Narrowing the gap between smart metering and everyday life.

Comfort, cleanliness and smart metering technologies in undergraduate students' households.

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‘Human coexistence is inherently tied, not just to practices, but also to material arrangements. Indeed, social life, as indicated, always transpires as part of a mesh of practices and arrangements: practices are carried on amid and determinative of, while also dependent on and altered by, material arrangements. I call the practice arrangement nexuses, as inherently part of which human coexistence transpires, sites of the social.’

Theodore Schatzki (2010, page 130)

‘…the temporalities of practices represent an instructive analytical theme for developing understandings of everyday life, consumption and particular forms of human action.’

Dale Southerton (2013, page 20)

‘Boundaries become fluid, space is conceived of as flowing [...] openings and boundaries, perforations and moving surfaces carry the periphery to the centre and push the centre outward, a constant fluctuation sideways and upward, radiating, all-sided, announces that man has taken possession of omnipresent space.’

László Moholy-Nagy, (1947, page 63)

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Abstract

Smart meters measure aggregate energy consumption for an entire building. Recent literature suggests that disaggregated information describing appliance-by-appliance electricity consumption is more effective than aggregate information (Kelly et al. 2016, Fisher 2008).

The thesis therefore investigates the potential for aggregated and disaggregated energy metering data but takes a different angle by trying to understand how newly established student households use energy in their daily lives and whether this can be changed with smart electricity display meters. The interdisciplinary methodology involved video recorded guided tours, focus groups, semi-structured interviews, photographs, video diaries and metered energy data. The data was collected in three phases. Initially, a video recorded guided tour was carried out in each student household to find out how students are sensing their environments as they move inside the house and how they are maintaining these environments through the sensory aesthetic of the home. This was followed by focus group sessions and semi-structured interviews in each household to find out how electricity was implicated in everyday practices. Next, students received three different types of smart electricity display monitors, aimed at assessing the implication of disrupting practices by real-time metering feedback.

The central finding of this work is that practices-that-consume energy cannot be reduced to attitudes or intentions. This finding is nuanced by an extended discussion on the relationship between practices and the temporal structuring of practices. The research identifies other types of feedback (such as social, material and sensory) that influence the energy use in practices or substitute practices for other non-energy using practices, suggesting that there are no simple technological or behavioural fixes. More profoundly, this thesis suggests that policy should focus on connection between practices, rather than technological performance or what consumers think about electricity display monitors.

The thesis concludes by discussing a re-framing of policy expectations; identifying the ways in which smart metering data could target domestic practices and its influencing elements potentially constrain or catalyse a transition towards a more sustainable way of living.

Abbreviations

ABC: Attitude-behaviour-context

AMI: Advance Metering Infrastructure

CCC: Committee on Climate Change (UK)

CO_2: Carbon dioxide

CPP: Critical peak pricing

CT: Current Transformer

DCLG: Department for Communities and Local Government (UK)

DECC: Department of Energy and Climate Change (UK)

DEFRA: Department for Environment, Food and Rural Affairs (UK)

DLC: Direct load control

DPP: Dynamic peak pricing

GHG: Greenhouse gas

ICTs: Information and communication technologies

Kg: Kilogram

kW: Kilowatt

kWh: Kilowatt hour

LED: Light-emitting diode

PV: Photovoltaic

SDSM: Smart Demand-Side management

SEDM: Smart Electricity Display Monitor

SEDM 1: OWL USB CM 160

SEDM 2: Energenie Energy Saving Power Meter

SEDM 3: EDF Energy Eco-Manager

SMS: Short message service

TPB: Theory of Planned Behaviour

TRA: Theory of Reasoned Action

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PART I.

Scene-setting and context

Chapter 1: Introduction and overview

Energy use in buildings is a major contributor to global carbon emissions (IPCC 2014) and in the UK 17% of carbon emissions are attributed to residential building energy demand (DECC 2014). In this context, attempts to reduce and decarbonise domestic energy use are a key focus of energy policies. One of the first steps in decarbonization of the grid is the roll-out of smart meters which the UK Department for Energy and Climate Change (DECC) plans to have installed in all UK households by 2020 (DECC 2014). The smart meters are accompanied by freestanding real-time displays or Smart Electricity Display Monitors (SEDMs) that provides real-time feedback to householders on their energy consumption patterns (DECC 2014).

The SEDMs allow residents to measure which electric appliances consume the most electricity and to use this information to review their electricity consumption (DECC 2014). Most importantly, from the perspective of this thesis, SEDMs provide householders with two forms of feedback of their electricity consumption: ‘near’ real-time feedback of current electricity consumption and historical feedback of electricity consumption. The expectation is that householders will use SEDMs in managing their electricity consumption and associated carbon emissions (DECC 2014). In addition to SEDMs, householders can also communicate with energy companies such as British Gas and OVO Energy, and commercial organisations, such as iMeasure and OPower, through web and app based electricity feedback platforms that make electricity consumption visible and accessible to householders at any time of the day. However, delegating smart metering to support energy efficiency on the individual user level poses challenges in monitoring usage and providing accurate load forecasting (Gajowniczke et al. 2013). For example, domestic electricity load profiles are often highly stochastic, influenced by several factors, such as user patterns, economic factors, time of the day, weather conditions or random effects that all influence the accuracy of load forecasting (Gajowniczke et al. 2013). One possible solution is to focus on the data generated by SEDMs on the end users responses to smart metering technology in everyday life where day-to-day practices, such as bathing, cooking, laundering and house cleaning, take place.

Everyday practices are commonly used as a site of social enquiry by consumption scholars in understanding the dynamics of practices that use energy and water, such as heating (Gram-Hanssen 2010), cooling (Strengers et al. 2011), showering (Hand et al. 2005) or freezing (Hand et al. 2007). Social practice scholar's findings suggest that everyday practices are continuing to shift and change, in ways that do not support energy demand policy intervention on how people choose to consume resources and how they change consumption (Pullinger et al. 2014). For example, bathing practices have changed because of the introduction of modern systems of energy and water provision, infrastructures such as the bath and the shower, but also because of the commercial promotion and social diffusion of common understanding regarding body odour, personal appearance and hygiene (Hand et al. 2007).

Nonetheless in smart policies, smart metering is positioned at the nexus between the messy and mundane of everyday life and the autonomous resource manager (DECC 2014). Thus, the dumb traditional energy and water meters remind consumers that responsibility for energy and water management rests outside the household in the separate sphere of production (Sofoulis 2005) and smart meters have the capability of extending inside the home, as well as back out again. This technology is assumed to offer opportunities to manage energy consumption, potentially reconfiguring the interconnected dynamics of everyday practices (DECC 2014).

In response to these concerns and potential opportunities, this thesis develops a distinctly different approach to 'human dimensions' research typically investigating the smart metering data effect in everyday practice, whereby social researchers have attempted to understand and overcome the barriers householders face in acting as individual and autonomous resource managers (Strengers 2013). Understanding how smart metering technologies are interpreted and used is dependent on understanding how these technologies fit within the existing way everyday life is organised and practices-that-consume-energy are performed. On this basis, the broader consequences of designing smart metering policies can be considered.

1.1. The research questions

This thesis addresses the following research question:

How can smart metering narrow the problematic divide between the policies and strategies of smart metering in students' day-to-day comfort and cleanliness practices?

Given the lack of attention previously paid to understanding comfort and cleanliness practices in students' households, or how energy feedback works in these households, a series of interrelated questions needed to be answered to inform the primary research question. These questions are addressed in the thesis in the following order:

- What are the problems and limitations associated with the energy metering data suppliers - energy consumption divide and how do these problems manifest themselves in smart metering demand programs (**Chapter 2**)?
- How do we understand, conceptualize and analyse undergraduates' everyday comfort and cleanliness practices-that-consume energy (**Chapter 3**)?
- How do we study undergraduates' everyday comfort and cleanliness practices-that-consume-energy and what methods can be usefully employed in this process (**Chapter 4**)?
- How do undergraduates manage their lighting, heating systems and indoor climate conditions after moving away from home to live more independently? (**Chapter 5**)
- How are undergraduates' comfort and cleanliness practices-that-consume-energy constituted after moving away from home to live more independently? (**Chapter 6**)
- How, if at all, do smart metering data reconfigure practices-that-consume-energy (**Chapter 7**)?
- What role can smart metering data play in a transition towards decarbonisation of the electricity grid (**Chapter 8**)?

Table 1.1 provides the thesis structural overview. This empirical study also offers methodological insights for other researchers wishing to understand and analyse the formation of everyday practices, particularly those wanting to apply these understandings into current smart metering management policy and practice.

Chapter Title	Summary
PART I. Scene-setting and context	
1. Introduction and overview	Defines the context as well as the aim and objectives of this research project.
2. Theoretical and policy context	Outlines the relevant policy and theoretical contexts as well identifies the research gap and research questions for the thesis to answer.
PART II. Research Design	
3. Understanding and analysing social practices	Chapter three presents theories of social practice with a focus on the definition and organisation of practice and the way practice theory illuminates this work.
4. Researching undergraduate's everyday practices that consume energy	This chapter outlines the methodological approach used for addressing the knowledge gaps identified in chapters 1 and 2. This chapter also includes discussion on the methodology, data and methods of the study.
PART III. Results, analysis and discussions	
5. Sensory and Invisible elements of energy consumption	Investigates the effect of moving to a new house on students' comfort and cleanliness practices-that-consume-energy.
6. Temporal structuring of comfort and cleanliness practices-that-consume-energy	Investigate the potential utility of using theories of social practice in conjunction with smart electricity display monitoring data in understanding of the way everyday practices-that-consume-energy are performed inside the house and the connections between comfort and cleanliness practices.
7. Understanding how systems of practices-that-consume-energy change over time	Investigates the cause of change in practices-that-consume-energy after receiving SEDMs.
PART IV. Conclusions	
8. Conclusions	In this chapter the methodological reflections, the applicability of the findings to policy and the potential for future research is discussed.

Table 1.1. Overview of Thesis Structure

1.2. Smart metering, comfort and cleanliness

1.2.1. Why smart metering?

Smart metering, often referred to as Advanced Metering Infrastructure (AMI) or 'interval metering', is best described as a platform which enables a range of services (such as automated meter-reading and accurate billings), peak demand programs and two-way communications between suppliers and consumers of power (DECC 2014). The definition of a smart meter may vary in both energy and water sector, partly because its smart functionality is still being defined. Generally speaking, a smart meter is the next generation of meter characterized by its two-way communication to and from the meter and by its half-hourly data reading and storing capability. Smart metering is most advanced in the UK electricity sector, and the UK government has mandated its roll-out by the end of 2020. The aim of the roll-out has been to assist a range of demand management programs aimed at reducing peak demand and greenhouse gas emissions, as well as paving the way to a smarter grid that would be able to handle large amounts of distributed generation. To date, there have been small size metering roll-outs in the water sector, and trials of automated meter reading organized by Southern Waters and Thames Waters are taking place in Kent, Sussex, Hampshire and the Isle of Wright.

The residential energy management and monitoring techniques enabled by smart metering include the provision of energy consumption feedback through an in-home display, variable real-time pricing regimes for electricity and direct load control involving remote control of appliances (DECC 2014). Furthermore, in the future, it is expected that smart meters will enable complex home automation functions or different price regimes for on-site electricity generation (DECC 2014).

As noted above, smart metering is defined as a remedy for the UK supplier-consumer divide (such as peak electricity demand) characterizing the energy sector (DECC 2014). Thus, for electricity suppliers smart metering is a solution for improving the efficiency of the grid through technological innovations such a direct load control or 'leakage detection'. Smart metering also encourages consumers to engage with smart metering by providing consumption feedback, price signal[1] or resource management education. The main benefit of the smart meters is its two-way communication; they let smart metering data enter and exit the home, changing the ways in which electricity is provided to householders and the way householders interact with their electricity. The smart meter and the smart metering data it enables the empirical exploration of the limitations of the smart metering supplier - consumer divide and potential ways to narrow it.

1.2.2. What makes 'data' interesting?

The term big data applies to the processing, management, and analysis of large amounts of data (Malik, 2013). In the thesis 'big data' is more than high-volume, high-velocity of data collected using smart electricity display monitors, it is a disruptive force that also includes smart metering technologies that allow data to be leveraged. Energy data is usually numerical, quantifiable and calculable in nature and is central to the 'smart agenda' (Strengers 2013) in four ways.

Firstly, in the cost-benefit analysis of smart metering projects and policies, data is used to quantify the benefits of capturing electricity consumption through smart tools (DECC 2014). Data is expected to illuminate the future of the energy industry, and therefore is a strategic resource, and is used in improving consumers' aptitudes towards smart energy technologies. On the other hand, the quantitative data used in the cost-benefit analysis of smart metering projects are collected and prepared by engineers and economists who in their analysis are not considering how the visibility of the 'kWh' influence consumers or how the visibility of '£' would encourage the use of smart technology in everyday life (Strengers 2013). In this perspective the data is the cornerstone of a new vision of the world that is ruled and ordered by data.

Secondly, data forms the 'win-win' relationship between the smart energy supplier and consumers of energy (DECC 2014). In the smart agenda, utilities and governments are positioned as smart data providing advisers serving the needs of the smart energy consumers. In a similar way, consumers of energy are positioned as data-hungry decision-makers, who make rational choices about how to use

[1] A price signal is information conveyed, to consumers and producers, via the price charged for a product or service, thus providing a signal to increase supply and/or decrease demand for the priced item (Strengers 2010).

energy in their everyday life based on the smart data. The smart data is delivered to householders in a number of ways: for example through website portals or through smart electricity display meters. Furthermore, the smart data can be incorporated into and delivered to household technologies, such as the TV or washing machine, which can be programmed to go to sleep or come on at specific times of the day. In this way, data and technologies that mediate it, represent the core through which suppliers and consumers of electricity interact.

Thirdly, the smart agenda suggests that by living the everyday life after the smart data will result in the decarbonization of the electricity grid (DECC 2014). In other words, it is assumed that collecting half-hourly data via smart meters will enable utility companies to analyse and to forecast demand profiles, and via smart connection provide back to householders the actionable data. It is expected that householders, after receiving the actionable data, take meaningful actions in everyday life. In this perspective data, together with technology, forms the basis of human action and social change (Strengers 2013).

Finally, data is collected in databases that inform the understanding and management of energy consumers. Recently, energy companies are using databases to understand the inner workings of the new energy consumer. The aim is to capture the practical data about energy consumers, to understand and target them. These groupings and sortings of the energy consumer have resulted in manufacturing and transforming consumers into data. It may seem odd to suggest that the databases can be used to understand energy consumers (what Ian Hacking (1990) has called 'making up the people'). In fact, these ideas are not new; they build up on market research techniques dating back to 1950s, based on classifying consumers according to a set of different motivations and priorities (Miller et al. 1997). Thus, by moving beyond the meter, utility companies view consumers as: '*half-hourly or night-and-day loads who are switched on and off to match certain network capacities, or as a series of hot and cold spots on infrastructure networks*' (Van Vliet 2006). Although, demand-side management requires a more active role for consumers in resource management - compared to supply-side options, little attention has been paid towards how consumers manage electricity in their everyday life.

In summary, in the smart agenda, energy data is crucial in explaining the gains from the roll-out of smart energy technologies; data forms the 'win-win' relationship between the smart energy suppliers and consumers of energy; the living after the data enrols energy consumers into new forms of social action and social change; and energy consumers are known and targeted by using practical data on their energy consumption.

1.2.3. Why comfort and cleanliness?

The most important residential practices that the smart metering aims to address are those relating to residential comfort and cleanliness. Smart metering policies largely ignore the composition and the dynamics of residential practices, focusing instead on supplying data in making energy consumption more efficient. This focus is potentially dangerous, as the history of comfort and cleanliness practices revealed 'dramatic variations' in household energy use. Elizabeth Shove (2003) argues comfort and cleanliness practices have been subject to distinctive forms of standardisation and escalation in recent centuries. For example, from the medieval times of dry bodily cleaning practices, to the 19th centuries weekly bath (Shove 2003) and more recently the daily shower (Hand et al. 2005), bathing practices went through periods of change in their resource consumption. In a similar way, heating, cooling, laundering (Shove 2003), and house cleaning (Martens 2007) practices, shaped by sociotechnical systems, have continuously shifted and changed their energy consumption trajectories (Shove 2003). Importantly, all these studies reveal that the transformation of comfort and cleanliness practices do not follow rules or rational choices and they neither result from a long-standing historical phenomenon nor of natural evolutionary processes (Shove 2003, Strengers 2013).

Furthermore, it is often thought that commercial interest is the driver in transforming the comfort and cleanliness practices, and it is rarely questioned how products should be designed around new or modified practices. For example, new heating or cooling systems are designed in laboratories around old technologies that have reconfigured and are still reconfiguring household practices (Strengers 2013). Similarly, cleaning products, laundry powders, shampoos, softeners used with old technologies, continually define new sensory benchmarks for smell, hygiene and presentability (Pink 2012). But by narrowing the focus on saving consumption, shifting everyday routines, and not challenging the taken for granted understandings of everyday practices, the resource consumption associated with everyday practices may continue to increase (Sorrell 2007). Householders with more efficient technologies may start to shower more frequently or heat and cool larger spaces for longer periods of time, as historical trends indicate they have done in the past (Shove 2003) and current trends suggest they will in the future. Furthermore, Shove (2003) warns that ignoring the '*inconspicuous consumption'* associated with these everyday practices may result in trajectories, habits and expectations that '*are obdurately resistant to change'* (Shove 2003, page 3). These are some of the reasons to account for and address, the changing composition of comfort and indoor cleanliness practices in smart metering agendas.

1.2.4. The significance of energy consumption data in household comfort and cleanliness

It has been claimed that energy consumption data from the SEDMs helps households to reduce energy consumption by up to 15% (Faruqui et al. 2010, Fischer 2008). Though energy data may improve energy awareness (Ehrhardt et al. 2010), not all households require this service. The rich literature on electricity feedback technologies suggests that householders have different expectations of the type of device and/or service required: basic or advanced real-time consumption monitor; disaggregated energy consumption per appliance or per room; monitoring for security reasons; more comprehensive advice on energy savings. Though such information is probably necessary, it is certainly not sufficient. The information is much more efficient when combined with other energy saving strategies. For example, the E.ON study (EDRP 2011) reveals that smart meters linked to a SEDM or to accurate billing with energy efficiency advice may result in energy consumption reduction of 2% to 4% in the short term. The limitation of these quantitative studies is their lack of understanding about how and why consumers decrease their energy usage. In filling in this gap, qualitative studies suggest going beyond the aggregated and average data, and towards investigating how energy is used in current domestic practices (Wallenborn et al. 2011). Thus, a contextualised approach into daily practices can help us in understanding how households integrate energy information in their lives.

The main benefit of the long-term monitoring data is that it provides understanding into the use of domestic technologies. Importantly, it is an access point for investigating the interconnections between technology and other elements of practice. Thus, by investigating householder's technological usage, monitoring provides a measure of performance and it serves as a proxy for everyday practices-that-consume-energy (Foulds et al. 2014). Monitoring data has been used as part of investigations into everyday practices. For example, Gram-Hanssen (2010) used heating-related energy consumption aggregates and internal room temperatures in investigating everyday changes in heating practice. Morley et al. (2011) constructed daily electricity consumption profiles for households in investigating the link between everyday practices and inter-household practices of energy consumption.

A gap thus exists around the use of SEDM data in social practice literature. For example, monitoring data could be used to examine how the elements of practice influence its performance. Moreover, monitoring data could assist in tracking the formation and evolution of a practice over time and space. These are some compelling reasons to focus an empirical study of smart metering in domestic energy consumption.

1.2.5. Why research undergraduate's energy practices?

According to the latest figures of the National Union of Students, 38% of the students in the UK are staying in privately rented housing while they study (NUS 2013). During this period, students learn to do things for themselves and to live lifestyles that are in accordance with their beliefs and values. While evidence from the academic literature suggests that behaviour changes occur during this period (Edwards et al. 2003), quantitative surveys fail in explaining the reasons leading to behavioural changes. In addition, individualistic approaches ignore the role of the social dynamics or the consequences of moving away that are critical in establishing new performances of everyday practices (Foulds et al. 2016). Therefore, from the perspective of the thesis moving away from home is a transitional period in student life, and is accounted as a moment of change for developing pro-environmental attitudes. The difference is that in this research moving away from home is used as an intervention in practice, and not as a change in individual attitudes and behaviours. Thus, it is particularly interesting to find out what kind of technologies they bring with them into their new home, when students move away from home? It is also particularly interesting to explore how appliance-using practices are performed and how they change because of moving away from home?

Previous research investigating undergraduate's energy conservation behaviour in halls of residence identified real-time electricity feedback as the key motivator towards energy saving. These studies recorded some interesting results when students received real-time feedback or near real-time feedback. For example, Petersen et al. (2007) after deploying real-time metering systems in halls of residences reports energy saving up to 55%. Similarly, Bekker et al. (2010) in combining daily feedback with visual prompts and rewards to reduce electricity recorded up to 57% energy saving. However, the accuracy of the recorded energy savings is a factor to be considered, as some readings were taken manually, while others were via a feedback system. Also monitoring was possible only for a short period of time and the usage of the feedback systems were heavily incentivised by researchers. Therefore, to obtain a sustainable and easy to implement energy conservation strategy, during nine months we investigated students' energy conservation practices before and after receiving real-time energy monitoring data.

Higher Education strategies for reducing students' environmental impacts focus mainly on greening the campus, particularly student residences. Through different energy reduction schemes, students receive advice (or tips) and follow instructions on how to conserve campus energy. Although energy saving instructions and advices result energy savings (Petersen et al. 2007) these are difficult to be maintained over a long period of time. One avenue for sustaining energy conservation behaviour is through energy education (DeWaters et al. 2011). In fact, energy education is regarded as pivotal for installing '*efficient behavior and attitudes in society'* (Zografakis et al. 2008) or for the creation of the energy literate individual who has thorough understanding of how energy is used in everyday life (DeWaters et al. 2011). Despite the growing interest for energy education, relatively little research has focused explicitly on the ways in which energy literacy might be developed. This research therefore contributes not only to understanding how everyday practices are composed and changing, but also how higher education policy makers and practitioners can attempt to reconfigure them in. less resource-intensive directions.

Chapter 2: Smart demand management strategies - assumptions, limitations and persistence

This chapter elaborates on the smart energy metering and energy consumption divide, focusing on the role of smart metering data in smart metering strategies. Assumptions, limitations and persistence of dominant paradigms will be considered and discussed. The chapter is divided into three sections to illustrate the problems associated with the smart energy metering and energy consumption divide and the way they are incorporated into smart metering demand management strategies.

The first section expands on the concept of smart demand management, where and how this is being used to address the impacts resulting from increased consumption of resources. In this section, we discuss the assumptions embedded into this approach and which can cause a practical divide between the smart data supplier and the energy data in everyday perspective (Strengers 2013).

