect	Low	Fixed (practice led)
	Exercise meditation &		0	n/a	Bedroom/Livingroom/ Garden	Indirect	n/a	Flexible (practice led)
	Sleeping/ resting	7-9h	0	n/a	Bedroom/Livingroom	Indirect		Fixed (practice led)
Food preparation	Breakfast/ Lunch	10min	X X X X	Kettle Microwave Electric hob Toaster	Kitchen	Direct	Very high Very high Very high Very high	Flexible (appliance led) Fixed (practice led)
	Dinner	10-30min	X X X X	Kettle Microwave Electric oven Food mixer	Indoor	Direct	Very high Very high Very high Very high	Fixed (practice led)
Eating	Eating and drinking	10-20min	0	n/a	Kitchen/dining room/ living room/ office/	Indirect	n/a	Fixed (practice led)
Housekeeping	Cleaning	10min		n/a	All rooms	Indirect	n/a	Flexible (practice led)
	Laundrying	10-40min	X	Washing machine Tumble/Washer drier	Kitchen/Bathroom	Direct	High Middle	Flexible (practice & appliance led)
	Dishwashing	30-120min	X	Dishwasher	Kitchen	Direct	High	Flexible (practice led)
	Vacuuming	10-30min	X	Vacuum cleaner	All rooms	Direct	Middle	Flexible (practice led)
	Ironing	10-30min	X	Iron	Livingroom/Bedroom/	Direct	Middle	Flexible (practice led)
Leisure	Mass/Digital media	10-160min	X	Radio Computer	Livingroom/Bedroom/ Office	Direct	High	Flexible (practice led)
	Hobbies	10-120min	0	n/a	Livingroom/Garden	Indirect	n/a	Flexible (practice led)
	Socialising	10-60min	X	Computer/smartphone	Livingroom/Bedroom/ Office	Direct/Indirect	High	Flexible (practice led)
	Communicating	10-60min	X	Computer/smartphone	Livingroom/Office	Direct/Indirect	High	Flexible (practice led)
Work/other	Computer work	60-120min	X	Computer	Office	Direct	High	Fixed (practice led)

Figure 5: Flexibility of daily practices, time and appliances’ use electrical load (n=4). (5, adapted from HETUS codes, 8, 7, Based on Powell et al. 2014, Wilson et al. 2015). 6 Activities that are taking place at home, indoor rooms, outdoor garden. Direct e.g. plugin electrical load and stand-by, Indirect e.g. lighting demand or

*programmed/automated appliances)*

Configuring socio-technical capacities by using less electrically intensive means and time settings can increase ‘peak demand flexibility’ [4] of practices. In food preparation Powell’s et al. [4] suggest the integration of different cooking technologies like slow-cooker that can allow people to continue eating together at peak demand hours while cooking performance is ‘programmed’ off peak demand hours. In other cases ‘substituting practices’ (i.e. having cold meal) or ‘changing the practitioner’ (i.e. going out for dinner instead of cooking) [28] is suggested in practice led responses to increase flexibility. We argue that alternative socio-technical capacities and flexibility mechanisms as such need more exploration on their implications to social and individual structures of practices to avoid traction and conflicting effects. For instance the enjoyment of time spent in cooking and eating was highly rated in the sample suggesting that cooking alternatives need to substitute or balance enjoyment effects. Economic constraints, health and nutrition requirements and the frequency of practices, for instance dining out, also need an interdisciplinary exploration on the causes and effects of energy reduction versus food cost, long term implications from eating habits in health or social skill deficiencies in healthy cooking.

#### **4. DISCUSSION AND CONCLUSIONS**

The aim of this paper is twofold, discuss the methodological approach from an on-going interdisciplinary research project and draw early insights from the implementation of this approach in a small number of cases. In study’s approach the strength of combining methods and techniques from different disciplines and research areas is on the use of multiple quantitative and qualitative data sources that improved the scope, resolution and robustness in exploring complex energy intensive activities in households. Developing individual and household level time-use profiles not only allows comparisons with other national time-use samples but also including different activities energy intensity generates indicators for patterning flexibility in energy data. The cross-check between data sources except from the data validation also revealed omissions in collecting activities from single self-report techniques only. Multiple-sources allowed time-use diaries outputs be revised and resolution of synchronised activities corrected expanding the mapping of relationships with energy use and physical activities. Managing a mixed method interdisciplinary approach it also brought to light certain methodological limitations of qualitative/quantitative techniques and each device technical intrinsic restrictions. For instance standardized time-use survey instruments for coding (HETUS, Harmonised European Time-Use Study) need to integrate and expand more ICT related activities improving the mapping technological implications to current everyday life activities. In calibrating the Autographer camera device issues of accuracy of temperature and light levels measurements also emerged and various challenges with cameras’ battery failures expectancy were faced. E-meter electricity sensors were continuously tested, monitored and upgraded to overcome problems accuracy in data collection. Another challenge lies in the interactions between the multi-disciplinary teams in creating mechanisms that communicate and visualise data analysis outputs by integrating multi-disciplinary interpretations in data analysis broadening the understanding of relationships between multiple aspects involved in everyday life practices.

The early insights discussed in this paper show that the complexity involved in energy intensive everyday activities needs an interdisciplinary approach not only to broaden and capture reliably activity-centred perspectives, but also to contribute evidence-base indicators of existing forms of socio-technical practices that allows considering the implications flexibility mechanisms can have to economies, industry and society.

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