In the second section, we discuss how smart metering data fit within this dominant paradigm that conceptually and practically divides the consumption and production of resources, and what types of strategies it enables. We divide the smart metering data into two broad categories: aggregated consumption data used for describing the consumption of an entire building and disaggregated consumption data used for describing appliance-by-appliance energy consumption.

Thirdly we will discuss why this dominant paradigm to smart demand management continues to persist, despite obvious problems and limitations. In particular, we discuss how the smart metering data constitutes a self-reproducing rationale of concepts, methodologies and responsibilities, which limits opportunities for change. We conclude this chapter by proposing an alternative understanding of everyday energy consumption, and the relationship with smart metering data that is required to narrow the gap between smart energy demand management and energy consumption in everyday life.

2.1. What is smart demand-side management?

Smart demand-side management (SDSM) is the provision of smart metering technologies and data in energy conservation and demand reduction incentives. SDSM emerged as a dominant strategy in the electricity sector in incentivising consumers to take an active role in managing their energy demand. It is characterized by bidirectional communication between a utility company and consumers that allows better monitoring of energy consumption and the introduction of flexible energy tariffs. The popularity of the SDSM in the electricity sector has arisen from various needs: smarter electricity infrastructure (Bulkeley et al. 2016), new environmental regulations, climate change, and peaks in demand (Strengers 2013).

2.2. Why manage demand with smart meters?

From a policy perspective, the EU Electricity Directive (CEC 2009) mandates that all member states shall ‘equip’ 80% of their consumers with 'intelligent metering systems' by 2020, such that householders have at their disposal their real-time energy consumption data at no extra cost, and that they *'are properly informed of actual electricity consumption and costs frequently enough to enable them to regulate their own energy consumption'* (CEC 2009).

Currently, smart meters are used in demand reduction applications, specifically in providing improved information feedback to domestic householders about their energy consumption. How smart meters with SEDM could be used as a support to demand side management strategies by increasing consumer knowledge and consumer engagement through relevant and personalized information feeds and two-way communication between suppliers and customers. The authors state that consumer disengagement with energy reduction incentives is linked to ineffective utility strategies designed to incentivise energy consumers to take part in demand-side management programmes. It is argued that relevant and personalized information feeds will help consumers to identify the best deals on their energy tariffs, and what they need to do to reduce energy consumption if they are part to a demand-side management programme.

An advantage of smart meters, when compared to traditional electricity meters, is their capability to receive and send electricity consumption data (Kelly et al. 2016). While in the shorter term this means moving from estimated billing to a more accurate billing process in the longer term, the real-time data flow is likely to open the door for a more cost-reflective time-of-use tariff (such cheaper rates when the demand is lower or free electricity on either Saturdays or Sundays) to incentivise consumers to reduce energy consumption during off-peak hours. It is expected that the new smart time-of-use tariff will increase economic efficiency, financially stabilise wholesale market power, improve reliability and reduce the need to build new generation and transmission infrastructure. Furthermore, the bidirectional communication is expected to enable suppliers to remotely disconnect consumers who fail to pay their bills. One of the key challenges of smart metering is the management of large volumes of data by energy companies in providing consumers with the relevant information leading to changes in energy consumption patterns (Tsuda 2013). In the UK, the government also appointed a Data and Communications Company (Smart DCC Ltd) to ensure the security of communications and data privacy during its rollout of smart meters between 2016 and 2020.

In the longer term, smart meters will provide the infrastructure needed for the deployment of smart grids and smart appliances (DECC 2015). They are seen by the government as the cornerstone '*in transforming how consumers buy and use energy*' (DECC 2015). Evidently then, it is expected that smart meters will have considerable impact on consumers' everyday lifestyles, both in the short- and long-term, and there is a clear need to reflect on whether these changes are perceived by consumers as opportunities or threats.

2.2.1. Changing comfort or cleanliness practices or individual behaviour?

The ability of the smart meters to interact in real-time with the energy consumer enables the application of different interventions from behavioural science (Sintov et al. 2016). Thus, the data collected by smart meters has the capability to identify consumer behaviour patterns and to give an indication as to which household appliances consumers are using and when. For example, if the smart meter detects something out of ordinary – such as leaving the cooker on for much longer than usual – it sends a notification to consumers to let them know something might be wrong.

Although smart meters provide actionable data on real-time electricity consumption their effectiveness in reducing electricity consumption is somewhat ambiguous (Darby 2010). Consequently, there is a need to understand how consumers interact with smart meters and how the smart meter data affects the interactions consumers have with smart grid technologies. One of the best-known theories in understanding energy use behaviour is the Theory of Planned Behaviour, proposed by Icek Ajzen (1985) as a development of the Theory of Reasoned Action (Fishbein et al. 1975). Its principles are the following:

1. The individual is the basic unit of analysis;
2. The individual is a rational decision maker;
3. Knowledge, attitudes, values and behaviour are related in a linear manner; such as higher levels of knowledge leads to more positive attitudes and more self-efficacy, which in turn lead to the desired action.

Many policymakers use behaviour models in defining behaviour change strategies. For instance, time-of-use pricing aims to encourage energy consumers to reduce consumption during peak times of the day by charging more during periods of peak usage and less during off-peak hours. The application of the time-of-use pricing strategies assumes that the consumer is a rational, utility maximising individual whose energy consumption behaviour is predictable. It is assumed that consumers weigh up the costs and benefits of consuming electricity at particular times of the day so that different time-of-use pricing strategies will result change in attitude and behaviour (Strengers 2013). Other example of people focused intervention is the use of the real-time metering data as a form of immediate feedback in changing energy consumption behaviour. The central assumption is that real-time metering data as a form of immediate feedback on energy consumption will raise awareness and encourage individuals to make the rational decision to reduce their consumption. On the other hand, aggregated, household level energy feedback requires consumers to identify appliances that are using electricity which can be time consuming and discouraging in changing behaviour. One suggestion on this would be the use of real-time appliance level feedback that informs consumers in real-time of which appliances are consuming energy helping them to associate behaviours with energy consumption. In addition, to remove the need to sustain behaviour change over time many smart devices have controls built into them so that they can be programmed and operated remotely; for example through a smartphone. Behaviour models are useful in identifying people motivations (such as environmental concern, better comfort, control over electricity bills) in adoption and use of automated and storage technologies such as internet connected smart thermostat, batteries and electrical cars.

This individual, positivist and technology centred approach to understanding energy usage has been challenged by the social sciences (Shove 2010, Southerton et al. 2011). Yolanda Strengers image of the 'Homo Economicus' or 'Resource Man' captures this ideal type of smart energy consumer, seen as being a technologically minded, information oriented individual who actively monitors his environment, using accurate and up-to-date energy information about the costs, resource units (kWh) and impacts (CO_2) of his consumption ensuring that he is not at risk of 'illness' or 'diseases' caused by his energy behaviour. His 'smartness' is defined by his engagement with the data and technology. On the other hand, the 'Resource Man' conceptualization ignores what individuals actually do in their homes or the way electricity is shared among household members. Furthermore, it offers a limited understanding of change in electricity consumption behaviour.

An alternative approach is to shift the focus of the analysis of the social change programmes from individual behaviour to social practices. In particular, policy makers focus should be on electricity consumption practices that are relevant to smart metering; such as comfort practices that constitute over half of a household's energy consumption and are the major contributor to peak demand. We argue that we need to understand the composition of practices-that-consume-electricity, the way they are organized, shared and interconnected in comfort and cleanliness practices and the ways in which smart metering programs can reconfigure them.

2.3. Opportunities and challenges of the implementation of smart demand-side management strategies

In Europe, the smart meter roll-out has experienced mixed consumer acceptance and in some cases due to concerns regarding privacy as well as possible cyber security threats consumer resistance has been significant (Ligtvoet et al. 2015). As a result of this early experience Member States recognize the importance of pairing smart meter roll-out with consumer engagement strategies that promote awareness and support during the roll-out of smart meters. For example, in the UK, during the installation process, suppliers must explain to customers what smart meters can do for them in managing energy consumption. A survey ordered by DECC showed that to date 89% of UK customers were satisfied with the installation process and 72% were satisfied with the smart meter and with the SEDM, whereas 4% were dissatisfied (DECC 2015). The most frequently mentioned concern and disadvantage was finding the SEDM difficult to understand and to use (DECC 2015).

Data privacy concerns caused a number of Member States to suffer delays in the roll-out of smart meters, such as in the Netherlands (Cuijpers et al. 2012). In 2009, the Dutch Senate rejected the Smart Metering Bill, which would have mandated the installation of smart meters in every home in Netherlands, arguing that the bill violated a citizen's right to privacy under European law. It was determined that data collection by smart meters would leak information about the everyday living patterns of consumers, and there is a risk of such information falling into the hands of a third party and used for ‘nefarious purposes’ (Van Elburg 2008). As a result, smart meters are now being rolled-out on a voluntary basis in Netherlands, considerably reducing their rate of deployment. In Finland, Sweden and Italy, the roll-out of the smart meters is complete (EPRS 2015). As a result of this, there is a growing interest for services to manage the data that smart meters receive and send (D’Oca et al. 2016).

In short, few European countries have completed their smart meter roll-outs and consumers are still exploring them (Raimi et al. 2016). Consequently, it is very difficult to estimate the effectiveness of the roll-out as the functioning of the two-way communication that underlines the success of the smart meters, leading to changes in energy consumption patterns (Pullinger et al. 2014). Furthermore, since the two-way communication system and smart meters are still under development, there is limited published information on the savings in electricity by using smart meters or if the aggregation or disaggregation of the smart metering data in real-time results in higher energy efficiency.

2.4. How does smart demand-side management enable understanding of consumption?

The primary focus of SDSM techniques is the exchange of information between suppliers and consumers in managing consumption. Examples of SDSM strategies include leakage detection in the water sector, or direct load control in the electricity sector (Strengers 2013). In these examples the smart data is the instrumental tool in a smart 'win-win' scenario supporting economic development and improvements in environmental sustainability. By contrast, in everyday life, there are many other forms of social, material and embodied sensory data that are already embedded in practices-that-use-energy (Strengers 2013, Foulds et al. 2014). Thus, the management of demand with smart metering data faces the challenge of suppliers producing and relying on aggregated household consumption data on the one hand, whilst consumers work with their social, material and embodied sensory data in everyday practices-that-consume-energy.

The divide between smart metered data and embodied sensory data defines the framework for assumptions and understandings of consumer choice and changes in energy demand (Shove et al. 2010)- that is the way consumers choose to meter electricity, the way in which they read metering data, and the ways in which they change their usage. Thus, suppliers view householders as consumers of aggregated smart energy data who attune their choices about their energy consumption based on information and cost of energy (Strengers 2013).

On the other hand, in everyday life consumers' electricity practices are not always informed by smart metering data, but rather by other forms of social, material and embodied sensory aspects of everyday energy consumption (Strengers 2013, Foulds et al. 2014). For example, a change in electricity consumption practices might involve friends giving tips on how to remove a stain from of piece of clothing, or a roommate complaining that the room is too cold. Our bodies may be seen as self-monitoring devices, providing visual and olfactory data on the environment in which we are consuming electricity. In these cases, only the relevant part of the data is translated by consumers into everyday routines powered with electricity (Strengers 2013). Furthermore, domestic technologies, such as washing machines, provide data in the form of temperature and laundering cycles, thus informing and organizing laundering practices.

How then, can smart metering data be used in understanding consumption? What types of assumption does it replicate? Smart electricity display meters (SEDMs)encourages participation in a small 'suite of energy saving actions (Goulden et al. 2014, Marres 2011) providing means of doing something – specifically about energy use – whilst not requiring anything, result labelled by Marres as '*change of* *no change*' (Marres 2011, page 517). Further, SEDM can provide a form of social feedback that add normative meaning (such as 'baseline' or 'normal') to how much or how little energy consumption practices ought to be consuming (Hargreaves et al. 2010, Strengers 2013). Although SEDMs currently appear to be irrelevant in the context of the home as many practices are considered non-negotiable or inflexible (Pierce et al. 2010, Strengers 2011), this does not mean that the aggregated or disaggregated SEDM energy data will not matter or matter less to everyday practice (Strengers 2013, page 93). As suggested by Strengers (2013, page 92):'*…in order for energy feedback to matter, energy itself must matter. Energy must become important to what it means to do laundry, cook a meal or entertain a guest.*'

In the following subchapter we will extend on the role of smart data in smart metering strategies, arguing that it has the potential to transform the meaning of the energy but only for a specific time and for specific practices (Strengers 2013).

2.5. How smart data is used in smart metering demand management strategies?

This section discusses three smart metering demand management strategies, and the kind of smart data these produce. These are: (1) real-time energy smart metering data as feedback on electricity consumption, (2) dynamic pricing tariffs as incentive in reducing energy consumption during peak hours and (3) automation, smart plugs and other technologies.

2.5.1. Smart metering data as feedback on electricity consumption

Van Elburg (2008), Fischer (2008), Faruqui et al. (2009), Langenheld (2010), Darby (2010) and ESMA (2010) extensively reviewed past research focusing on a range of consumer feedback methods and mechanisms. From these reviews the three key types of feedback of energy consumption by which behaviour may be changed are summarized in Table 2.1.

Real-time energy consumption data from SEDMs as a form of immediate feedback is thought to be the main mechanism in engaging consumers to manage their electricity use (Darby 2006). In this perspective smart metering data is collected and transferred to supplier at half-hourly or more regular time intervals as a combination of parameters such as electricity usage values or time spam. The actionable data (such as savings by using less or later) is transferred back to the householders via SEDMs or web portals. The ability of the smart meters for bidirectional communication of data enables accurate billing, the implementation of a dynamic tariff scheme and the remote control of electricity load and devices (Goulden et al. 2014). In this data-based environment smart metering is not only important but is necessary to learn how to control devices (Darby 2006, Strengers 2013).

Till today there is no agreement over the best format, form or frequency of the smart metering data. For example, Vassileva et al. (2012) found that using an interactive web page to display household consumption smart metering data achieved a 15% reduction in electricity consumption from those households that visited the web page at least once (Vassileva, et al. 2012). Others suggests that with time the SEDMs stop offering new information and 'fallback' into the background of everyday life (Hargreaves et al. 2013). This loss of interest was documented in a government survey which found that one in five people reported never looking at their SEDMs (DECC 2015).

Similarly, the growing popularity of health and fitness apps and wearables (such as Fitbit One, Jawbone Up or Nike+ Fuelband) is enabling the collection of a large quantity of actionable data that in turn can be shared and compared with other data through a range of associated technologies (such as heart rate monitors). Unlike the SEDMs data, the fitness data feeds back to participants how fit they are, where they can improve, and how much more training they need to do (Asimakopoulos et al. 2017). Thus racing or time trialling are oriented towards acting on data: here the engagements, know-how, institutional knowledge and technologies of calculating and establishing benchmarks are essential to the performance of the fitness practice (Strengers 2013).

Category of Feedback	Description
Direct feedback Direct feedback is feedback presented immediately to the consumer without processing (so called raw data), either from a smart meter or from an associated smart electricity display meter.	
Basic Metering without Separate Direct Display Monitors	The standard electricity meter provides consumption feedback, usually measure in a single unit (kWh). Information is not benchmarked and individuals would need to take the readings from the meter (that is usually kept out of sight).
Keypad Meters or Key Meters	Keypad or key meters are 'semi-smart' (Darby 2006) in that they allow transfer of metering data 'to and from' the key-code at the payment point or shop and allow customers to access information on current and past usage on annual, quarterly and monthly basis.
In-Home Displays or Smart Electricity Display Meters (SEDMs)	SEDMs are stand-alone displays with data communicated uni-directionally showing near real-time consumption data.
Use of Mobile Applications to Track Energy Usage	Smartphone Apps (such as Smappee or Kill-Ur-Watts) use specific software packages to show historic and current consumption data, with relevant environmental and social comparisons.
Ambient Devices	Ambient displays (such as orb lamps) illustrate or alert a change in electricity consumption or supply through the use of colours or sounds. Darby (2006) and Martinez et al. (2005) define this as a 'pre-attentive' processing of presenting information.
Indirect feedback Indirect feedback is feedback presented to the consumer after being externally processed (for example by a utility company). The best way to describe this form of feedback is as 'learning by reading and reflecting.' (Darby 2006)	
Informative Billing	Energy bills tend to be based on estimated consumption rather than actual meter readings and provide a benchmark by which evaluate previous terms energy consumption, or means to see the effect of technical changes.
Utility Controlled Feedback Utility-controlled feedback (or load monitoring) concerns the control and provision of data of an individual's energy consumption data back to both the individual and the utility provider. This is the so called bi-directional communication and is typically termed as smart.	

Table 2.1. Summary of Direct, Indirect and Utility Controlled Feedback (Darby 2006)

While there is some evidence from the literature on how 'sharing' works as a practice of consumption within students' accommodation (Richards 2013), to date the literature has paid no attention on the way electricity is consumed and shared by students in shared accommodation. There have been a number of studies focusing on the effect of the metering data as feedback on electricity consumption in campus dormitories and residential halls. Emeakaroha et al. (2014) did a systematic review on energy saving information feedback for promoting energy saving in halls of residences (Table 2.2.).

Author(s)	Resident type	Feedback mode	Further incentive	Duration	Energy saved
Petersen et al. (2007)	Dorm.	Real-Time feedback via web pages	Educational competition	2 weeks	32-55%
Odom et al. (2008)	Dorm.	Eco-visualization displays and social incentives	Student pledge wall	Not given	33,008 kWh of electricity
Marans et al. (2009)	Uni.	Non real-time feedback. Multiple focuses	Survey	Not given	Not measured
Bekker et al. (2010)	Uni.	Combination of visual prompts, daily feedback and rewards to reduce electricity	Education	3 weeks	57% and 48%
Johnson et al. (2010)	Dorm.	The Kukui Cup: Proposal for University Hall Resident Energy Competition (University of Hawaii)	Competition	4 weeks	10%
Peschiera et al. (2010)	Dorm.	Feedback visualisation via Chart presentation	Competition	5 weeks	10-26%
Brewer et al. (2010)	Dorm.	Energy competition focused on sustainable behaviour change and energy literacy.	Education	4 weeks	Not given
Emeakaroha et al. (2014)	Dorm.	Real-Time feedback via web pages	Energy delegates and email alerts	6 weeks	1360,49 kWh of electricity
Sintov et al. (2016)	Dorm.	Real-Time feedback via touch screen kiosk	Competition	3 weeks	6,4%
Alberts et al. (2016)	Dorm.	Different treatments: Real-Time feedback and norms as well as Real-Time feedback and competition	Survey	10 weeks	22% (real-time feedback with norms)

Table 2.2. Energy saving information feedback for promoting energy saving in halls of residences (Emeakaroha et al. 2014, page 359)

Most of these studies specifically focused on the delivery of energy consumption data with social incentives (such as energy saving competitions) to motivate behaviour change in halls of residences. While all studies suggest that provision of smart metering data can achieve resource savings in residential halls, there is a wide degree of variability in its effectiveness. This variation may be attributable to differences in study design as feedback has taken a variety of forms (such as marketing campaigns vs. real-time monitoring). For example, Peterson et al. (2007) investigation (Figure 2.1.) suggests that high-resolution (or real-time) metering data motivates students' energy conservation behaviour as they saved almost 50% of electricity when receiving real-time data on electricity consumption in a college dormitory compared to low-resolution (or manual reading provided to residence once per week) metering data.

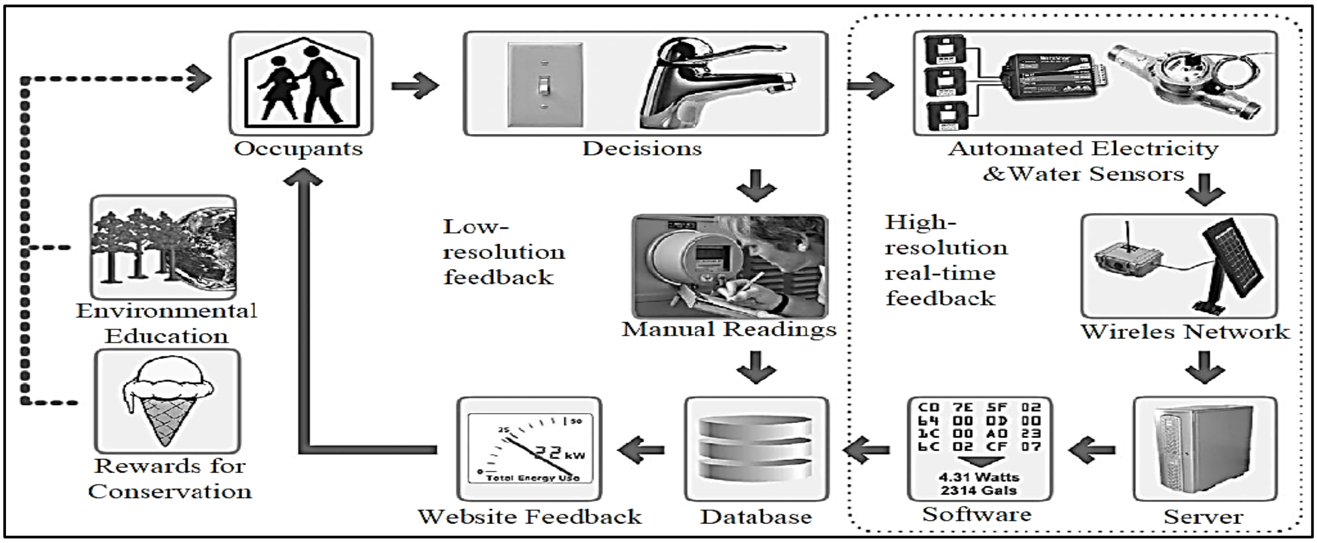


Figure 2.1. Oberlin College Energy Saving Competitions. Two students' dormitories were equipped with automated monitoring systems that provided high-resolution, real-time feedback (dotted box on right). The other 16 dormitories received low-resolution feedback, electricity meters were read by hand and consumption data was posted on a website once per week (Peterson et al. 2007, page 22).

Emeakaroha et al. (2012) discussed the challenge of improving students' energy conservation behaviour through the application of smart sensors together with a human energy delegate located in halls of residences. The energy delegate's task was to monitor students' electricity consumption activities and mentor them towards a more electricity conscious consumption. The results of the study is displayed in Figure 2.3 and Figure 2.4. suggesting that a meeting with an energy delegate instead of only a visual display seems to be more effective. In addition, Emeakaroha et al. (2012) findings suggests that the real-time information on energy consumption had a positive influence on students and made them to be more aware of their way of living.

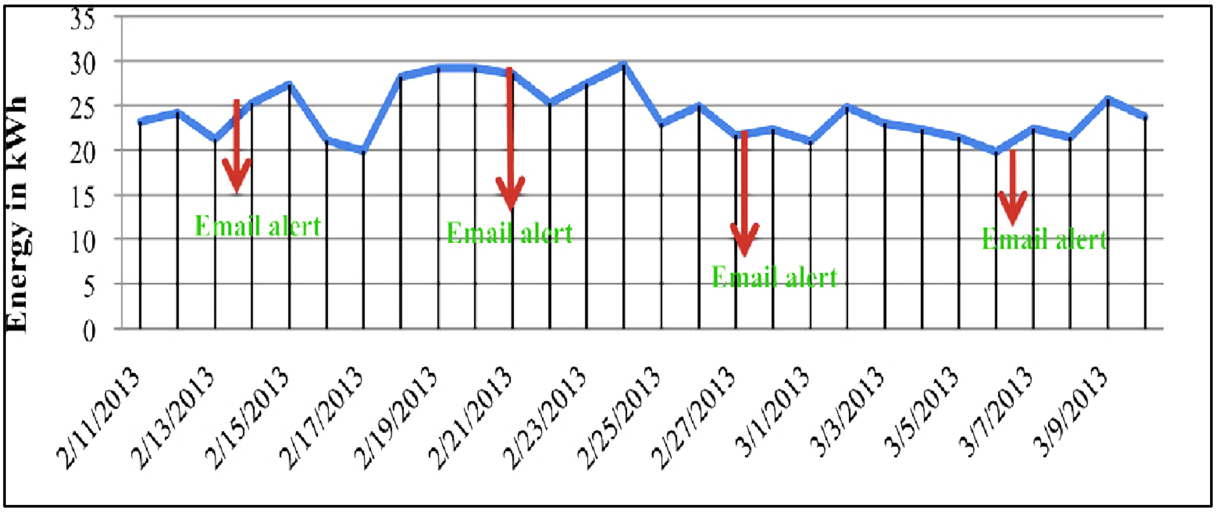


Figure 2.3. Consumption data with email alert (Emeakaroha et al. 2014)

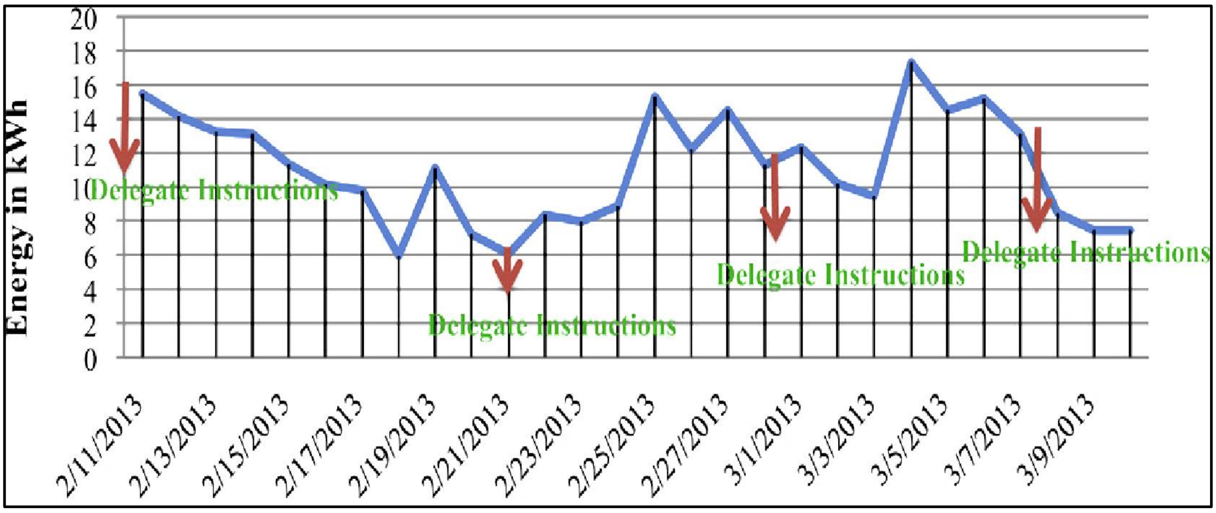


Figure 2.4. Consumption data with energy delegate (Emeakaroha et al. 2014)

While all of these studies suggest that energy metering data is a powerful tool in engaging students in energy conservation, none of these studies tells us why (or if) the metering data changed students' energy consumption behaviour? Instead, it seems that energy reduction resulted from meeting energy delegates or participating in energy saving competitions. Thus, while the numerical data as feedback on energy consumption has an important role to play in energy conservation, in order to significantly reduce energy demand we need to experiment with other types of feedback (Hargreaves et al. 2010, Pierce et al. 2010, Strengers 2013). Foulds et al. (2014) expands this idea by suggesting other forms of feedback processes to include performance, cognition, sensation, materiality, sociality, policy and politics. Perhaps we should focus on the non-numerical feedback and try '*to get better at using of these to reduce rather than increase energy demand*' (Hargreaves 2016).

Recently, researchers suggest a feedback mechanism on behaviour that is more effective than appliance specific feedback. For example, Harries et al. (2013) underlines the importance of providing feedback in terms of activities rather than kilowatt-hour or pounds; and to talk in terms of wastage. Similarly, Pullinger et al. (2014) argues for a practice-based advice (such as how to save energy while doing the washing) and a user-friendly assistance to understand '*how much energy each practice uses and derive options for change*' (Pullinger et al. 2014, page 1150). Perhaps most crucially for the smart meter roll-out programmes Pullinger et al. (2014) suggests '*specific disaggregation algorithms, types of feedback and criteria for tailoring their delivery to households based on their specific [energy use] practices*' (Pullinger et al. 2014, page 1159). As such, it is expected that the disaggregated (or appliance specific) real-time smart electricity data would generate the necessary knowledge allowing consumers to better control their energy consumption. Kelly et al. (2016) conducted a systematic review with the aim to identify differences in savings between aggregate and disaggregate feedback. Only for studies from Kelly et al. (2016) systematic review compared aggregated feedback against disaggregated feedback. Three of these studies identified aggregate feedback to be more effective than disaggregated feedback (Krishnamurti et al. 2013, Churchwell et al. 2014, Sokoloski 2015). The fourth study identified disaggregated feedback and aggregate feedback to be equally effective (McCalley et al. 2002). Evidently, the lack of research on the metering and representation of the energy data that makes it difficult to ascertain whether aggregated data is more effective than appliance-specific disaggregated data or if a combination of these two may result energy savings (Sokoloski 2015). Yet, if appliance-specific disaggregation might save more energy than the aggregated energy data the processing would be computationally expensive to run '*on an embedded processor inside a smart meter or in-home display*' (Kelly et al. 2016, page 4).

To summarize (i) there is a scarcity of research on students' energy consumption and (ii) the evidence that there is does not make a compelling case for the smart metering data as feedback in reducing energy consumption in students' dormitories.

2.5.2. The role of smart metering data in variable pricing policies

Generally, the energy consumption data is derived from utility bills on a monthly basis. The data is based on accumulated readings submitted by the consumers and the billing period is variable. In order to get more accurate energy consumption data, the alternative solution is to read the meter more regularly, for instance, on a daily or weekly basis. Therefore, the existing tariff structure must be re-organised to provide time of the day tariff information that in turn provide financial incentives to consumers.

Time-varying pricing is the practice of charging higher prices during periods of peak demand to encourage customers to reduce their electricity consumption during those times. A time-of-use tariff typically sets out several peak and off-peak tariffs, which are charged consistently across every day; the peak period being the most expensive. For example, the Economy 7 tariff involves two prices: a cheaper night-time electricity tariff, which normally operates from midnight where seven hours of low tariff electricity at night and a more expensive tariff throughout the day. In the UK, this is most effective for those customers who use electric heating. When billing the consumers, the aggregated day and night energy readings will be multiplied with the relevant price of electricity.

When prices are less predictable, data is collected by the meter at regular intervals such as every 15 minutes, 30 minutes or hourly and transferred to an external party (the so-called Data Collector and Aggregator) responsible for billing. In this case, the disaggregated, interval data makes possible the identification of different energy consumption patterns, that would be impossible to observe in the aggregated energy consumption data. While the quantitative interval data makes possible to plot the variations in building energy consumption over a period a time, still provides limited information about opportunities to save energy. Large industrial companies with dynamic pricing contracts are invoiced in this manner.

Smart meters provide aggregated price information data to encourage consumers to weigh up the costs and benefits of consuming electricity at particular times of the day. Price information is communicated in real-time, to many meters at once and the smart meter itself calculates in real-time the energy consumption bill. The use of smart meters that send price information to SEDMs has been investigated in pilot studies (EDRP) to determine the benefits of smart metering. The Energy Demand Research Project (EDRP); a smart metering trial in the UK, used about 18,000 smart meters and concluded that the aggregated smart metering data with SEDMs resulted in higher energy saving (around 3% higher) than smart meters without SEDMs.

The UK's biggest smart grid project, worth £54 million, highlighted some evidence that time-of-use tariffs of the SEDMs is able to reshape domestic energy-use practices. While participants reported electricity prices from the SEDMs to be the main reason of reducing or delaying practices-that-consume-electricity there was evidence of huge variation within peak hours in some cases within the same household. The investigators concluded that the practices that cannot be delayed with the time-of-use tariff are mainly practices that relate to the rhythms of daily life (such as leisure time) and to activities that connect consumers to external environments, such as work or social activities. For example, dishwashing and laundry practices responded well to the time-of-use tariff scheme while cooking was a 'non-negotiable' practice in households with children (Strengers 2013). These findings suggest that time-of-use tariff needs to take into account other structures that are connected with householders everyday lives.

Most importantly, smart metering data and dynamic pricing is a tool to be used in reshaping the meaning of electricity, by raising the emphasis of electricity to users with regard to practices-that-consume-electricity or by creating new skills to perform practices-that-consume-electricity in more efficient ways (Strengers et al. 2011). This conceptualization of price tariffs as a disruptor of everyday life already exists and has many similarities to electricity blackouts (Rinkinen 2013), that have long been part of the electricity system and that are well known amongst energy consumers (Strengers et al. 2013). Power cuts are disruptive moments, making the running of normal, electricity-dependent activities impossible (or difficult running on batteries) (Rinkinen 2013). Other disruptions with knock-on effects on electricity consumption are house moves (Gnoth 2013), home renovations and changing family roles (Shirani et al. 2013). One could argue that dynamic pricing is different from blackouts, and other forms of disruption in a number of ways. Firstly, its main purpose is to disrupt electricity consumption during predictable periods. Thus, as Strengers et al. (2013) suggest, dynamic pricing creates an '*ordered disorder*' (Strengers et al. 2014) by creating exceptional circumstances during which the role of electricity in everyday practices is temporarily reconfigured (Strengers et al. 2013). Secondly, while power cuts are considered to be the *'failures of the electricity systems'* or failure of those who supply it, the main role of dynamic pricing is to make electricity available at all times at an affordable cost. SEDMs which make sounds or change colours according to the price of electricity are important in this case as they are notifying and communicating the exceptional circumstances that should reconfigure the meaning of the electricity for a period of time (Faruqui et al. 2011).

Finally, as peak hours are predictable, dynamic pricing is a tool for shifting demand or creating cold spots when the normal everyday practices are temporarily suspended in favour of family time (Southerton 2003). The terms '*cold spots'* and '*hot spots*' illustrate that activities are not evenly spread in everyday and are constrained by collective and institutional rhythms. In this view, while social loads do not always correlate directly with peak loads, by making electricity matter, social and environmental circumstances can influence and disrupt everyday practices-that-consume-electricity. In the following, we explore how smart automation may influence and reconfigure everyday routines.

2.5.3. Smart metering data for automation and control of appliances

Smart metering offers opportunities for automating demand responses using protocols such as ZigBee or Bluetooth. Basically, these protocols enable the smart meter to control and interact with smart appliances around the home by collecting electricity usage data from them. Such smart appliances might include refrigerators that delay defrosting or dishwashers and washing machines that slow down their cycles during peak hours. These strategies are based on rational actor logic, in that it assumes that the consumers benefit from automation and remote control of appliances by paying less for their consumption.

This is less evident for the energy consumers who are worried about their privacy and losing control over their time dependent daily routines (Darby et al. 2013). Indeed, research by Krishnamurti et al.

(2012) suggested that, the more energy consumers believed that smart meters would let their electricity company control their energy use, the less likely they were to desire one. While external control by utility companies is less desirable, energy consumers do find the idea to have the opportunity to remotely control their energy consumption attractive. Cole et al. (2008) suggests that the key element of being comfortable when inside a building is the ability of the user to have control over the environment. Furthermore, they claim that individuals experience comfort in different ways and have different needs, and these may change when individuals gather in groups, as well, these groups may develop collective understandings and practices around comfort. It is suggested that the human factors should not only be included in new notions of comfort, but also considered in the environmental assessment methods as they will affect the building's performance and, in particular, its sustainability (Cole et al. 2008, page 323).

On the other hand, studies have shown that people are not good at manually managing their comfort levels in comparison with automation technologies and are therefore likely to feel less 'comfortable' when inside buildings (Hinton 2010). Schwartz et al. (2017) defines this as a '*the control paradox*' the fact that more advanced the control capabilities of the homes the more out of control are the householders. Going further, Strengers (2013) argues on the way home automation can act back on everyday routines encouraging householders to act in different ways in response to technological signals. For example: *'A busy parent can be making plans to pick up a child by SMS while cooking dinner. At the same time, automation may be enabling another domestic activity, such as laundering, to be performed in the background.* (Strengers 2013, page 127)'. Indeed, home automation may be used in ways that allow householders to engage in new energy-intensive activities, or to engage in existing activities in more energy-intensive ways (Strengers 2013). Thus, even though home automation technologies may provide householders with more control over their everyday lives there is no guarantee this will be used to reduce energy consumption (Strengers 2013). Evidently, understanding control is important because it mediates the impact of homes on energy demand (Hargreaves et al. 2016). This makes it important to investigate people's willingness to delegate control to their domestic appliances. Fundamentally, smart automatization is problematic because of the way the consumer is positioned in the smart system. As Strengers (2013) suggests, in most cases the energy consumer is removed entirely from the network (and replaced with smart metering data), and is manipulated and controlled as part of that smart system. This makes sense from an engineering point of view, but this conceptualization it is rejected by consumers (Strengers 2013).

2.5.4 The limitations of the dominant smart metering demand strategies

While there is considerable evidence to suggest that smart metering demand strategies, either independently or in combination with other smart strategies, are capable of achieving resource savings, these strategies leave unanswered questions about how energy is consumed in the everyday and how savings occur. In all of the smart metering demand strategies, the way everyday practices change in response to the smart metering data is ignored (Strengers 2013). Furthermore, while all the smart metering trials suggests that energy demand and practices-that-consume-energy can be changed with smart metering data, almost all highlight the importance of smart data to avoid impacts on everyday comfort (Hargreaves 2010).

Thus, smart data is important for suppliers in monitoring and collecting information about household energy consumption but is less important for energy consumers in everyday life. This is mainly because smart metering policies ignore the changing nature of comfort practices, and how smart metering data can be used to make less resource-intensive everyday comfort expectations. For example, smart metering policies that use smart data as feedback do not challenge consumers on the way they are using electricity; instead it engages consumers in a limited number of 'energy saving practices', to 'switch off' unnecessary lights, unplug appliances or, in the best case scenario, encourage consumers to make energy efficiency changes such as installing energy-efficient light bulbs or an energy efficient refrigerator. Thus, the smart demand management strategies focus on making, managing and using technology more efficiently rather than investigating the necessity of the technology in changing everyday practices (Strengers 2013).

In order to address these limitations, we need to investigate everyday practices-that-consume-electricity, and consider how and why these might change. But, before doing this, it is important to reflect on the persistence and application of the smart demand management strategies. Thus, we need to understand why policy makers assume that electricity consumers' practices are 'non-negotiable' or 'fixed' when trials indicate that they are not (Strengers 2013), and why this understanding continues to replicate itself in smart management policies. The final part of the literature review will address these questions by highlighting the rigidity of the smart demand-side management policies to everyday energy consumption.

2.6. The self-reinforcing rationale of smart demand management

The first section of this chapter outlined the assumptions embedded in smart demand management policies that real-time energy metering data makes consumers decide how to consume electricity and help suppliers to forecast everyday electricity demand amongst consumers. The second section identified how these assumptions are applied to the specific case of smart metering, the problematic questions left unanswered as a result of this application, and the problems that arise from this approach. This final section expands on the ways in which these assumptions constitute a self-reproducing rationale for smart demand management policies, ignoring the way electricity is consumed in everyday lifestyle.

There are three components that define the dominant smart management strategies discussed in this chapter. These are: principles, methodologies and responsibilities. (Strengers 2013). The first is the assumption of economic rationality that underlines the management of electricity with smart meters; the second concerns the way in which studies, trials and evaluations reproduce these assumptions; and the third concerns the roles and responsibilities attributed to providers and consumers, which at the same time legitimize the theory and methodology (Strengers 2013).

2.6.1. The underlying economic principles in designing smart demand management strategies

The application of economic principles in smart demand management programs are part of the smart policy approach in the form of decision-making (such as cost-benefit analysis) and understanding of the electricity consumption and choice discussed previously in this chapter. These economic principles inform the design and evaluation of, and justification for, smart meters and smart metering strategies (Nyborg et al. 2013). However, the application of economic principles in understanding everyday electricity consumption is problematic for several reasons. Firstly, the economic models ignore how practices-that-consume-electricity are learned or shared between consumers: '*Consumption is embedded in the way that different social groups engage in practices and that practices are almost always shared enterprises that are performed in the (co-)presence of others and therefore subject to collective norms of contextualized engagement'* (Southerton et al, 2004, page 34). Secondly, by suggesting that everyday electricity consumption decisions are always calculated, they ignore the habitual nature of electricity consumption (Warde et al. 2012). Thirdly, they ignore the co-dependent relationship of smart infrastructures, smart technologies and wider systems of provision in everyday electricity consumption (Shove 2010). But most importantly they ignore the ways in which practices-that-consume-electricity change over time.

2.6.2. Methodologies in designing smart demand management strategies

The underlying economic principles of smart demand management are reproduced in the method of smart-demand management itself (Strengers 2013). Thus, suggesting that energy demand is a non-negotiable phenomenon suggest simultaneously that smart strategies need to focus on defining ways to manage consumer energy consumption rather than on understanding the ways electricity is consumed and how everyday life and practices change.

Managing demand smart policies are frequently defined in accordance with rational decision principles and based on the 'customer satisfaction' surveys. For example, in Australia, several smart demand management programs were designed after multiple-choice surveys and focus group sessions suggesting that the main drivers in using less energy are price, potential resource savings, time availability, attitudes and beliefs (Jelly 2008). All collected information fits together into single profiles of costumer. In this way, the energy 'consumer' became a 'customer' who requests a service to satisfy their individual needs or wants.

2.6.3. Responsibilities in smart demand management strategies

In understanding the persistence of the smart demand-side management models we need to investigate the relationship between energy companies, smart demand-side management policy makers and consumers, and how this relationship in embedded into smart infrastructures, smart technologies and other energy systems.

While at the beginning the energy management was always the responsibility of the governments and energy companies, with the time this role was delegated and later embedded into energy infrastructures such as smart networks or smart technologies (Strengers 2013). Thus the role of the utility companies was always to supply the amount of electricity demanded by consumers, who continually expect to receive this type of service (Shove et al. 2010). In order to fulfil the increase in demand (or make it more efficient), energy companies developed smart infrastructure, such as smart networks and smart technologies, that manage everyday electricity demand.

The role of the smart meters is to improve this service by providing control of everyday electricity demand. In this process, aggregated and disaggregated smart metering data speaks to consumers about the roles and responsibilities in managing everyday demand (Darby 2010). For example, in turning on our heater, smart meters represent electricity consumption in form of kilowatt-hour (kWh), carbon dioxide (CO_2) or pounds (£), and they consequently ignore the large-scale impact that energy consumption has in supplying the electricity. Thus, while asking consumers to reduce or shift their demand is considered to be one of the main advantage of smart meters this contradicts with the smart infrastructural context, designed to improve the continuous supply of electricity.

In this view, consumers are treated as independent entities of the socio-technical context, the focus is on the acceptability of using smart meters in the everyday instead of on the impact that they might have on their electricity use and the impact of the production and supply of that electricity. In other words, smart demand management strategies that attempt to engage householders with their electricity demand hide the role of energy companies as suppliers of unquestioned demand (Chappells et al. 2004). On the other hand, some of the smart meter trials suggest that everyday electricity consumption can be reconfigured with smart data that in some cases engages consumers in managing demand (Foulds et al. 2014).

2.7. The role of smart metering data in community demand response programmes

A possible solution to further increase the effectiveness of the smart metering roll-out is to connect the use of SEDMs to community-based activities (Burchell et al. 2014, Catney et al. 2013, Darby 2006). While the concept of 'community' (Burchell et al. 2014) is itself ambiguous there is evidence suggesting that community based demand response programs may encourage consumers to '*develop and adopt new ways of doing everyday things, such as heating and lighting their homes, so that they consume less energy*' (Burchell et al. 2014, page 15).

The idea of building smart learning communities that would support the development of 'energy know-how' is discussed by Burchell et al. (2014) and Catney et al. (2014). Perhaps more relevant are findings from the 'Reducing Energy Consumption through Community Knowledge Networks', that call for 'Community Knowledge Networks', which provide opportunities for peer learning about energy through discussion and sharing of tacit knowledge in a face to face interaction, '*making energy discussable*' in an '*atmosphere of conviviality'* (Catney et al. 2014). However, for consumers to discuss about their energy use the right environment (and context) had to be made (Burchell et al. 2016). Furthermore Catney et al. (2013) suggests that energy information is the most useful to householders when it is tailored and interactive, such as energy suppliers designing specific price plans through energy bills. The perceived trustworthiness of the information is also important: peers with experience of measures were perceived to be trustworthy (Catney et al. 2013). This would suggest that community energy projects might be able to change behaviour where traditional consumers cannot because of the interaction with peers (Simcock et al. 2014).

Whilst there are some examples of small-scale community demand response programmes, these tend to be in remote locations such as islands. For example, the community energy subsystem operating on the Scottish island of Eigg has a wind, solar and hydropower based energy system, with battery bank and backup diesel generators. Islanders can consume up to a maximum of 5kW[2]of power at any given time (10kW for businesses).

[2] 5kW is enough to power an electric kettle and washing machine, or fifty 100W light bulbs.

If a household goes above the 5kW limit, they are automatically switched off and must be reconnected manually by the Eigg energy maintenance team (Community Power Scotland and Friends of the Earth Scotland, 2016). When generation from renewable resources are running low, islanders are alerted through a traffic light system with green/amber/red light, and encouraged to voluntarily reduce their demand (Yadoo et al. 2011). As such the household energy consumption that is below 5kW is a private matter, but any consumption above 5 kW becomes a public issue. The example of the isle of Eigg show that communities can successfully manage their electricity system, and live well within load limits something, which could be useful for achieving demand reduction.

Currently, existing government approaches to smart metering demand response programs are highly individualised and the focus is on the design of smart technology and smart grid. Based on the available evidence, the success of the smart metering feedback depends on user engagement, that can be supported by locally trained expert who can provide detailed advice or reassurance on areas of uncertainty were is needed. Perhaps, most importantly for the smart meter roll-out, the Eigg island model showed that community based programmes could be a powerful tool for capturing the full value of the smart meter roll out (Buchnell et al. 2016). Is therefore important, that the smart meter 'roll-out' to be supported locally by third parties (such as energy agencies and institutions) whose access to smart metering data is not obscured by government policies and who are financially supported in development of community demand response programs that would support peer learning and effective use of smart grid technology (Catney et al. 2013, Burchell et al. 2016). Finally, importance of learning and acting collectively could be supported by making visible the collective impact of actions (Melville et al. 2017).

2.8. Conclusions

Based on the reviewed literature, it can be concluded, that there is a high degree of technological determinism in the dominant smart metering energy paradigm. We have argued that this paradigm is based on a series of premises and assumption that view smart technologies as autonomous forces that either rationalise energy saving practices or eliminate (by taking control over) energy waste practices from everyday life.

A distinctive feature of the smart metering demand policies and approaches is that they equate technological change with social change. One of the implication of this is the fact that smart demand management strategies currently take for granted existing practices-that-consume-energy, leaving them free to continue changing in more or less resource-intensive directions (Strengers 2013). Furthermore, we suggested that the smart demand management strategies are part of a self-sustaining rationale underpinned by economic concepts and methodologies (Strengers 2013). This is counterproductive because pre-scripting how consumers use, become engaged and relate to technologies (such smart meters and SEDMs) ignores a wide range of social factors that influence the way consumers use technologies in everyday life.

We argued for an alternative framing of smart demand programs and the assumptions underpinning it — one that contextualises energy consumption within the realm of everyday life. The next chapter undertakes this task, outlining practice-based approach for understanding and analysing smart energy demand. In particular, we focus on the comfort and cleanliness practices-that-consume-energy which constitute more than half of a household's energy consumption and are the major contributor to peak demand (Strengers 2013). We discuss why we need to understand and analyse practices-that-consume-energy in order to develop strategies that address the resource management challenges they give rise.

PART II.

Research Design

Chapter 3: Understanding and analysing social practices

In Chapter 2, we argued that the dominant smart demand management paradigm is characterized by a divide between the spheres of supply and consumption, which result in unrealistic assumptions for understanding individuals' energy consumption. Furthermore, we also exemplified how the taken for granted rationale for the technology and information mediated demand consumption obscures understanding of the way demand is consumed in daily life. In this chapter, we reframe energy demand in terms of individuals daily practices in presenting the framework used for understanding how practices-that-consume-electricity are established, sustained and transformed (Schaztki 2002, Shove et al. 2012, Nicolini 2012). In particular, we are interested in '*rich and nuanced'* (Nicolini 2012) understanding of practices-that-consume-electricity in everyday life perspective. In this chapter we will explain why this conceptualisation is useful for analysing comfort and cleanliness practices?

The chapter begins with an overview of everyday life, where practices-that-consume-electricity are carried out, by explaining its importance in evaluating and developing smart demand management strategies. We argue that social practice theories provide a useful set of concepts for understanding and analysing everyday practices-that-consume-electricity. We distinguish between four intersecting theoretical concepts: know how/embodied knowledge, institutional knowledge, engagements and technologies. We consider how the elements of practices are established, sustained and changed through processes of reproduction and routinisation. We are interested in understanding the connections between and within practices. Finally, we expand on how social practice theory can be used in designing social change programmes for everyday comfort and cleanliness practices.

3.1. The importance of everyday life

In the previous chapters we argued that the conceptualization of the energy consumer as a rational actor who uses technology to manage demand generates limitations in understanding how demand is constituted and changing. Instead of characterizing individuals' electricity usage based on their monthly electricity bill, it is useful to investigate how and why householders consume electricity in their everyday lives.

In this conceptualization energy consumption is not the outcome of an individualistic desire but is defined by the everyday performance of practices (Warde 2005, page 137). Following this understanding, individuals consume energy in order to carry out day-to-day practices that they make possible (Wilhite et al. 2000). On the other hand, everyday life is rarely the focus of research. It is mundane, messy, on-going, consisting of fully familiar events that made Sofoulis (2005, page 448) to remark:

> *'The problem with researching - or transforming - everyday water use is precisely its everydayness; so normal it retreats into the background of awareness as part of 'inconspicuous consumption' (Shove, 2003, p. 2). This consumption is not readily disclosed in the opinions and attitudes surveyable by questionnaires, but involves an almost wordless 'practical consciousness' (Giddens, 1984; Tudor, 1995) of actions and interactions normalised as part of quotidian habits and routines. Who normally entertains an attitude about a tap, a drain, or a sewage pipe? Change in water use habits would not just require information, but more importantly, the de-routinising of normal habits and the learning new ones.'*

Despite its wordless and hidden characteristics, it is within the everyday tasks, routines and rhythms that energy consumption takes place, from getting up every morning, having breakfast, going to work or school, having lunch, going home, having dinner, reading a book, surfing on the internet or watching television, and probably doing similar things again and again. Most importantly, everyday life is by no means stable and unchanging. As argued by Shove (2003), the normal routines householders engaged in last century are very different to those we take for granted today. It is the dynamic and transforming nature of daily life, and in particular the everyday practices which constitute it, that makes everyday life critical in addressing resource management issues. Thus, as practices are modified, so too is the resource consumption required to maintain them.

Other scholars have studied the everyday as a site of social reproduction and change (Pink 2012, Shove et al. 2010). In this case, the term everyday is broadly used to describe a bundle of activities routinely enacted in the course of everyday life, but not just amongst the social sciences (such as sociology and anthropology) dealing with theories of social practice, but also across disciplinary boundaries (such as engineering and design) and extending into the realms of cultural politics. This has been made explicit by Pink (2012, page 5), everyday life:

> *'…is the domain of activity that the interventions of many policy makers, designers and engineers seek to reach. It is where we make our worlds and where our worlds make us. Therefore everyday life is a context of human creativity, innovation and change, and a site where processes towards a sustainable future might be initiated and nurtured. It is moreover, subsequently a locus from which and in which contemporary concerns about environment might be addressed.'*

From this perspective, if we take practices as the primary locus of interest, everyday life becomes a political domain. For example Shove et al. (2010), in analyzing socio-technical transitions toward sustainability, suggests that a '*strong emphasis on practice dynamics points to a new set of problems to do with the governance of seemingly uncontrollable processes that characterise the emergence, reproduction and disappearance of more or less sustainable patterns of daily life*' (Shove et al. 2010, page 472). Likewise, the transition toward a more sustainable future involves new expectations and understandings of everyday life and different forms of consumption and sets of practices (Shove et al. 2010). But, most importantly, the socio-technical transitions toward sustainability is not just a matter of paying closer attention to users, or of emphasising their role within existing supply oriented narratives, but involves '*more strongly examining how various sustainable practices come into existence, how they disappear and how interventions of various forms may be implicated in these dynamics*' (Shove et al. 2010).

3.2. Site ontology, practices, carriers, careers and recruitment processes

If the behavioural approach to energy consumption would be based on the often cited quotation '*Buildings don't use energy: people do'* (Janda 2011, page 15) practice theorists would disagree with this assertion, arguing that people do not consume energy, but that instead it is their routinized activities (or practices) that do. Whilst this may seem like a small or unimportant alteration, methodologically it has profound implications when designing social science research and in interpreting and analysing its results. As Shove (2011) remarks, when comparing individualistic models with the practices approach, they have fundamentally different ontologies, making them as different as '*chalk and cheese*' (Shove 2011, page 262).

To fully understand the distinctive nature of practice theory is to recognize that it builds on a flat ontology or 'site ontology' (Schatzki 1996). For Schatzki (1996), social life is tied to a 'site' of which it is inherently a part, theorizing that the site of social life is composed of a nexus of human practices (or actions) and material arrangements. On a smaller scale, these sites can for instance be workplaces or households. In this research, the students' collectives are perceived as such sites, where multiple practices co-exist, co-evolve, and interact. The site ontology of practice theory has implications for the understanding of the individual. Rather than individuals, it is individuals' practices that are the unit of analysis in practice research. Furthermore, humans are carriers of practices operating within a socio-technical landscape. Therefore, understanding the way humans become carriers of practices and what their relationship with practices is, could help in understanding the differences between practice theory and behavioural approaches.

Firstly, if in behavioural models the individuals and their attitudes, behaviours and choices form the basis of action, in practice theory the individuals are seen as '*knowledgeable and skilled 'carriers' of practice who at once follow the rules, norms and regulations that hold practices together, but also, through their active and always localised performance of practices, improvise and creatively reproduce and transform them'* (Wilhite 2012, page 8). Thus, the practitioners are seen as powerful agents who have the skills to creatively engage, transform, or ignore performances of practice. As such, humans are the '*unique crossing point of practices, of bodily-mental routines'* (Reckwitz 2002, page 256).

Secondly, while in behavioural models the understanding of individuals is related to a functional context (such as urban areas or markets) and activity (such as engineers or doctors), that is what groups individuals in practice theory the individual is capable of being a carrier of multiple practices, or bodies of knowing, thinking or acting in multiple contexts. Therefore, practices are those who are recruiting the actor, and with the continuous performance of practices, actors become skilled over time. According Warde (2010), the process of enrolment starts with domestic practices during infancy through formal associations, and social or recreational activities (Warde 2010, page 96). Shove et al (2012) are more explicit, arguing that practices evolve through competition with each other. Using the ecological analogy of Britain's forests, they show that the practices in existence today are results of an 'unbroken lineage' from practices that existed in the past, but that also compete which others in the present to capture the human resources that are available (Shove et al. 2012, page 65).

How practices are shared and transmitted from one carrier to another is still being understood but one way in which new recruits are initiated into practices is through social networks. History or location are some examples of important social networks. Many researchers who write about innovations in practice, emphasize the significance of social networks '*as containers that limit their diffusion and as conduits through which they flow*' (Shove et al. 2012, page 66). For example, Shove et al. (2012) describe the ways showering on a daily basis spread and became embedded through the design of the bathroom and expectations of friends and family. To a large extent this suggests that it is possible to transmit practices through networks, infrastructures, tools and rules, but when it comes to the practical know-how, it is more challenging to understand the recruitment process. By definition, practical knowledge is not fully available to the realm of discursive consciousness (Shove et al. 2012). As a solution, Shove et al. (2012) argue for *the 'apprentice-like mimetic processes'* where potential new carriers of a practice learn new skills and competences '*as much from each other as from their 'masters'* (Shove et al. 2012, page 72). In this process, learning and sharing are transformative, both the practice and practitioner become mutually transforming as their careers intertwine (Shove et al. 2012). As individuals become committed to the practices they carry, their competence improves so their status changes, sometimes to the point that they become what they do (Shove et al. 2012). For example, Richards (2013) in analysing students '*practice of sharing*' in new accommodations suggests that new residents 'had to 'learn the ropes' of a new shared house and acquire knowledge and experience of those practices through '*mimetic apprenticeship'* (Shove et al. 2012, page 70) – *often a case of watching and learning*' (Richards 2013, page 197). What this means is that the old residences expected new ones '*to take to shared living as 'fish to water', transferring experiences of practice from other, similar contexts, such as previous shared accommodation or university. However, those who lacked* *such experiences could find such expectations disconcerting, and noted that they often did not know the 'rules of the game' at the outset of house sharing.*' (Richards 2013, page 197).

Finally, if the above discussion was focused on the routes through which individuals become committed carriers, in the following, we will expand on the meaning of carriers in the careers of the practices themselves. The careers of practices are responsible for the trajectory of the practice as whole. In some cases, high level of expertise may allow practices to develop and evolve resulting in a situation in which experienced practitioners define career paths that others follow. There are cases when the aspirations within the practices are contested and practitioners remove the original system, by revolutionizing a practice (Warde 2005). For example, renewable energy systems (such as wind turbines or solar panels) continued to revolutionize the practices-that-consume-energy (Strengers 2013). This suggests that practices-that-consume-energy are undergoing a process of 'remediation', whereby the practices are transformed as a result of changes in the technology (Shove et al. 2012).

Furthermore, as suggested by Warde (2005), conventions and aspirations '*will normally be differentially distributed among and observed by its practitioners*.' In other words, while some practitioners will aim towards best practice, others will be satisfied with more 'ordinary' performance and so practices become internally differentiated.

In summary, this subsection briefly introduced the practice approach by considering the benefits of focusing on practices as opposed to structures or individual agency. In the next subsection, we turn to the important endeavour of defining practice.

3.3. Practices as configurations of elements

In this section, we identify two common definition of everyday practices which we refer as practice-as-entity and practice-as-performance. A practice-as-performance takes place at a particular time and space when understandings, technologies, practitioners and activities come together in a specific way (Schatzki 1996). For example, at 8.00 a.m. on 10th September 2017, I submitted my electricity meter reading using our accommodation digital electricity meter, the reading from the meter and a smartphone application.

Active and constant reproduction, undertaken by multiple practitioners in diverse spaces and times can be conceptually brought together in considering a practice-as-entity (Shove et al. 2012). In this case the entity in question could be the practice of submitting meter readings, or more specifically the practice of monitoring home electricity usage or even of using a smartphone energy tracker application.

In the first example a focus on performances may reveal the variation and potential transformation of my electricity meter reading activity. For example, even if I submit regular meter readings (once a month), this activity precludes an exact duplication. Despite my best effort, I will never submit my electricity meter reading at exactly the same time (such as 8.00 am) and in exactly the same order.

There may be disruptions, such as being on holiday or receiving a text message in the middle of the reading submission activity - that transform the performance of the meter reading process. In the second example I described the practice of submitting regular meter readings as comprised of multiple non-dependent and recognisable activities (such as monitoring electricity consumption and using smartphone energy tracker application). Together these activities form the entity of submitting regular meter readings. In the following we will expand on the definitions of practice-as-entity and practice-as-performance.

According to the widely cited definition by Reckwitz (2002, page 250), a practice:

> *...is a routinized type of behaviour which consists of several elements, interconnected to one another: forms of bodily activities, forms of mental activities, forms of mental activities, 'things' and their use, background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge. A practice - a way of cooking, of consuming, or working, of investigating, of taking care of oneself or of others, etc. -forms so to speak a 'block' whose existence necessarily depends on the existence and specific interconnectedness of these elements and which cannot be reduced to any one of those single elements..*

From this definition, it becomes clear that practices consist of recognizable and interconnected elements: forms of bodily activities, forms of mental activities, things and their use, background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge. Other authors have simplified this list by denoting practices as consisting of three or four elements (Gram-Hanssen (2010) page 154, provides a useful summary of different elemental groupings of practices).

The terminology used in this thesis is know-how or embodied habits, institutional knowledge, engagements and technologies; interpretation and terminology developed by Gram-Hanssen (2009) after domestic energy consuming practice research (Gram-Hanssen 2010, 2011), and adopted in several domestic energy consumption investigations (Foulds et al. 2013).

Know-how, for Gram-Hanssen (2010), refers to local knowledge, developed through tacit learning and experience of performing a practice multiple times in certain ways, such laundering when the wash basket is full, or cleaning the house on a Saturday. Institutional knowledge refers to expert-advice, instructions, laws or policies on how to perform practices, such as laundering clothes at certain temperatures considering the manufacturers' advice, or following the instruction manual of the washing machine when laundering. Engagement can be individually or culturally determined and refers to social expectations, symbolic meanings or motivations, such as washing T-shirts after every wear to make sure these are adequately clean, but may also include use of different detergents, softeners etc. Technologies refer to objects, tangible physical entities, infrastructures; anything that makes up the actor's physical environment, such as the electricity grid or the washing machine. The dynamics of practices evolve as these elements interact with one another over time, and new people are recruited to perform the practice.

Practices are performed in time and space, and this is another important feature of practices. Schatzki's defines practices as a '*temporally unfolding and spatially dispersed nexus of doings and sayings*' (Schatzki, 1996, page 89), where the emphasis is not so strongly on connected elements, but rather on spatiotemporal structures. As explained by Schatzki (1996), the set of actions that compose a practice 'hang' together through (1) practical understandings, (2) general understandings, (3) rules and (4) teleoaffective structure. Schaztki does not call the terms listed elements because, in his view, what makes up a practice is best considered when investigating the relation of practices to each other. Practical understandings refer to certain abilities related to actions of a practice: '*Knowing how to X, knowing how to identify X-ings, and knowing how to prompt as well respond to X-ings'* (Schatzki, 2002, page 77)'. For example, when an individual feel hot, he draws on his practical understanding in deciding what practices should be undertaken, such as putting on a jumper, shutting blinds, turning on the heater or taking a hot shower.

What follows from this is that, what makes sense for individuals to do, at any given moment, is informed by what the individuals have always done (Schatzki 1996). Importantly, practical knowledge is not something actors born with, but rather is a product of social history such as education, or social experience. General understandings are social understandings about right and wrong ways of doing things. They are often referred to as norms, conventions, traditions or public opinion that inform acceptable and unacceptable practices. For example, in this thesis, social expectations of appearance, smell or hygiene inform how and when comfort and cleanliness practices should be undertaken. Rules link the doings and sayings of a practice and can influence the future course of activity. Rules or recommendations are introduced by those with the authority to reconfigure or reinforce a practice or specific components of it. For example, recommendations about how to save energy are given by utility companies and governments in pricing rules for electricity.

Rules can also be incorporated into things through building standards, or shower timers. Schatzki defines teleoaffective structures as, '*a range of normativized and hierarchically ordered ends, projects, and tasks, to varying degrees allied with normativized emotions and even moods*' (Schatzki 2002, page 80). According to Schatzki, a practice always displays a range of tasks to do in order to realise projects with specific ends. Thus, while practices are learnt, the way learning takes place is through doing and mental or affective performance. For example, actors can power down domestic appliances in managing electricity with a feeling of obligation but without any interest in reducing consumption. The interest can however lie in the project of showing examples to others on saving electricity, with the end of reducing electricity bill.

In summary, the elementary approach is useful in guiding empirical inquiries, in particular in zooming in (Nicolini 2012) on the dynamics between elements of practice, how they collectively or separately interact with other practices that shape the performance of practice over time and space, or how technologies are used. The main limitation of the elementary approach is that it may lead to oversimplification or predefinition of a practice. For example, to say that heating times in campus accommodation are a rule imposed onto heating practice would be misleading. Heating times in campus residences can be conceptualized as a rule, but they contribute to and emerge out of existing know-how or embodied habit and institutional knowledge about residential heating practices, with reference to material configurations of technologies and systems of provision.

3.4. Practices in performance

While the analysis of the practice-as-entity focuses on the structured organisation of the practice, the analysis of the practice-as-performance is interested in the moments of integration that occur when practices are in action. Thus when a practice such as bathing, laundering or hoovering is performed, its elements connect in different ways and it is thought that the successive reproduction of the connection between the elements of practices are the fundamental structures of the practices that drives everyday energy use (Nicolini 2012).

A practical example, in this sense, are the indoor household cleanliness routines consisting not only of a '*nexus*' (Schatzki 1996) or '*specific interconnectedness*' (Reckwitz 2002) of inconspicuous practices of consumption, such as showering, laundering or cooking, but also of ways of performing (or doing) these everyday cleanliness activities. In this sense, the introduction of a new '*institutional rule*' or 'technology' is influential for the practice itself only if it is captured and used in the reproduction of the practice over time. To give a practical illustration, showering became a common practice long after the mass installation of the electric showers in the 1970s (Shove 2003). At the beginning, showering was thought to be dangerous for the skin, particularly for women (Southerton et al. 2004), but with changing ideas about the body, regular showering became a normalised practice. As such showering only existed as a recognizable conjunction of elements, but through regular performance, the connections between elements that constitute the showering practice sustains and legitimates showering practices (Shove 2003).

The performance of practices differ from each other as the elements of the practice are always brought together differently. Thus, the practices are sustained, changed or destroyed as the connections between them are created, maintained or broken (Shove et al. 2012). Similarly, the connections between know-how, institutional knowledge, engagements and technology are made or broken through successive moments of performances, so the practice advances or is 'fossilized'. The latter is defined by Shove (2012) as a process whereby practices disintegrate when connections are no longer sustained.

One of the reasons for the changing nature of the performance of the practice is that practices are inherently social in nature as participants learn practices from each other therefore new standards or norms emerge. Thus, as participants in social practice discuss the practice with each other, they identify the correct ways of undertaking it, and change their routines to either conform to, or deviate from, this new understanding. Therefore, different configurations of practice components lead to change.

When existing connections break and shift, or the elements become unstable, innovations may occur and practices and elements of practices may be reinvented (Shove et al, 2012). 'Breaks' and 'shifts' in the reproduction of practices emerge from: *'everyday crises of routines, in constellations of interpretative indeterminacy and of the inadequacy of knowledge with which the agent, carrying out the practice, is confronted in the face of the 'situation'* (Reckwitz 2002, page 255)'. A particular situation leading to household crises of routines are moving home (Foulds et al. 2014), power blackouts (Rinkinen 2014), a new household member, introduction of a new appliance, or illness in the household.

In summary, the literature used above defines practices as enduring and recursive entities reproduced through recurrent performances. The transformation of practices is a dynamic process involving shifts and breaks in their reproduction. Importantly, complexes of practices exist only because the connections between different elements are consistently reproduced in '*timespace*' (Schatzki 2010).

3.5. Tracing practices in time and space

As mentioned in Section 3.3, practices do not exist in isolation but rather form a nexus of interconnected practices within a particular site that is held together by practices, artefacts, and spaces

(Nicolini, 2011). For example, doing the laundry consists of several individual practices such as selecting the laundry, loading the washing machine, drying the clothes, ironing and storing laundered clothes and others. While these are separate practices they are usually bundled together when performing the laundry practice. More generally, as elements connect together to create a social practice, practices connect together to create bundles that are '*loose-knit patterns based on the co-location and co-existence of practices* (Shove et al. 2012, page 81)' and complexes that are '*stickier and more integrated combinations'*. When practices are bundled they can share elements and co-evolve. For example, with the evolvement of wireless technology, the use of laptops, tablets and smart phone becomes less spatially constrained. As the outcome of the wireless connectivity, bundles of household practices-that-consume-electricity, such as heating, changed. Thus, if in the past the whole family might spend the evening together in the living room, only heating one room, today family members could be dispersed around the house watching or communicating, using multiple electronic devices while heating the whole house. Understanding how and where wireless connectivity fits into other practices that form everyday life is important in the design of heating behaviour change initiatives.

How then can we identify a practices boundary? One way is to classify practices as dispersed or integrative (Schatzki 1996, Warde 2005). According to Schatzki (1996, page 92) dispersed practices appear in many different contexts of social life, and their performance requires the 'know how' and 'understanding' of how to carry out an appropriate practice. Examples of dispersed practices are turning on and off thermostats, switches or using remote controls. Integrative practices are '*the more complex practices found in, and constitutive of, particular domains of social life'* (Schatzki 1996, page 98). Examples of integrated practices with relation to energy consumption in households are cooking, laundering and heating.

Schatzki defines several ways of thinking of an integrative practice, three propositions are important for this thesis. The first proposition is that the performance can be read and judged as correct or acceptable (Schatzki 1996, page 100-102). The second proposition suggests that integrative and dispersed practices are socially organized and coordinated bundles of activities or in Schatzki's (1996, page 105) words '*practices are social, above all because participating in them entails immersion in an extension tissue of coexistence with indefinitely many other people'*. Participating in practices entails immersion in an extensive tissue of coexistence that embraces varying sets of people performing intermeshed practices (Shove et al. 2012). For Schatzki (1996), integrative practices are more complex partly because of the pressure exerted by the four components of the practice functioning with their '*own logic and its own different coordinating agents and organizations.'* (Warde 2013, page 25). Coordinating agents are responsible for the interaction and communication between practices (Warde 2013). What follows from this is that the coordinating agents can be identified and drafted as nodes in a socio-material network (Vihalemm et al. 2015, page 40). One of the benefits of this network map is visualizing the variation in the density of relationships between practices. Furthermore, a network map often suggests boundaries between different practices because there is a high density of interrelationship between some components forming distinct nodes.

3.6. Organization of practices in time and space

Practices are situated in objective time and space and result from particular historical, cultural and social conditions (Schatzki 2009, Shove 2012, Southerton 2006). Time and space are not separable matters and are central to the organization of practices. Time and space are constituted by practices (Shove 2009) meaning that the patterns of time and space are reproduced in everyday life through participation in different practices (Shove et al. 2012). In a practice theory perspective, an individual follows a path in time and space, participating in practices and projects that leave 'sediments' in their minds and bodies, which support participation in certain practices at the expense of others (Røpke 2009). When practices are performed collectively this implies the coupling and uncoupling of constraints. As Røpke (2009, page 2493) argues: '*As practices often involve other people, other living organisms as well as man-made and material objects, they depend on the coupling and uncoupling of the paths of all these human and nonhuman "partners".*' In this representation the coupling and uncoupling relates to the idea of polyrhythms (Lefebvre 2004) or the overlay of multiple particular places at particular times, with the bundles of rhythms interacting with each other in order to find a shared 'pulse' – a time and place at which the rhythms cross – in order to perform a practice such as family meals.

In this representation the practitioners' time is a limited, finite resource and its allocation *'reflects the relative dominance of some practice over others'* (Shove et al. 2012, page 127). This means that the dominant practices are those which consume most of the time and their dominance and continuation depend on how practitioners spend their days (Shove et al. 2012, page 127).

Practices thus compete for time, but from the point of view of the practitioner enacting a practice properly, it is '*a matter of weaving it into an existing rhythm'* (Shove et al. 2012, page 127). Although in theory, everyone has access to the same amount of time, in fact practitioners have limited amounts of time free from their scheduled activities (such as work practices) meaning that the new practices need to be inserted within these temporal rhythms or have the ability to push aside established practices (Røpke 2009). Southerton (2006) has proposed that social practices operate along Fine's (1990) five dimensions of time: tempo (or speed), duration, timing (synchronization), sequences (ordering of events) and periodicity (rhythm). Southerton's (2006) investigation also revealed that the temporal rhythm of the day is predictable and manageable by practices, which hold a fixed position in the sequence of practices (Southerton 2006, page 436). In relation to energy consumption life events such as, house moves (Foulds et al. 2016, Gnoth 2013), home renovations (Energy Saving Trust 2011) or changing family roles (Shirani et al. 2013) can create conditions where individuals or households are more receptive to an adjustment in their energy-related practices. In this way, life events may represent a window of opportunity for inducing change in practices-that-consume-electricity.

While the conceptualization of practices as competitors in time and space entails that practices require recurrent performance, practices are rarely continuous. Rather, practices are active and at other times '*lie dormant*' (Shove et al. 2012, page 128). This suggests that the elements of the practice must be 'lying around' and waiting to be integrated in a practice to be able to bridge between performance moments (Shove et al. 2012, page 128). Seen from this perspective time and space have a dual role: connect performances in objective time and '*move structuring in the way in which time is experienced and organized within society'* (Shove et al. 2012, page 129). This leaves the question of how dormant practices continue to exist or how they can be revived at different moments in both time and space?

Whereas it seems that the commonly accepted approaches to time and practice frame practices as '*consumers of resources*' (Shove et al. 2009) that are competing with each other for practitioner's attention, it is possible to conceptualize time as the product of practices that is an '*integral part of a systems of practice in which we are all engaged*'(Shove et al. 2009, page 24). In this framing time is integral part of practice, in other words: it takes certain time to accomplish properly a practice that would suggests a zooming in (Nicolini 2012) on how everyday practices are the makers of the time (Røpke 2009). If we want to comprehend the ways in which everyday electricity consumption participate in the constitution of domestic temporalities then is important to engage not only with practices-that-consume-electricity from a macro perspective, but to examine how electricity is experienced in the living of everyday life.

Schatzki makes distinction between the experienced time and space (so called timespace) and on the other hand 'space-time' which stands for objective space and time. The difference between the two is that '*Human activity...institutes and bears a timespace whose temporal and spatial dimensions are connected inherently - and not contingently as with objective space-times'* (Schatzki 2010, page 38). Putting it simply, in Schatzki (2010) conceptualization time and space come together through action and are derived from '*time-space actions and from the practices that actions compose*'. Schatzki argues further that '*an important feature of temporality as a feature of human activity is its relation to teleology*' (Schatzki 2010, page 28). Thus the teleological characteristics of time suggests a strong orientation towards all kinds of ends. In this sense, the '*timespace'* (Schatzki 2010) of human activity is defined as '*acting toward ends from what motivates at arrays of places and paths anchored at entities'* (Schatzki 2010, page 38). Schatzki's definition of 'timespace' could help in understanding practitioners embodied actions as mutually constituting domestic 'timespace'. For example, the practice of cleaning the bathroom is a routine process through which the rhythms of renewal and re-growth are regulated (Pink 2012). The connections between the growth of limescale and accumulation of dirt and the performance of cleaning, defines both the orientation of the practice and its gives its timing a moral meaning (Pink 2012). The relationship between the performance of cleaning and the phenomenology of times also significant in that 'cleaning time' is made meaningful (Pink 2012) through the listening of radio or music - which in itself contributes to the sensory framing of the timespace of cleaning. This way the moral and the affective meanings of learning are defined in different timespaces (Schatzki 2010).

The thesis will explore the temporal nature of energy-related practices and, in particular, the way in which practices are adopted, by practitioners, when moving house. Furthermore, the thesis will investigate how at different moments in time and space, know how, institutional knowledge, engagements and technologies all interact to produce various shared ways of understanding electricity-related practices.

3.7. What energy consumption is for?

A growing body of literature advocates that in everyday life energy consumption is not a conscious act, but is a by-product of performing everyday routines that are powered by energy (Shove et al. 2014). Thus, while the electric current is sourced through sockets and appliances most of the time, energy remains invisible to householders. This is acknowledged by Wilhite (2005, page 2) who notes that '*people do not consume energy per se, but rather things energy makes possible, such as light, clean clothes, travel, refrigeration and so on.*'

Sociological studies of domestic energy consumption create a route through which energy consumption can be approached indirectly by researching not the energy per se but the '*enmeshed...network of related practices and habits'* (Shove et al. 2002, page 246) through which practitioners consume electricity (Gram-Hanssen 2011). One of the advantage of the practice approach is that it allows understandings of how energy is integrated as a constitutive ingredient for everyday routines (Shove et al. 2012) or in complexes of practice (Schatzki 2010).

There are grounds to consider energy as an ingredient of practice (Strengers et al. 2012). Strengers et al. (2012) provide inspiration in their research on migrant families, where they suggest that a focus on everyday practices that use energy '*pays close attention to energy in action and conversely in inaction.*' In this conceptualization different energy-making practices can create distinct '*object-like energies... [that] intersect with other elements to reproduce (or limit) resourcefulness*' (Strengers et al. 2012, page 26). The term '*energy-making practices*' refers to the practices of making usable energies, such as chopping wood for a fire or using micro-generation. For example, in some cultures, making energy involves distinct arrangements of '*technical equipment (donkeys, axes, clay pots), practical knowledge, and understandings to produce specific energies that are integrated into practices that are dependent on them (such as cooking)*' (Strengers et al. 2012, page 26). These in turn give different energies specific skills - for instance around reusing water in showering or laundering practices that become active in response to everyday challenges such as water restrictions or prolonged drought. Strengers et al. (2012) conclude that the qualities and characteristics of different energy systems define how energies are constituted and become integrated into practice as a distinctive, traceable gathering of material things (Shove et al. 2012). A related implication of this is that the supply and demand of energy is no longer viewed as separate and separable, but as a suite of intimately interwoven practices, whereby the technologically mediated energy provision (sockets and wires) interact with the ways energies are consumed and used in the course of everyday life.

While studying energy as a material of practice could help in understanding the role of energy and its associated technologies in everyday energy demand, energy itself is not material or visible, '*it is not something we touch, listen or smell'* (Pink 2012, page 69). Schatzki (2010, page 125) offers a way out of this blind, suggesting that human coexistence is inherently tied, not just to practices but also to material arrangements that are not constitutive elements of practices:

> *'The activities that compose practices are inevitably, and often essentially, bound up with material entities. Basic doings and sayings, for example, are carried out by embodied human beings. Just about every practice, moreover, deals with material entities (including human bodies) that people manipulate or react to. And most practices would not exist without materialities of the sorts they deal with, just as most material arrangements that practices deal with would not exist in the absence of these practices (Schatzki 2012, page 16).'*

More expansively, because bodily doings and sayings, and humans, are classified as part of the material arrangements, practices are by default material. Thus, there is not practice which is not material. Bundling this with Shove et al.'s (2012) conceptualisation of materiality, it is possible to study energy as ingredient of practice - material element that sometimes makes demands on practice through its immateriality, or through other tangible technologies (Strengers 2013). In this framing, energy enables practices to work as being a constitutive element of social practice, as the engagements, know-how, institutional knowledge and technologies. This position extends understanding of the way energy is handled around the home and how energy becomes a constitutive ingredient of social practices (Pink 2004, Walker et al. 2014).

In summary, there is an ontological difference in defining energy in practice either as constitutive element of practice (Shove et al. 2012), or as a material arrangement that together with practices bundle and constitute the site of social (Schatzki 2012). The classification of practice elements in know-how (or embodied habits), engagements, institutional knowledge and technologies is useful in understanding the constitutive role of energy in accomplishing a practice in time and space, and how practices emerge, develop and fossilize (Shove et al. 2012). This view of energy as an ingredient of practice underlines the view '*that individual technologies add value only to the extent that they are assembled together into effective configurations'* (Suchman et al. 1999 in Shove et al. 2012, page 10). The materialities of SEDMs, smart appliances and programmable thermostats will also be analysed in this thesis.

3.8. How practice theory illuminates this work?

The most relevant domains within which selected empirical aspects of the smart metering technologies have been explored are the reams of consumption, domestic life and everyday practices. Within these literatures, significant attention has been paid to the role of smart metering data (such as feedback mechanism or building energy efficiency standard in Passivhaus) when people are moving to a new house. Research highlights the messy and non-negotiate nature of the domestic organisation of tasks and responsibilities within households, and has indicated that sociability, commitments and obligations help to shape practices-that-consume-energy.

However, there is no detailed account of smart monitoring practices outside of the privately owned households, raising the question of how smart electricity monitoring is organised and negotiated in privately rented student households. To analyse the social organisation of everyday practices-that-consume-energy, we turn to theories of social practice that provides a useful analytical focus on the coordination and collective nature of everyday social practices-that-consume-energy. Zooming in and out (Nicolini 2011) on practices-that-consume energy helps understanding how students are recruited into energy monitoring practices and experience change through them, as well as to how practices-that-consume-energy change and develop over time.

In the empirical analysis of a shared student accommodation, this underlines the importance of analysing the ways in which students are recruited into energy metering and monitoring practices and the way they become career within practise-that-consume energy over time. To further, address the significance of the temporal dimension of how monitoring practices-that-consume-energy are organised, the thesis links theory to electricity metering and monitoring approach, that provides additional information about energy use and is possible to identify the time when appliances that have been used.

While existing research has investigated the effect of '*moving house'* on practices-that-consume energy such as comparing aggregated energy data before and after moving into a new house, such research does not zoom in (Nicolini 2011) on change in practices-that-consume-energy due SEDMs specifically. Furthermore, if smart electricity metering and monitoring differs across appliances, services, spaces (appliance specific metering is different to all household metering) as well as according to the consumers who are doing the smart metering and monitoring, than it is clear than a fuller sociological and technical account must address the mechanisms by which (different types of) energy monitoring and metering practices occurs.

And finally, as electricity metering and monitoring is an inherently relational concept and practice (as this thesis will demonstrate): something must engage (or attract) individuals for smart metering and monitoring to occur, so the nature of the relationship between those who use smart meters in everyday is another aspect to explore.

3.9. Operationalizing theories of practice in social change programme design

This subsection discusses the application of social practice theory in preparing a social change programme (Spurling et al. 2013, Vihalemm et al. 2015). There is an agreement in the literature that the decarbonisation of the electricity grid requires intervention in practitioners' social practices (Shove et al. 2015, Spurling et al. 2013, Spurling et al. 2014, Watson 2012, Vihalemm et al. 2015) instead of continuing the dominant focus on ineffective technical innovation and behaviours that are readily observable. These scholars suggest that policy interventions need to focus on changing the practice elements configuring the entity of electricity consumption and aim to reconfigure the interconnected bundles of social practices that are directly or indirectly linked to electricity use. However, determining the practices in which to intervene is a complex issue (Vihalemm et al. 2015). A detailed account of how to frame the problems of intervening in practices is given by Spurling et al. (2013), with a further development by Vihalemm et al. (2015).

Spurling et al. (2013) distinguish three points of intervention into practices as entities: re-crafting the elements of existing practices, substitution (new or old) practices and changing how practices interlock. First, re-crafting practices refers to reducing the resource intensity of existing practices by zooming in (Nicolini 2012) to investigate the elements of practice and their interaction (Spurling et al, 2013). This is mostly applicable in the context of compound practices that are weakly coordinated (Vihalemm et al. 2015). For example, showering as a practice is connected to material arrangements and infrastructural relations that shape the performance of the practice. Hand et al. (2005) show how the infrastructural arrangements and material resources that are associated with the resource-intensity of routinized showering in households. Thus, the showering pipes, electrification, the continuous availability of hot water, the public, the design of power-showers influence the resource intensity of the performance of showering. They suggest a systematic approach that intervenes in all the elements of showering practice.

Second, substituting practices refers to replacing unsustainable practices with more sustainable version of practices (such as replacing showering with bathing, by changing bath tubs to shower rooms). This implies that practices need to be *'well coordinated but not very dense'* (Vihalemm et al. 2015, page 63) to have space for changes in socio-material network that they are embedded in (Vihalemm et al. 2015). This framing zooms out (Nicolini 2012) to look at the pairings of potentially '*substitutable practices*' - a resource intensive practice and a more sustainable counterpart, and intervening in both practices at the same time, focusing on harnessing the competition for time, space and resources between practices (Spurling et al. 2013). In doing this Spurling et al. (2013) argues for the intervention in the recruitment and reproduction process of several practices by changing how practitioners' needs and wants are met (Spurling et al, 2013). For example, substituting the practice of driving with the practice of cycling would involve discouraging, driving or encouraging cycling by creating more cycling lanes. Another, often-cited example is the 'Cool Biz' programme in Tokyo, carbon emission reduction campaign encouraging office clerks' not to wear ties or jackets and to set their office air conditioner thermostats higher, at 28°C. Fashion designers were requested to develop lighter clothing brands information sheets were designed with suggestions of how to dress during summer and fashion shows (such as Cool Biz fashion or Cool Biz haircut) were held that encouraged abandoning jackets, while at the same time, new standards were promoted – importantly by government officials and captains of industry. As a result the emissions were reduced by half a million tonnes.

Third, Spurling et al. (2014) highlight interventions that alter the sequencing and/ or synchronisation of practices to '*change how practices interlock'*. This strategy can be used where the boundaries of practices can be drawn and their level of coordination is not very high (Vihalemm et al. 2015). In their conceptualisation of relations, connections and links between 'bundles' and 'complexes' of practices (Shove et al. 2012) suggest that the interventions need to change the complex interconnections between practices, that for example produce the need for energy. Furthermore, in their conceptualization any intervention in a single practice related to electricity consumption, has a crucial effect on the systems of practices (Watson 2012) of which it is a part. Synchronisation of practices is critical for peak energy loads or morning rush hours (Shove et al. 2009, Southerton 2013), and sequences relates to the performance of practices in a specific order (e.g. shopping, cooking and eating).

In addition to the strategies identified by Spurling et al. (2013), Vihalemm and collegues (2015) define a new strategy which they call as disruption of problematic/unwanted practices. This is a good strategy when we operate in the context of high density, tightly coordinated, culturally rooted integrative practices. Disruption means that the socio-material network in which a practice is embedded is dismantled completely. Examples of the situations in which problematic practices can be disrupted include moving house, having children or transferring to a new workplace. Darnton et al. (2011) label these events '*windows of opportunity*', where interventions may result habit change. While this is a behavioural change strategy it is possible to conceptualize in terms of 'life transition practices', such as activities that practitioners carry out in exploring their new environments (Keller et al. 2016, Gram-Hanssen 2014).

3.10. Conclusions

In the first part of this chapter, we highlighted the role of the everyday practices in constituting the consumption of electricity in the home. This was followed by a discussion on how practices are organised in time and space as entities and performances. How materials constitute practices and are parts of material arrangements, is also relevant. Finally, the application of social practice theory in preparing a social change program was discussed.

It was discovered that there is lack of research about what types of comfort and cleanliness practices exists in student households. It is, therefore, very difficult to make assumptions about them or to develop strategies to reduce their resource intensity. On the other hand, scholars suggest that in reconfiguring the divide between resource consumption and everyday life starts with researching the dynamics between what people do and why they do it. Furthermore, we have no understanding of the way comfort and cleanliness practices are constituted, used and changing in student households. Thus, after exploring the dynamics of comfort and cleanliness practices, we are able to research the effectiveness of the smart metering demand management strategies in student comfort and cleanliness practices. This way we could investigate why are smart demand management strategies effective, or ineffective, in shifting everyday practices-that-consume-electricity? In summary, there is a need for a longitudinal research that identifies the current and changing nature of comfort and cleanliness practices in student households and the role of smart metering demand management strategies in reconfiguring these practices.

Chapter 4: Researching undergraduates' everyday practices-that-consume-energy

In this chapter, we discuss the complexity and contradictions in studying students' everyday practices-that-consume-energy, as these form the primary focus of my investigation. We discuss the selection and installation of the Smart Electricity Display Monitors (SEDMs) used in this study, outlining what we mean by this term. Each of the SEDMs will be discussed in detail, as well as the limitations associated using SEDMs. We will then move on to discuss the methods employed in this investigation, namely energy profiling, focus group sessions, semi-structured interviews, observations, guided video tours, video recording of everyday activity, house plans, photography and video diaries.

4.1. Research scope

My interest in energy metering and monitoring technologies emerged from a desk-based literature review of energy consumption behavioural change strategies (Abrahamse et al. 2005, Fisher 2008) and green campus incentives (Barlett et al. 2004). This initial direction was influenced by my master's thesis topic, which included an investigation of the role of the '*energy lectures'* (DeWaters et al. 2011) in promoting energy conservation among students. Amongst this academic literature, I was drawn to the extensive body of work investigating the effect of energy metering information (Darby 2006), the role of values and attitudes in energy consumption (Poortinga et al 2004), the role of information and communication technologies (ICTs) in energy consumption (Martiskainen et al. 2011), and theories and models of individual behaviour and behaviour change (Ajzen 1991, Jackson 2005).

In my master's thesis, I sought to identify individualistic and technological factors that could influence the uptake of energy conservation measures in students' households. One of my dissertation findings is cited by Soares et al. (2015, page 671):

[…] energy lectures stand as long-term measures that influence students' intention to engage in energy saving measures. They have stronger influence on students' energy saving intention than the television campaigns, i.e. higher education plays a critical role in sustainable education and it is a

perfect environment to get people involved in multi-disciplinary activities, promoting the education for sustainability.

Amongst the behavioural implication of the energy lectures, we conducted several interviews with different universities energy managers on campus buildings renovations and energy awareness activities. We identified that the installation of smart technology in residential buildings (such as energy saving monitors, motion detectors or LED lighting systems) was being counted as long-term solutions in conserving energy while little was known by the energy managers about the ways students consume energy in their everyday life. We became concerned about the data-driven retrofitting of campus buildings without considering students energy consumption behaviour and how energy lectures could increase their motivation to perform energy conservation measures. While countless scientific evaluations of the effect of the smart technology have been and are being undertaken, an empirical study was required to evaluate the effect of smart technologies (specifically the data generated by these technologies) in students' households. Furthermore, we assumed that this investigation would need to remain relevant to the national building retrofit policies, by addressing the dominant energy demand policies in the energy sector.

To undertake, this task, after graduating from my masters I moved to Keele University; an institution committed to developing an environmentally aware and sustainable campus community. The decision to move to Keele University was also influenced by the RECCKN (Reducing Energy Consumption through Community Knowledge Networks, Catney et al. 2013, Simcock et al. 2014) interdisciplinary project which investigated how energy knowledge travels within communities and networks. In investigating '*the way people gain knowledge about energy from each other'* (Catney et al. 2013) the researchers rolled-out in 55 households the 'Eco-Eye Smart' free standing real-time display that was monitoring and representing in real-time energy use in kilowatt-hour (kWh) and pounds of CO_2 emission. During 18 months three times the aggregated electricity data was collected, analysed and reported back to the householders. Part of my aim was long-term monitoring domestic electricity consumption, I started researching SEDMs, focusing on the two types of metering data generated by the meters. I hypothesised that SEDMs that provide disaggregated, tailored data on electricity consumption result in higher electricity savings that aggregated electricity consumption data (Fisher 2008). In order to investigate this hypothesis, I had to understand the way electricity is metered and consumed in halls of accommodation. Therefore, during the national Green Week campaign, I co-organized with Keele Estates the one-week long Energy Saving Competitions between residential halls. At the end of the Energy Saving Competition twenty students from different halls of residences were interviewed to identify reasons for the energy conservation. The key findings of the interviews were (1) students' residential energy consumption behaviours are influenced by many drivers and values are not good predictors of energy conservation behaviour; (2) students could not associate values to a given conservation behaviour, (3) the most common rationalisation of the heating-behaviour was situational constraints (heating pipes) or opportunities (students don't need to pay for their consumption) and (4) due to infrastructural constraints accurate electricity metering can be done only to a limited number of blocks. Furthermore, we became concerned that aggregated energy metering data with interviewing on behaviour will not be enough to explain how and why energy is consumed in halls of residences. Therefore I hypothesized that we would require a good understanding of students' everyday practices-that-consume-energy but also of the context within which energy conservation is being introduced.

As mentioned in Chapter 1, my primary research aim was to identify and analyse strategies to improve the uptake of energy feedback technologies and interventions using smart metering data and comfort and cleanliness practices were the focus of my empirical inquiry. In order to achieve my aim, we needed to investigate how students comfort and cleanliness practices are composed and changing in students' residences, how smart metering data or other demand management policies are reconfiguring them and what role Universities play in the current and changing practices-that-consume-energy. We therefore required a methodological approach to research everyday practices-that-consume-energy, as well as how these were, and could be, reconfigured through smart technologies, and how universities potentially shape and constrain opportunities for change. The remainder of this chapter briefly describes the approaches and methods used to collect the empirical data necessary to address my aim.

4.2. Researching students' everyday practices

Knowing that individualistic (Ajzen 1991) and rational decision models (Jackson 2005) do not adequately explain the composition and the transformation of everyday practices-that-consume-energy (demonstrated in Chapter 3), the aim of this thesis is to improve understanding of how students', as carriers of practices-that-consume-energy, experience, understand and reproduce comfort and cleanliness practices. In order to understand the ways which undergraduates perform practices-that-consume-energy, we employed a qualitative approach of studying '*things in their natural settings, attempting to make sense of or interpret phenomena in terms of the meanings people bring to them'* (Denzin et al. 2013, page 7). On the other hand, my goal was not only to learn about students comfort and cleanliness practices but also to produce explanations and understandings that could be attributed in some way to a broader '*energy cultures'* group (Stephenson et al. 2011). This research was therefore ethnographic in approach, exploring the ways in which students engage in everyday practices-that-consume-energy or the way they interact with each other and/or with technology as they engage in practices-that-consume-energy. Ethnographic studies are intensive and open-ended. As such, Wilk et al. (1985, page 52) argue that ethnographic researchers '*yield finely grained and detailed information that cannot be obtained through questionnaires, and they often provide unexpected insights and lead to productive new lines of inquiry'*. On the other hand, in analysing social practices the focus is on practices themselves rather than individuals that undertake them (Reckwitz 2002, Ward 2005). However while practice theorists (Reckwitz 2002, Gram-Hansen 2011) argue that the methodological focus of the social practice theory needs to be focused on practices; so far, they have failed to develop algorithms on how to study them.

4.3. How to study students' everyday practices?

Studying students' everyday practices-that-consume-energy is a 'Herculean task', that till today nobody has ventured to undertake; I did not embark on this research knowing from the initial stage that students' practices would be the primary focus of my analysis. Thus, I discovered social practice theory during my second year, before starting my fieldwork when I was researching literature useful for analysing and understanding the role of electricity metering data in everyday life. Thus, I did not originally intend to understand students' practices-that-consume-electricity but rather to meter and compare students' household electricity consumption data before and after receiving SEDMs.

In attempting to negotiate between these different approaches, I focused my analysis first on the *'explanations offered by respondents for their actions in response to direct or indirect questioning'* (Wilk et al. 1985, page 57). Using this approach, we sought to interpret householders' descriptions and understandings of their practices-that-consume-energy. The second level of data was obtained through ethnographic research, namely '*synthetic explanations composed by ethnographers as interviews are dissected and analysed'* (Wilk et al. 1985, page 57). Wilk et al. (1985, page 57) argue that the second layer of the analysis is uncovered when the investigator places the respondent's actions in a cultural context ('practice context' in this case) and seek deeper meanings to their 'folk explanations'. Through the second level of data, we sought to interpret householders' understandings of the electricity metering data in the dynamics practices-that-consume-electricity (Kuijer et al. 2013).

While focusing my research methods primarily on practices-that-consume-electricity we had to find a solution to document the dimension and re-configuration of practice. Martens (2012) argues that it is intangible to observe or interview something dynamic as a practice. For example, we cannot interview the development of social understandings, practical knowledge or rules defining practices in students' doings and sayings. However, we can video record the performance of practices, such as laundering, and the explanation what they do and why they do it, when these everyday practices are carried out.

4.4. Researching students' everyday practices thorough quantitative data

'Big data' data has been used during this investigation. The SEDMs record real-time and historical electricity consumption data. Indeed, the monitoring data was used in exploring how the elements of practice influence performance (Chapter 3. 3. and Chapter 3.4.). On the other hand, my primary research aim was not concerned with metering consumption reductions with SEDMs, but rather with the limitations that emerge from relying entirely on the big data.

Thus, while quantitative data indicate that SEDMs are able to reduce energy consumption up by up to 15% (Faruqui et al. 2010, Fischer 2008), it does not tell us why or how this reduction occurs. The big data identifies when and where individuals consume electricity in the home, and if this changes in response to SEDMs, but not why or how individuals change their practices-that-consume-energy. Furthermore, quantitative surveys could be designed to focus on practices, but there is a risk of generalization ignoring the cultural meanings that should be captured. Therefore, a mixed methodology was considered to be the most appropriate for the purposes of this investigation.

4.5. Selecting Smart Electricity Metering and Control Systems

The selection of the SEDMs involved two key considerations: firstly, how can we procure different off-the-shelf based SEDMs within the financial and time constraints of the research; and which SEDMs will be most suitable in answering the research questions. In the next section, we elaborate on the way we selected the SEDMs and what we planned to do with the SEDMs. We will discuss in detail the three SEDMs involved in this study, and conclude by identifying the limitations of using off-the-shelf based SEDMs in this research.

4.6. Identifying Smart Electricity Metering and Control Systems

The rationale behind the selection of the SEDMs was our motivation to investigate with different displays the aggregated (whole buildings electricity consumption) against the disaggregated (or appliance specific) metering data on students' practices-that-consume-electricity. Identifying suitable SEDMs involved a number of steps. Firstly, we conducted a literature review and web based search to identify feedback technologies being trialled with domestic households in UK. However, the identification of the SEDMs was a hand-picked selection, was an ongoing process resulting from emerging opportunities and evaluating the most suitable meters for use with student participants. For example, discussion with Keele Estates highlighted potential issues with the technical implementation of the on-campus electricity monitoring systems. It also revealed privacy concerns and concerns around accessing and downloading metering data. This eliminated a number of potential SEDMs from the available selection. In particular two SEDMs were unable to be included due to financial and technical difficulties. They were the EFENERGY ENGAGE HUB SOLO and SMAPPEE SMART ENERGY MONITOR providing online, real-time, appliance specific electricity consumption monitoring through mobile device or computer. A summary of the selection process or the characteristics used to select the SEDMs for this study can be seen on Figure 4.1.

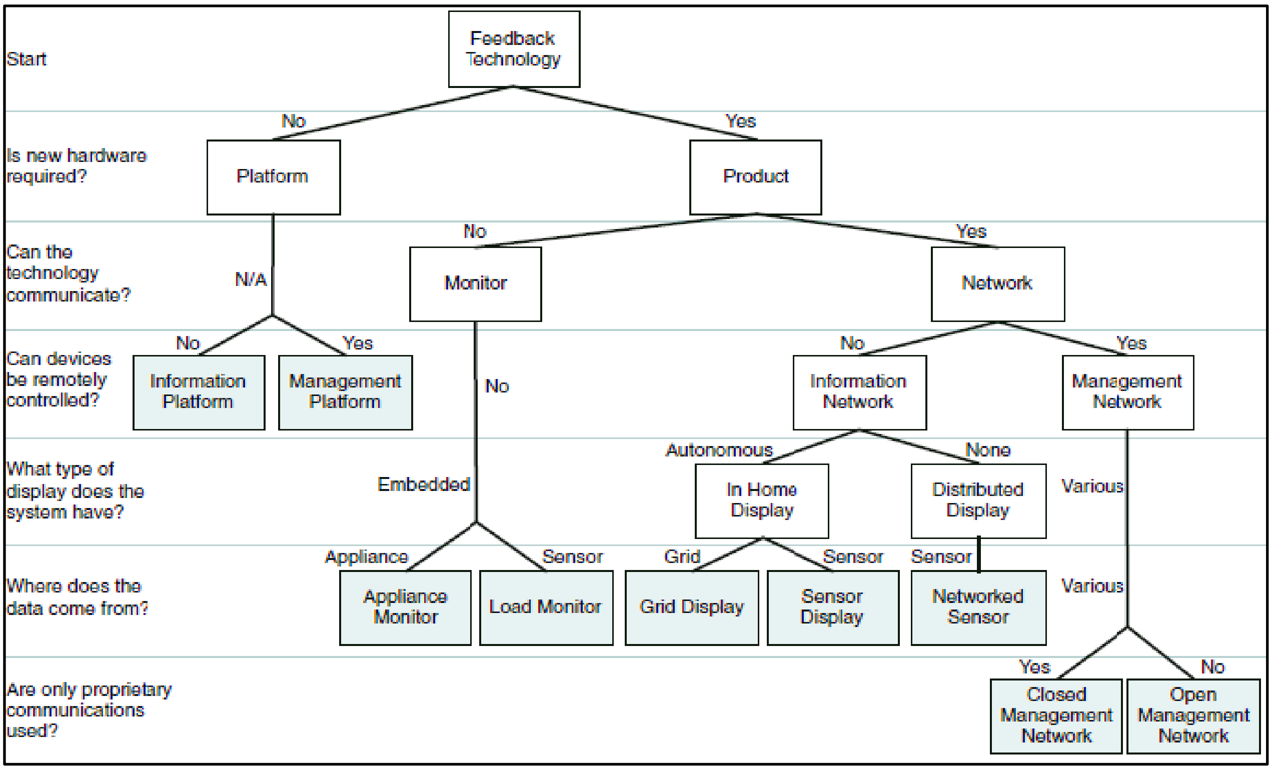


Figure 4.1. Taxonomy of energy feedback (Adopted after Karlin et al. 2013, page 89)

While the selection of the SEDMs was largely opportunity-driven, each SEDMs was targeted based on type of the data provided ignoring the physical design and operating differences. The classification 'taxonomy' (LaMarche et al. 2011) were: (1) display that communicate with different appliances enabling metering and controlling appliances, (2) display that provide real-time or historical data to consumer and (3) enabling technologies (such as smart plugs or platforms). Three SEDMs were selected over a period of 10 months: the OWL USB CM 160 (SEDM 1); ENERGENIE Power Meter (SEDM 2) and EDF ECO-MANAGER (SEDM 3).

In the following subchapter, we briefly present each SEDMs in detail. In particular, our discussion will focus on how each SEDMs was identified, selected, relevant characteristics, type of data provided, how the data is visually displayed.

4.6.1. SEDM 1: OWL USB CM 160

The OWL USB CM 160 (SEDM 1, Figure 4.2.) is a commercial, portable, smart electricity monitor that allows the monitoring of whole house electricity consumption. While the OWL USB CM 160 did not offer appliance specific data, it allowed long-term electricity monitoring and recording electricity consumption. The OWL USB CM 160 meter consists of two main parts: a portable display unit and a sensor (or Current Transformer clamp) that is connected with a wireless transmitter (or data logger). In metering the electricity consumption, the real-time energy monitor was clipped onto an electrical cable on the house electricity meter (Figure 4.2.). The clip ends in a transmitter that is communicating wirelessly with the display transmitting data at 12 second intervals. The aggregated data is converted, stored and displayed in kWh, £ and kg of greenhouse gas emissions. Data can be accessed live from a computer.

One drawback of the clamp style energy meter is its' accuracy in terms of the zero A (Ampere) output voltage as well as changes in sensitivity with temperature. The OWL USB CM 160 was not designed to be or to replace energy metering devices. For example, if the consumption is below 300W (or metering just the electricity consumption of a desktop computer that is around 150W-300W) it is possible to encounter large errors.

The OWL USB CM 160 records power, current and greenhouse gas emissions once a second, for up to 30 days. The historical data can be transferred to a computer via USB using a Windows utility, which outputs a CSV file. The CSV file was uploaded into LibreOffice Calc software to remove all columns except the 'Time' and 'kW_Raw_Data' column. After charting the data, it was possible to differentiate between different appliances that have recognisable cyclical patterns or use a lot of energy.

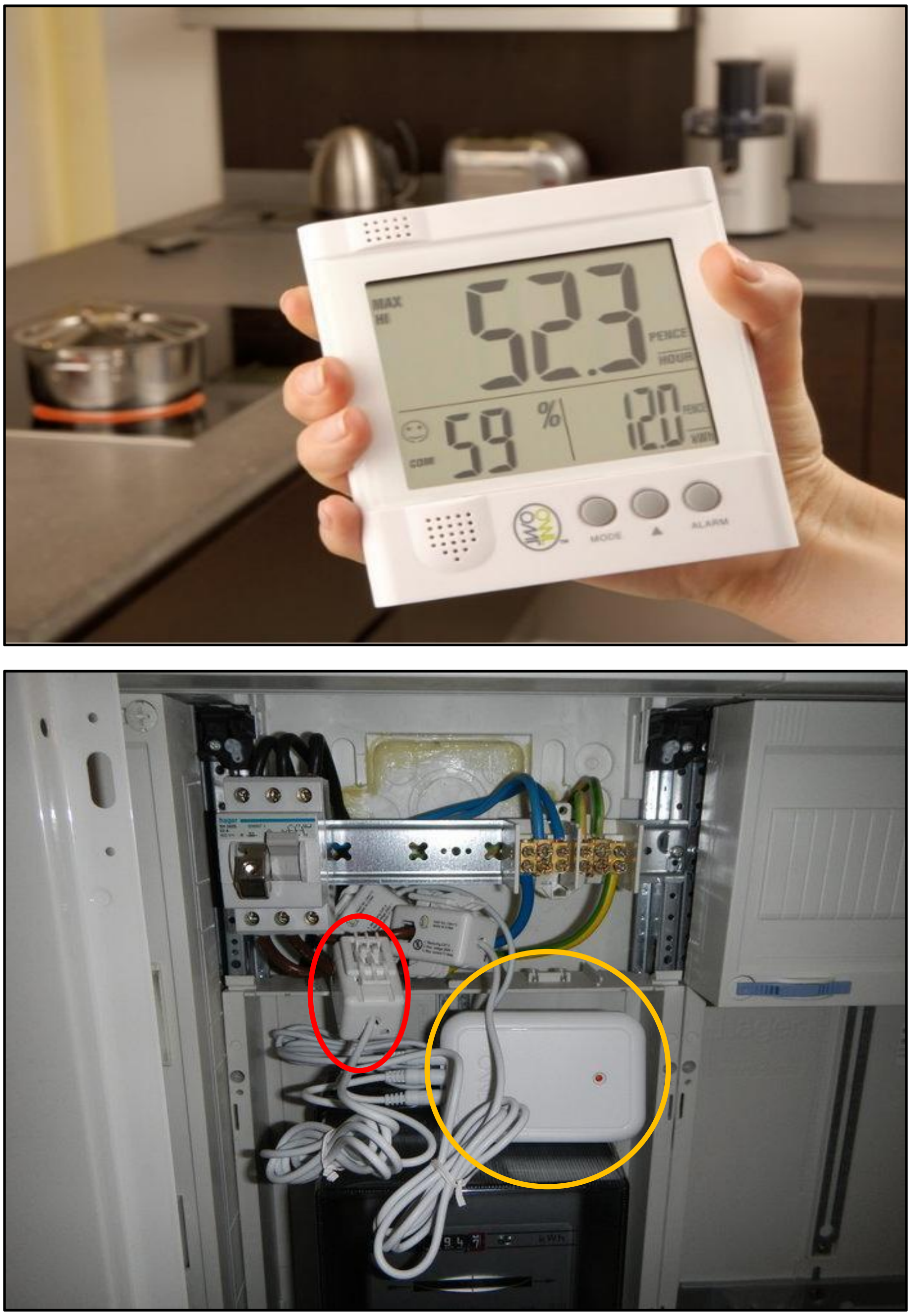


Figure 4.2. SEDM1: The OWL USB CM 160 display (top picture), CT clamp and wireless transmitter (button picture)

These appliances were electric showers, heaters and tumble driers, and that can be identified by means of their specific ‘signature’. The simultaneous use of appliances (such as microwave and TV) means that energy usage cannot be attributed to an appliance. An example of a chartered signature recorded by SEDM 1 is shown in Figure 4.3.

A total of 10 OWL USB CM 160 commercially designed products were handed over to students to provide both live and historical energy data and usage patterns. Data recorded on the OWLs' memory card was download to the researcher's PC and the smart metering data was used during the focus group and interview sessions.

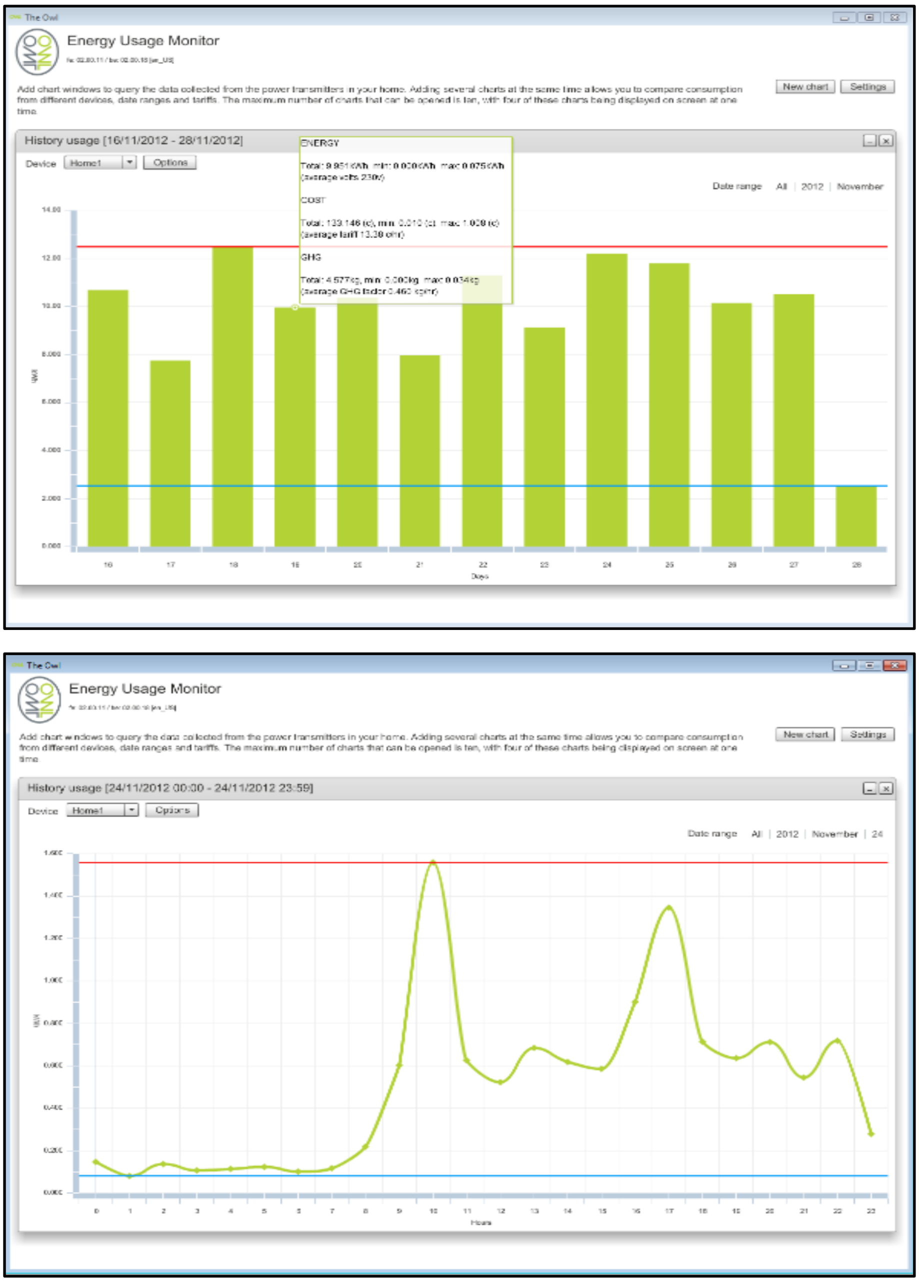


Figure 4.3. The OWL USB CM 160 software screenshots of energy usage: daily (top picture) and hourly (button picture)

4.6.2. SEDM 2: ENERGENIE Energy Saving Power Meter

The ENERGENIE plug-in power meter (SEDM 2, Figure 4.4.) is a commercial smart electricity monitor that allows appliance specific monitoring. Before starting my fieldwork, we planned to use the ENERGENIE Power Meter during the Energy Saving Competition in nudging students to meter and to reduce electricity consumption in their hall of residence. We assumed that these meters would make electricity consumption visible, discussable and the appliance specific data would engage students to save energy.

Figure 4.4. ENERGENIE power meter displaying Power (W), Energy (kWh), Volts, Amps, Hertz, Power Factor, Date and Time

Before starting my fieldwork we trialled these meters in my office and in my own home measuring the energy consumption of appliances that were on all the time, such as fridge or desktop computer. My first impression of the meters was that they are visible and easy to use, but they have design limitations. For example, the meter is too big and its display is not visible when plugged into low mounted sockets (or under the desk), so you would need to plug into an extension lead to read the display. The biggest limitation of the meter we found was that the power meter required re-setting every time when we wanted to meter different appliances. This loses the accumulative power, cost and time and loses the electricity tariff values that need to be entered again. It is worth mentioning that the power meter has a battery backup (so if the unit is unplugged it won't lose the data), that has a battery saving feature, meaning that after unplugging the unit will display the data for about 30 seconds before powering down, but by pressing any button the meter can be turned on again.

The ENERGENIE Energy Saving Power Meter displays the voltage, current, power and greenhouse gas emissions in real-time. The meter also records the accumulated consumption in kilowatt-hour (kWh) and allows the user to meter the running of different appliances at different times of the day. Thus, the accumulated cost of running a fridge can be metered even when the charging tariff varies with the time of the day. In recording consumption at different times of the day with different tariffs of consumption a written note of the connection date and time needs to be taken as the meter's 24-hour clock starts at zero again after 24 hours. The ENERGENIE Energy Saving Power Meter is good for measuring small loads and it gives a good indication of the energy consumption of different appliances, but it cannot measure devices that don't have plugs such as electric showers or lights.

Seventeen ENERGENIE Energy Saving Power Meters were donated by ENERGENIE Ltd. and given to students to meter the electricity consumption of different appliances at different times of the day.

4.6.3. SEDM 3: EDF ENERGY ECO-MANAGER

The EDF Energy home management gadget the ECO-MANAGER (SEDM 3) is different from SEDM 1 and SEDM 2 as it was primarily designed for monitoring and controlling individual and groups of appliances. The ECO-MANAGER works with individual plug-in socket monitors (Individual Appliance Monitor or Transmitter Plug – IAM, Figure 4.5.) that allows wireless monitoring and controlling specific appliances from wherever the device is plugged in.

Figure 4.5. Two EDF Transmitter Plugs (IAMs) installed in kitchen

The EDF monitor (Figure 4.6.) does not offer whole energy consumption data, but it can be converted to a standard energy monitor by using the EDF whole house transmitter. In metering individual appliance electricity consumption, the IAM communicates with the unit display sending information approximate every six seconds - so changes in energy use are displayed more instantly as with the SEDM 1 (or the OWL USB CM 160). The IAM does not provide real-time metering data on individual appliance's energy consumption (as the SEDM 2 does).

When the monitored appliance or appliances are switched on, its corresponding button on the screen displays in red. The monitor shows which appliances are on and which appliances are off. Furthermore, the monitor displays the relative running costs and greenhouse gas emissions for each appliance in real-time.

Figure 4.6. EDF ENERGY ECO-MANAGER display that allows wireless control over individual or group of appliances.

Data (time, unit running cost and historical data) is stored in the controller unit memory and it requires an expensive technological add-on to be transferred to a computer (Kelly 2016). The decision to include Eco-Manager in my research was made after testing the device in my home and experiencing the convenience of remotely controlling individual and groups of appliances. For example, I connected one IAM to the house modem and before going to sleep in my bedroom using the ECO-MANAGER display, I remotely switched off the modem. I also saved money by switching off my microwave from the IAM, without using the display. Disappointingly, the ECO-MANAGER did not offer any historical data on the energy consumption of my modem or microwave. Furthermore, in trialling the device, the display was automatically flipping between energy usage and greenhouse gas emissions, which was inconvenient when viewing the data. The ECO-MANAGER is a convenient home energy management tool used for measuring and controlling individual or groups of appliances, it gives an indication of the energy consumption of different appliances, but is less accurate in metering whole house energy consumption.

A total of seven ECO-MANAGER devices with 3 IAMs' was left in 7 students' households (with 17 students who had already participated in the first focus group) with the purpose of metering and controlling the electricity consumption of different appliances at different times of the day. These students were selected at random. In order to avoid biasing the research, no training from the researcher was given to the students at this time. The students could interact with the devices and use the instruction manuals independently.

	SEDM 1	**SEDM 2**	**SEDM 3**
Is new hardware required?	No	No	Yes
Can technology communicate?	Monitor	Monitor	Network
Can devices be remotely controlled?	No	No	Yes
What type of display does the system have?	In Home Display	In Home Display	In Home Display and IAMs
Where the data comes from?	Sensor Display	Appliance Monitor	Networked Senor
What kind of data is provided?	Real-time, appliance specific house hold consumption data and historical data.	Real-time, appliance specific consumption data.	Real-time, appliance specific and all house hold consumption data.

Table 4.1. SEDMs comparison (based on Karlin et al. 2013, page 89)

4.7. Students households recruiting issues and concerns

The recruiting of students households raised a number of methodological concerns. The first was that the environmental focus of the research would attract participants with strong values associated with sustainability. Smart metering demand management policies are not dependent on a sustainability focus, rather have a resource management one (Strengers 2013). The sample may have been environmentally biased, although this was not evident during research activities with the households. However, SEDMs played an important role in highlighting within and between students' houses non-environmental associations with comfort and cleanliness practices. Thus the SEDMs revealed that comfort and cleanliness do have environmental impact and their resource implications are taken for granted in everyday life.

A second concern was the absence of financial compensation provided to students' households for joining this research. We could hypothesise that this biased the research by recruiting non-financially motivated students households, whose energy bill is included in the rent and who were less interested in the cost of the electricity in their everyday practices. However, this research found that students' household comfort and cleanliness practices-that-consume-energy are not primarily motivated by financial loss or gains. On the contrary, students in households where the bill is included in the rent talked about financial aspects a great deal. During our meetings we discussed these financial considerations in the context of comfort and cleanliness practices but many of these practices were taken for granted or considered non-negotiable (Strengers 2013). Economic savings were discussed in relation to ownership (Foulds et al. 2016), wasteful practices and switching off or powering down practices.

A third concern relates specifically to the Sustainable Student Bungalow, whose electricity consumption due to infrastructural problems, such as electric car charging point, was difficult to monitor. The inaccuracy of the SEDM 1 could influence householder's ability to modify their comfort and cleanliness practices. However Sustainable Student Bungalow students, as a condition of their tenancy, must report details of their sustainable way of living in a written document that can be accessed online. A year before starting my fieldwork students in the Bungalow had received a meter as part of the RECCKN research project (Catney et al. 2013) and had monitored and recorded their electricity consumption with the Eco-Eye Smart meter. When recruiting the newly moved in students they were happy to participate in this new project and have these meters inside their home to meter, record and to reduce their carbon footprint. The inaccuracy of the SEDM 1 was also offset by SEDM 2 and SEDM 3 that provided accurate metering data on their electricity consumption.

Finally, studies have shown that that the consumption reduction resulting from data can disappear after the 'novelty effect' wears off (Strengers 2013). Nonetheless, this issue was offset by the inclusion of newly established students' households with different numbers of tenants, geographical location and tenancy contract, demographics whose electricity consumption was investigated before and after receiving three different SEDMs. This suggests that aggregated SEDMs data is largely ineffective in reconfiguring comfort and cleanliness practices, but disaggregated data reduces electricity consumption.

4.8. Identifying and selecting students' households

Recruiting took place during the Welcome Festival, Society Sign Up, Fresher's Fair and during other student 'gatherings' where students could test the SEDMs. To increase participation, I shared my experience with SEDMs in Concourse (Keele student newspaper, Appendix 9) and I set up a stall inside the Keele Student Union where students could sign up for the research (Figure 4.7.).

During the recruiting process mainly first year students who moved away from their parents (Subsection 1.2.5) were targeted. While first years students visited my Students Union stand and left their contact numbers none of them joined this research. One of the reason was that they could not convince the other household members to sign up for this research. Therefore, we asked those students who were willing to join my research to invite us for a household meeting, to meet with the other tenants. During these meetings students had the opportunity to use the SEDMs, to use my video camera and to ask me questions about the research itself. While housemates joined these meetings, it was not possible to pursue them to sign up for my research. Factors that discouraged participation were: (a) the length of the study; (b) finding time for the focus and interview sessions; (c) the use of the camera inside the home; (d) if the video recordings will be presented to a larger audience and (e) the research takes up too much study time.

Another way of recruiting first year students was through different student society meetings (such as Think:Green Society, Keele Craft Society, Keele Sikh Society, etc.). For example after meeting personally with the Think:Green Society president, we agreed that during their first social we will have the opportunity to present my research and they will encourage society members to join my research. This way I met with Emily from House 4 and Marcus from House 7 who encouraged by the Think:Green Society president signed up their houses for the study.

Households' '*active occupancy profiles'* (Richardson 2008) was another selection criteria. In modelling domestic household electricity consumption, Richardson (2008) remarks that the use of electrical appliances '*varies considerably with respect to time'* and depends on the number of people who live at a property but also whether they '*are at home and active*'. Unsurprisingly, Richardson (2008) identifies that the 'active occupancy' is a key driver in appliance use in the home. Broadly, we might say that active occupancy 'correlates' with domestic electricity demand (Richardson 2008) and is of interest in investigating electricity-use practices. Thus, it was important to know and record whether students were working from home, cooking at home and laundering at home.

Figure 4.7. Recruitment stall (top picture) where students could try the SEDMs and subscribe for the research. Meeting and recruiting 'freshers' on Campus during the Welcome Festival (button picture).

It was challenging to recruit students for the study, mainly because students were hesitant about the amount of time they needed to spend on doing this research. In total, 10 students' households with 28 students were selected for this longitudinal (10 months) research. The distribution of the students' households is shown on Figure 4.8.

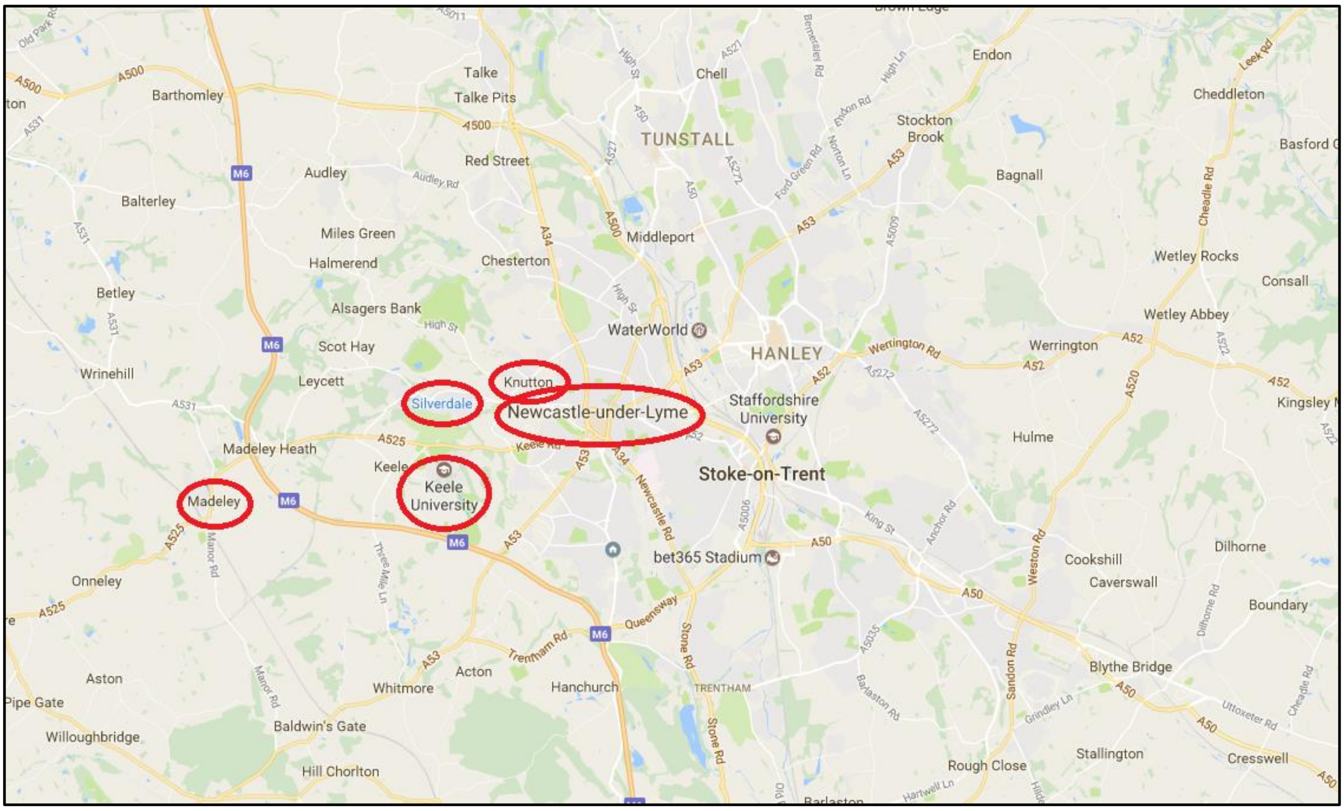


Figure 4.8. Map illustrating the location of the student households

A broad range of household types were self-selected for this study, including single-person households of varying ages, students in their first year of studies, finalists, students returning from abroad, part-time working students and students who were interrupting their studies while attending a work placement. Students were from a broad range of educational background, and four households had at least one student studying a sustainability-focussed subject at Keele University (Table 4.2., page 80). While landlords were informed about the study, they were unavailable for the interview session or home visits.

Incentives in form of a pack of 6 local oatcakes (after each home visit) and a £15 iTunes voucher (at the end of the study) was offered to participants who completed all stages of the research. While the incentives role was to encourage students to participate in group discussions and to reduce the drop-out rate, many individuals who took part in this research were more interested to learn about smart meters than receiving gifts.

House 8 and House 9 before the first focus group session would withdraw from the study. The main reason was the impossibility to find time for the focus group and interview sessions. This was due family (House 9) or work commitments. On the other hand, they allowed me to use the collected data (such as electricity metering data and guided video tours) in my research. Appendix 8 offers a brief description of the houses who finished the research.

Throughout the thesis, we anonymously refer to these households by their house id (see Table 4.1.) and student id (see Table 4.1.). We will distinguish between students within households when a particular attribute is relevant to the discussion. We undertook semi-structured interviewing, focus group sessions, guided video tours, participant observation, photography and energy metering with all households and we collected 10 video diaries on the role of metering energy consumption in everyday life. We discuss each of these methods below, focusing particularly on the way we analysed the role of the real-time energy metering data in students' everyday life. We outline the use of the video diaries and we conclude the section by discussing the limitations and strengths associated with these methods.

House ID	Student ID	Age	Gender	Year of study	Education
House 1	Steve	35+	Male	4th year	Pharmacy
House 2	Arthur	24	Male	4th year	Pharmacy
House 3	Jake	24	Male	3rd year	Music
House 4	Emily	31	Female	4th year	Environmental Sustainability and Green technology
	Steven	22	Male	3rd year	Law
	Giulia	32	Female	PhD	PhD Social Science
House 5	Melanie	23	Female	3rd year	Environment and Sustainability
	Paula	23	Female	3rd year	History and Politics
	Julie	23	Female	3rd year	Physiotherapy
House 6	Alison	22	Female	2rd year	History and Politics
	Sandra	21	Female	2rd year	Social Work
	Rosie	24	Female	2rd year	Business and Management
	Paul	20+	Male	3rd year	Environment and Sustainability
House 7	Marcus	22	Male	2nd year	Politics
	Ayesha	21	Female	3rd year	Environment and Sustainability
	Kerry	21	Female	3rd year	Applied Environmental Science and International Relations
	Chadni	21	Female	3rd year	Environment and Sustainability
House 8	Catia	23	Female	2nd year	Biomedics
	Kendeel	25	Male	2nd year	Pharmacy
	Omar	21	Male	2nd year	International Relations
	Bolu	23	Male	2nd year	Human Biology
House 9	Samara	22	Female	2nd year	Medical Chemistry and Biomedics
	Yasmin	23	Female	2nd year	Pharmacy
	Nadiya	17	Female	-	Newcastle under Lyme college student
	Shammi	20	Female	2nd year	Economics and Mathematics
	Aisya	35+	Female		-
	Aahmed	35+	Male		-
House 10	Abu	25	Male	2nd year	International Relations

Table 4.2. Demographic profiles of the participants in the study

4.9. Overview of the methods used

To investigate, explore and develop how the use of SEDMs can be implemented within smart metering demand strategies towards the reduction of domestic energy consumption; a case study research approach is presented. The initial focus of the case study approach was to understand through building monitoring data, semi-structured interviews, focus groups, video recorded guided tours and video diaries how students define and control comfort and cleanliness practices-that-consume-energy. In-depth case study approaches affords the ability to explore in substantial depth the contemporary case in qualitative terms within its natural setting (Yin 2014).

A longitudinal case study approach was selected for this doctoral study to explore in depth the practices-that-consume-electricity before and after receiving SEDMs. The biggest limitation of using case studies are with lack of rigour and issues relating to generalisation (Yin 2009, page 40). The lack of rigour in case study research is associated with lack of thoroughness in the data collection and analysis techniques that can be addressed through good designed research methods. Generalisation, is not automatic Yin (2009, page 15) argues that case studies are '*generalizable to theoretical propositions and not to populations'*. Stake (2013) also argued that with case studies researchers make '*naturalistic generalizations*' develop by recognizing similarities of objects and issues within a context. In terms of this research, the specific issue of interest is the integration of smart metering and monitoring data into practices-that-consume-electricity before and after receiving SEDMs within students' households. With regard to case study design, it may be termed as a single longitudinal case study design, studying the 'same single case at two or more different points in time' (Yin 2009, page 49).

Furthermore, there has been a lack of research concerning everyday practices-that-consume-energy in student households and how to study them. We therefore employed a range of methods with all participating student households. Drawing on multiple methods of source of data in the study of a social phenomenon is referred to as 'triangulation' (Brymann 2012, page 392). Triangulation is commonly used to cross-check findings within or between qualitative and quantitative methods (Brymann 2012, page 392). We used triangulation '*as a strategy that adds rigor, breadth, complexity, richness, and* *depth*' (Denzin et al. 2012, page 82) to my inquiry and to identify methods that are useful in understanding everyday practices in student households that consume energy.

4.9.1. Use of software for data management and analysis

While there is a debate between authors (Weitzman 2000) on effectiveness of using qualitative data analysis software in qualitative research, the existence of the semi-automation tools such as word frequency counts, text searches, auto coding or graphic mapping provide tools for the labour-intensive activity of data analysis. The approach taken in this thesis was that the qualitative software may support the data analyses process but the ideas, reflections must come from the researcher while conducting the data analysis (Weitzman 2000, page 807). It is further argued by Weitzman (2000, page 807) that although the positive attributes of utilising qualitative software to reduce the amount of time spent on organising data and findings it may also produce false hopes and fears, such as oversimplification and encouraging the researcher to take shortcuts within data analyses (Weitzman 2000, page 808).

For this study a word processor (such as Microsoft Word), a data analyses and visualisation tool (such as Microsoft Excel) and the qualitative analysis software (such as NVivo) were used to support the analysis and to help manage the qualitative (focus group and interview transcripts) and quantitative (spreadsheets and energy diagrams) data. In this thesis NVivo 11.0 qualitative software was used for organising, re-arranging, managing and analysing the 24GB amount of field data. Interview and focus group transcripts, photos, video recordings and energy diagrams of the case were imported into the software. A preliminary set of codes was established prior the analysis, based on the thesis aim and research questions, and they key factors that were drawn from the reviewed literature (Strengers 2013, Gram-Hansen 2010, Southerton 2006). Memos were written throughout coding to keep track of thoughts and ideas regarding the data analysis. These informed the first versions of the NVivo 11.0 project. This list of codes was revised continuously as the transcripts were coded. The codes were modified and verified by being applied to transcripts, energy diagrams and video recordings but stayed alike for the most part. Subsequently, the codes were incorporated into the NVivo software to allow searching the transcripts, re-sorting of materials and continuously redefining of codes in order to support the analysis process.

NVivo 11.0 proved to be invaluable tool both to store the data in nodes and to visualize emerging patterns. Based on the analysis by NVivo 11.0, this thesis can connect the analysis results with relevant smart metering policies concerning everyday practices-that-consume energy to do further data analysis and discussion. For example, if the NVivo 11.0 analyses would show temporal organization towards practices-that-consume-energy then this thesis will use smart demand side polices for further analysis this issue. In this way, all relevant literature and analysis will be attributed to, and reflected, the original data itself.

4.9.2. Interrogating the mundane

Fontana et al. (2005, page 699) argue that interviewing '*has become a routine and nearly unnoticed part of everyday life*' and '*it seems that everyone - not just social researchers - rely on the interview as a source of information. Thus, the routine nature of interviewing allowed me and my participants to focus on the 'personal, sensitive, upsetting or accusatory*' aspects of practices-that-consume-electricity without significant discomfort.

Surveys could also be viewed as forms of 'gathering data', but they were not considered appropriate for asking the depth of the responses sought. One of the limitations of surveying practices could be 'short answers' (or less detailed) about personal, sensitive practices or misunderstanding survey question about practices. Thus, even during the interviews, students often required 'further information' in responding the questions. However, giving thorough descriptions may skew the research, students' rather than reflecting on their own practices, they may have 'picked up' my suggestions. Therefore, prompts and probes were often used in understanding students' everyday practices.

To uncover the taken for granted practices of comfort and cleanliness, we employed the methodological strategy of viewing students' practices as problematic, which is a way of interrogating people about an issue which is normally taken for granted. Bell et al. (2005) introduce the notion of 'defamiliarization' to information technology as a strategy to look at things from a novel perspective by removing them from everyday and familiar context and understandings. For example, using this technique of defamiliarizing led me to be observant towards the atmospheres (Pink et al. 2006) created by students inside their houses. The colourful, warm and smelly rooms were not just because of the décor but also because of the students who were using the house.

Semi-structured interviews and focus group sessions will display only a limited insight into the structure or performative aspects of practice itself (Martens 2012). As Martens (2012) argues, talk about practices tends to elicit the meaning of a practice to an individual, without necessarily revealing more about the practice itself. Therefore, Martens et al (2012) suggests different form of participatory observation (such as CCTV technology) that would record in detail the physical aspects of the context, the technology and objects as well the rules of the practices as enacted by the participants of the practice.

4.9.3. Semi-structured focus group sessions

A focus group is an open ended, dynamic interviewing process that involves a group of participants and a moderator in discussing a specific list of topics: the focus. The advantage of the focus group sessions over individual, face-to-face interviewing is the group's interaction. Thus, during the session interactions take place between the participants that may open up insights that might not otherwise come out of a conventional interview (Bryman 2008, page 502). The main disadvantage over the semi-structured interview format is primarily one of control. Thus during the session once debates take shape, some participants may dominate the group discussion in a way that hinders other participants experiences and perspectives to be shared (Halkier 2012, page 13). Therefore, the role of the moderator is to ensure a constructive environment for discussion and ensure that participants feeling comfortable enough to talk openly, so that no one individual assumes control over conversation (Bryman 2012). Furthermore, the moderator needs to account the potential group effects that may arise from social interactions (Halkier 2012). Thus, as suggested by Halkier (2012) focus group sessions have the tendency for polarisation that may limit participants willingness to share and interact.

In the context of this research, the focus was around exploring everyday routines and personal and social uses of electricity, with a specific focus on concrete, identifiable and conspicuous ways of engaging with electricity consumption. Focus group sessions were used for exploratory purposes, in uncovering opinions, experiences or motivations in using electricity and metering data in everyday routines rather than validating or quantifying domestic electric technologies design characteristics (Mitchell et al. 2015). Therefore, as an evaluation technique, the focus group session explored students thoughts and opinions about what electricity is for, how they realize the electricity, how they quantify electricity and what they actually want electricity to be.

During 10 months, we conducted 8 focus group sessions with all selected household participants, in order to obtain a holistic picture of comfort and cleanliness practices and the role of the electricity data in reconfiguring these practices. Methodologically my aim with the focus group sessions was to depart from the individually-centred analysis of social practices and to investigate whether electricity consumption is composed in part through the dynamics of a student household. The focus group sessions helped me to identify the tensions and differences in householders' everyday practices-that-consume-electricity.

4.9.4. Semi-structured interview sessions

Interviews were semi-structured in format and a series of themes and questions were explored (see Appendix 1 and Appendix 2). During the interviews I used open-ended questions and the questioning line was often directed by the students' reactions or observations which focused specifically on 7 comfort and cleanliness practices: - heating, lighting, showering, ironing, laundering, cooking and hoovering. Students were also asked about their life experiences with electricity consumption technologies and infrastructures. We were interested in students' historical experiences with practices-that-consume-energy to understand where these practices emerged from, and how past experiences shape (or had shaped) their everyday practices-that consume-energy.

We started the interview session with the least personal questions, reserving the more 'sensitive' practices (such as showering) towards the end of the interview. During the interview my objectives were to identify where current practices had emerged from, why and how often are undertaken, how they are being carried out, what data that is guiding these practices, and how they were changing, if at all. Before the interview session we visited each student household, we downloaded the SEDM 1 monitoring data and together with the students, we set-up a convenient interview time. During this meeting, we told students that we need to interview everybody from the household and we will ask questions about their practices-that-consume-energy. Interviews were generally conducted in the evenings, when students were home together. Following Pink's example, the interviews took place inside householders' residences that added a special kind of engagement and understanding: *'by sitting with another person in their living room, in their chair, drinking their coffee from one of their mugs, one begins in some small way to occupy the world in a way that is similar to them'* (Pink et al. 2015, page 86). The interviews took 35-60 minutes, with an average time of just over 50 minutes. All interviews were transcribed and imported into NVIVO software for coding.

4.9.5. Electricity metering and monitoring data for investigating mundane practices

Aggregated monitoring data provide little understanding into everyday lifestyle (Fisher 2008). For example, a stated (such as 10%) reduction in energy consumption does not reveal the change to the performance of everyday practices-that-consume-electricity (should we think about 10% shorter showers or 10% less by switching off standby devices when showering). On the other hand, disaggregated monitoring data can help in understanding how technologies interact with elements of practice (Foulds et al. 2013). For example, Bates et al. (2012) disaggregated the total energy use in 4 student flats, to determine the role of specific domestic services (such as lighting). While, it is an insightful study, the investigation's primary focus is using qualitative inquiry in explaining variations in energy usage, rather than explaining how technologies relate to elements of practice in shaping everyday life (Foulds et al. 2013). The collected smart metering data was used use in understanding practices-that-consume-energy in students' households.

Aggregated monitoring data (such as all household metering data) was available from SEDM 1 and it was downloaded after the monthly home visits. However, even after getting to know the students' households from the data, some trends in the monitoring data could not be explained without students' assistance and specific discussion about the time periods of consumption (Southerton 2006). Therefore, on the morning of the first round of interviewing, we visited all the students' households and we downloaded the building monitoring data from the SEDM 1. Later we represented in a A3 graph the hourly electricity consumption (kWh/min) from the previous day, and students were asked to remember their electricity consumption following the peaks and troughs of the graph. Co-investigating the monitoring data helped me to disaggregate the big data and to bring the mundane of everyday dynamics into the dialogue.

Much of the success of this approach was due the possibility of using the historical data to investigate how electricity is consumed when not at home or to compare electricity consumption during different periods of the day.

4.9.6. Interactive floor plan

The interactive floor plan followed the discussion of the SEDMs metering data (Chapter 4.9.5) and was designed to explore the way students used their house. Floorplans have been utilized previously when studying technology in the home (Pink 2012, Mateas et al. 1996). For example, as part of an interdisciplinary energy project, Pink et al. (2012) asked participants to recollect their daily routines on a pre-prepared house plan. The specific aim of the floor plans was to investigate how ‘house electricity’ is used on a typical week and a weekend day.

An A3 floor plan was produced individually for each house based on the video recorded guided tours, photographs taken during the first home visits when the feasibility of the SEDMs had been established and installed. Each student received a coloured pencil and was asked to plot on the floor plan their daily routines and movements through the house, for a weekday and a weekend day. One by one, students were asked to mark on the sketch their individual movements and activities in relation to time of the day. Throughout this activity students reflected on what they do on an everyday basis and why they do the things they do. Visualizing and reflecting on the movements and routines allowed me to situate students’ activities regarding to the home as both a social and spatial-temporal environment (Pink et al. 2012). If the ‘spikes and troughs’ of the aggregated data revealed insight into how everyday practices are performed, the coloured trails and narratives of the house plan helped in disaggregating the data into ‘peak times of the day’.

While with the interactive floor plan, we gained insight into personal and social use of domestic technologies these should not be accounted as an accurate reflection of a typical day in students’ life.

Nevertheless, the floor plan helped me to further disaggregate the building monitoring data in relation to students' activities on week and weekend days.

4.9.7. Photography

During home visits photographs were taken of the material infrastructures used (such as domestic technologies or student personal digital technologies) to undertake comfort and cleanliness practices. The photographs were used to visually record my observations and to support the descriptions and explanations provided by students during the investigation. Photographs with technologies (such as lamps, laptops, laptop chargers, washing machines, cookers, etc.) were printed and used in identifying appliances when discussing the 'spikes and troughs' of everyday electricity consumption.

4.9.8. The 'sensory home' route to disaggregating monitoring data

A guided home video tour is an observational method that involves one or more participants guiding the researcher through their home (Wilson et al. 2013). In exploring the sensory aspects of experiencing the home we used the notion of the '*sensory home*' (Pink 2004) as a methodological entry point. Rather than audio recording or photographing the way students consume electricity, we video recorded their multi-sensory experiences in making the home '*feel right*' (Pink et al. 2015). This included the way they are decorating their room, the way they are heating or airing the house. According to Pink (2015) sensory ethnography is an ethnographic practice that is focusing on the sensoriality of human experience by keeping a '*double focus*': on the ways in which research participants explain, and categorise their multisensory everyday experiences; and on the way in which the ethnographer itself experiences and learns about other people's lives through her own sensorium (Pink et al. 2015).

Thus, by moving around with my camera, joining in and video recording performances and re-enactments of everyday practices that take place inside students' homes was a '*form of sensory apprenticeship*' as we was learning '*how to sense one's environment in a culturally specific way'* (Pink et al. 2015, page 70). For example, while filming Paula's re-enactment of laundering practice, we crouch down, as she does when loading the washing machine. By taken a similar body position we was able to imagine and to feel the pressure from crouching in my hips that is captured through the lens of my camera.

Following this perspective, we suggest that the video materials that resulted from my research provide a route to disaggregate electricity consumption in two main ways. Firstly, they reveal the multisensory aspects of students' experience of the home (Pink et al. 2015). For example, while video recording Paul cooking practices we could hear the music coming out from Sandra's room and one could see the condensation of the kitchen on the lens of the camera (fog on the lens) produced by the heating of the house. These multisensory aspects are framing students' everyday electricity consumption and the camera made it possible to understand the sensory aspect of the aggregated data embedded in students' lifestyle. Secondly, by filming the way students are setting their radiator, or loading the washing machines helped me to investigate specific domestic technology energy consumption data. For example, having monitored Steve's laundering practices with SEDM 1, later we would video record the way he launders. Thus, spikes and trough of the washing machine is not just about choosing washing machine cycles is about the cleanliness, the 'whiteness' and 'freshness' of whatever has come out of the machine. Furthermore, laundering is socially shared practice across and between students' households. For example, if Melanie is laundering after Paula she would adapt Paula's washing machine setting.

The route to disaggregating monitoring data through the use of the video camera is reflexive in two important ways: (1) the video shows the multisensory aspects of the aggregated energy data within the home and (2) it captures the way the different activities make up the disaggregated data.

4.9.9. Video Diaries on practices-that-consume energy

The next method was participant-led and asked students to self-video record their reflection on the role of the energy metering data in their everyday lifestyle. We wanted to provide students' opportunity to video record what they consider important in metering electricity. The participant-generated video accounts (Holliday 2000) were inspired by a hand written diary approach used in analysing household water consumption practices in Sydney (Sofoulis et al. 2005). Much of the difficulty we had was in developing a process to undertake this method. We were concerned that students will not share their experiences on electricity metering data. To overcome this problem we began researching different diary processes from handwritten (Sofoulis et al. 2005) to the video recorded (Holliday 2004) one. We decided to go with a longer timeframe and to allow for more engagement with the participant. Rapport and trust with the students during this stage played a crucial part in terms of the information that each student was willing to give me or trust me with.

All seven students' households took part in this task making video clips and the recording time for each student house varying between 3 to 20 minutes. Students recorded the video clips using digital technologies that were part of their everyday routines. Some of the video recordings were collected during the home visits, others were shared with me over the internet. After receiving the video recordings, we began analysing footages.

The video-diaries are different in both content and aesthetics (the way they were recorded) across and between students' households and we found hard to think about analysing them as a set of aggregated material. For example, in one case the video recording reveals the nature of the interactions between students in a more intimate way than what can be learned through interviews or through the guided video tours. Furthermore, the recordings show the multisensory and emotional dimensions of metering electricity in different context.

4.10. Ethical Considerations

The aim of this section is to provide a summary of the ethical procedures executed within this research study. To provide ethical integrity to the research, several documents were administered by the researcher before recruiting households. These documents include an Ethical Clearance Checklist as provided by the Ethical Advisory Committee at Keele University to determine the overarching ethics of the project; as well as an Ethical Protocol in relation to the security of research participant's personal information and data storage. Requirements included within this protocol are; the provision of information sheets and the requirement of signed consent by all participants, the guarantee of participants confidentiality and anonymity, as well as matters relating to the safe storage of data and the limiting of data access. At the end of the study participants were debriefed and they had the opportunity to view the video recordings and photos made during the research.

While some students joined this research to experience the use of SEDMs others planned to look into the data generated by the SEDMs. For example in House 6 the data generated by the SEDMs was planned to be used in understanding and calculating monthly energy bills:'*Even when we moved into here, the first bill we paid wasn't even our bill. But then like, it was because we never had an account, but because it came to our house we thought it was our bill. But then, when we got the second bill, when we phoned up npower, they were saying like we shouldn't have paid that money because it wasn't ours. And so... It's just always been complicated, never been straightforward for us to actually analyse. Is this bill too much, or is it okay?*' For Emily (House 4) this study was more about learning how to manage electricity consumption: '*I think after having the meeting, it's kind of educated us. You know, when you was going through the charts and asking us what we're doing at each time of the day. It just kind of made you, like, think more. I just thought, if you can cut down on something, why not? I just stopped using it.*'

The SEDMs could give rise to potential tensions between household members. Thus the SEDMs identified the use of electric heaters inside students' rooms making aware householders that some of the tenants were consuming higher energy than the others. While this data did not discouraged the use of electric heater fans it made electricity consumption discussable such as: '*Before you started talking to us about electricity consumption, which obviously will bring to life how much we are using… I think I would say, apart from your heater which I didn't know about, I think we are quite low energy consumption. Even with that potentially… Compared to most people, because when I got to people's houses I notice that there are a lot of appliances all working at the same time and people have TVs and things and obviously we don't…' (Emily, House 4)*

4.11. Conclusion

The methods employed with the students' brought forward a number of methodological concerns. Firstly, during the research, students have assumed that the researcher was an energy expert. They often asked questions about my (the researcher's) own energy, as well as my opinions on issues such as climate change and sustainability. We always tried to avoid (or ignore) these questions to minimise my influence on students' responses. Secondly, some students' who viewed me as an energy expert requested an informal energy audit of their home. For example, we were questioned about whether installing solar panels is a better or worse for heating the house. In these cases, usually, we told students to ask their landlord for more detailed information. Thirdly, some students continually desired to discuss about efficiency and retrofitting measures rather than their practices-that-consume-energy. However, (some) students would focus on conserving energy as an important finding, underlying the impact of normalised practices such as laundering and heating.

My biggest concern was self-reporting action bias. Donaldson et al. (2002) analysing the self-reporting bias have found a considerable variation in results because employees often report what they believe the interviewer wish to hear or what they think is socially desirable answer. In this case the focus group sessions eliminated some degree of this bias. However, when discussing the building monitoring data, in some cases, students could not remember what they did or when they did it and they may have produced a false answers. This is a problem when interviewing people about mundane, invisible, inconsequential practices (Lutzenhiser 1992) therefore the research findings should be treated with caution. Furthermore, if the co-investigation of the building monitoring data may reveal some energy consumption trends, it cannot be used to confirm or dismiss students' description of how and why they undertake practices. Video recordings may indicate how students undertake everyday practices but it may raise concerns regarding the Hawthorn Effect. Therefore, during this research we applied mixed-methodology approach to reduce this bias as possible, in analysing the dynamics and reconfiguration of social practices.

PART III.

Results, analysis and discussion

Chapter 5: Looking at Sensory and Invisible Elements of Energy Consumption

As we argued in Chapter 3.7., in order to better understand the potentials and challenges in the ways in which the electricity industry relates to its consumers (Strengers 2013) recent studies have argued for new ways of thinking about energy consumption as happening for the sake of accomplishing social practices (Warde 2005, Shove et al. 2012). Furthermore, in Chapter 3.9., we argued that the type of intervention in practice needed to replace unsustainable practices with more sustainable practices (Spurling et al. 2013) could be gained by a detailed analysis of the 'ideal type' practice-as-entity, which involves a commonly-held idea of the normal, typical or ordinary way to carry out a practice (Spurling et al. 2014). It is assumed that such an analysis will consider questions of why, when and how resources such as energy are consumed and this result a more thorough understanding of how practices-that-consume-energy can deliver more sustainable outcomes (Spurling et al. 2013).

An entry point for this thesis is the notion of disruption (such moving house, blackouts) that have suggested to bring practice dynamics 'to the front' and therefore offer a research arena where the dynamics of practice are open for inspection for the practitioner and for the researcher (Southerton et al. 2004, Rinkinen et al. 2013). For example disruption could influence people: to invent new ways of performing practices-that-consume-energy (such as cooking without oven); to re-negotiate the needs and outcomes associated with practices-that-consume energy (such as microwaving food instead of preparing a healthy meal) or to abandon the practices-that-consume-energy (such as dining at a restaurant instead home). However, as the energy metering data suggests that at the end of these periods of restriction practices that often 'bounce back' to their previous forms.

During the Green Week (February 11-17, 2013) together with Keele Estate we organized an energy saving competition between Barnes Halls Residences (N=23 blocks) to investigate, among other things, students intention to participate in energy conservation activities. While during the competition students did not received any information about their energy consumption, the competition was incentivised with a free entrance for the winning block to a Student Union event. Keele Estates preliminary findings suggested that during the energy saving competition (February 11-17, 2013) all Halls of residences (not only Barnes Halls, N=23 blocks) reduced their energy consumption was reduced but it went back to 'normal' as the competition ended. A more detailed analysis of the data, revealed different consumption patterns across residential halls, suggesting different energy cultures (Stephenson et al. 2010) between halls of residencies (Figure 5.1.).

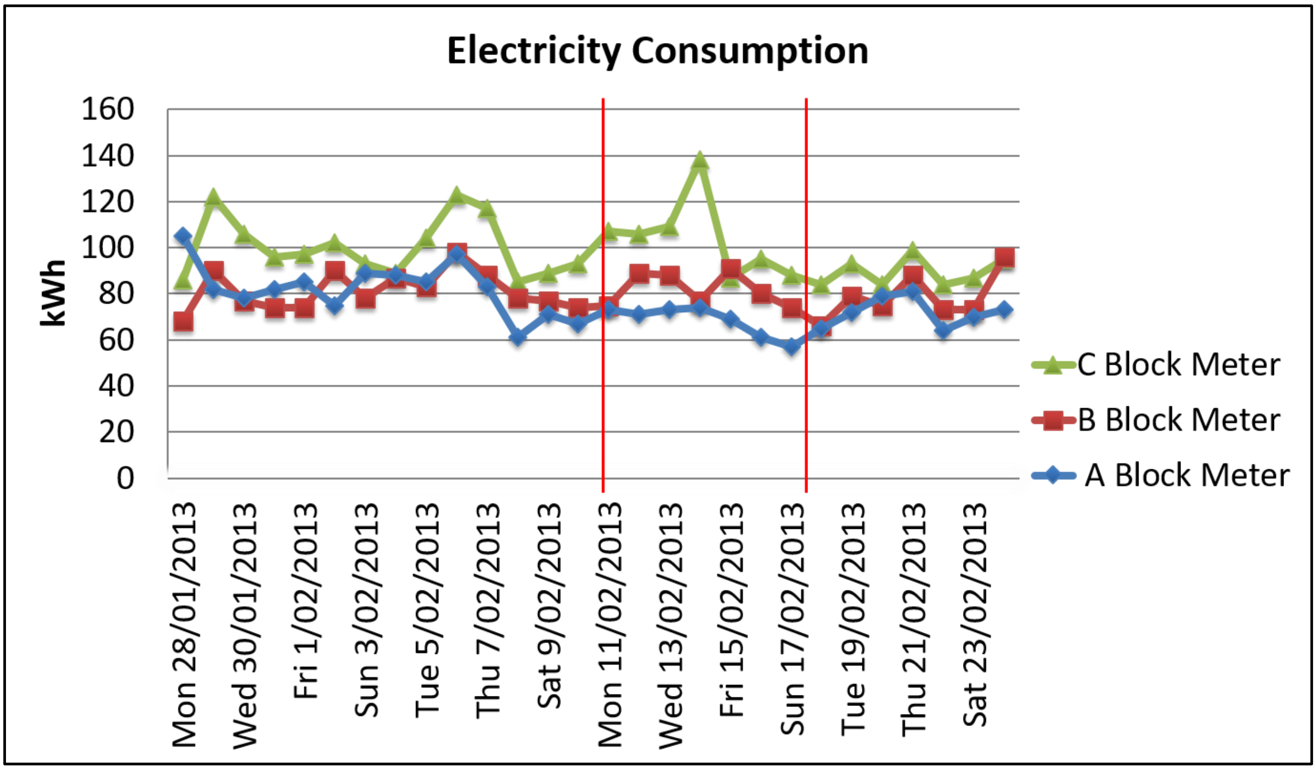


Figure 5.1. Keele University Seven Days Energy Saving Competition, organized during the Green Week (organized in 2013). The above graph represents Barnes Hall A (blue line), B (red line) and C (green) blocks residential electricity consumption during the energy saving competition. While the residents from the A (blue line) block lowered their electricity consumption, C (green line) block residents peaked their electricity consumption during the energy saving competition. The average highest temperature during the Green Week was 6 °C and the average lowest temperature during the Green Week was 2 °C.

In order to learn why *groups of* students changed their energy consumption practices we developed this analysis on Naus et al. (2015, page 133) who suggests that energy managing practices *'...may be better conceptualized as an emergent bundle of practices or as a distributed set of tasks that together make up a practice of domestic energy management.'*

These provocative propositions will be investigated in this thesis with the aim to better understand less resource-intensive forms of practices after an immediate crisis (Strengers 2013) and to suggests interventions that, '*rather than seeking to change an objectified unit of human activity (such as behaviour or a practice), instead become ways of integrating change comfortably into activity in which people already habitually and ongoingly engage'* (Pink et al. 2015, page 175).

This chapter presents findings from the home visits with the aim to look at practices-that-consume-energy as they are experienced by students in their everyday life. In doing this, first we will present Pink et al. (2015) 'flow management' concept and its implication for energy consumption studies. This will be followed by Maller et al. (2015) 'practice memory' concept that advocates for resurrection and recirculation of past sustainable practices to reduce energy consumption.

5.1. 'Flow management' as an intervention in everyday life

In Chapter 4.9.8., we argued for the use of video camera in the exploration of the sensory practices of households (Pink 2012) and placemaking (Pink et al. 2016). This approach made me understand students' routines when going to bed, getting up in the morning or doing laundry. Moreover, it helped me understand how students are sensing their environments as they move inside the house and how they are maintaining these environments through the sensory aesthetic of home. Most importantly for the aim of this thesis, the video recordings suggested that the design of any intervention in everyday energy consumption needs to focus on 'ways of living' and 'improvisatory interventions' (Ingold 2012, page 23), rather than suggesting change in the entities of practices-that-consume energy (Pink et al. 175).

As my video-tours progressed new research questions were formulated with the intention to identify students' desires and intentions to reduce their electricity consumption. Thus, we were interested in video-recording what students are doing when consuming energy, and we wanted to understand them as active and improvising humans (Pink et al. 2015, page 169). In doing this we turn to phenomenological anthropology and ethnographic knowing to understand domestic environments as constituted by multiple flows – people, material flows and immaterial resources – through the concepts of '*placemaking*' and sensory aesthetic of the home (Pink 2007, 2012, Pink et al. 2014). In this context, we explore how flows are made and managed through the example of air, which provides *'experiential qualities of heat, cold, odours and more'* (Pink et al. 2015, page 169). This allows me to conceptualize students as the directors of such flows in their homes, and to question about what kinds of '*flow management*' might limit or reduce energy demand and to suggest ideas for how smart technology designers might intervene in the flow of everyday life (Pink et al. 2015). From this perspective students are more than just '*carriers of practices*' (Schatzki 2001), but are also active and corresponding agents who cope with new and challenging situations (Pink et al. 2015, Martens et al. 2017).

In the following, we will present the way students sensed, directed and managed flows while engaging with the shifting environment of home and through their own movement and everyday activity (Pink et al. 2015, page 169).

5.2. Making and Managing flows through the senses

The first interesting theme that emerges from the findings, and that is central to the way students are consuming electricity inside their homes is the process of learning through making and managing flows through the senses. As we argued earlier flows and their management are important to how energy is consumed, since they are frequently associated with the use of appliances and systems that generate temperatures and consume electricity and gas and other resources (Pink et al. 2015, page 175). In this subchapter using the video recordings of the home, we will show that flows (such as flows of fresh, cold and warm air) act as learning portals for students in making and managing flows around heating and lighting practices.

The first part therefore asks the question: Is the heating turned on? or how the heating is turned on? The second part asks how do students know something as abstract as how to regulate the room heating system? How do they navigate, self-track or manage their energy consumption while creating the atmospheres they want? Following Pink et al. (2016, page 173), we have written the cases in the present tense *'to more loyally represent the way our participant sets his/her generalisations in the present of the moment when we did the ethnography.'*

5.2.1. Air as temperature flows

In the autumn of 2014, I set off for Steve's home (House 1), which is a 2 bedroom privately rented semi-detached house in a quiet area of an English town. Steve, who is a 35+ Pharmacy student, heard of this research from me during the 'Society Sign Up' event and volunteered to try to live with smart electricity display meters. Steve's privately rented house is easy to find, it is located on a residential street within a quiet residential area of Madeley. Steve wears a jumper and was waiting for me to arrive. The floor has carpets but the house is slightly chilly. I take my shoes off and I ask Steve to guide me through his privately rented home. We start our house tour in the living room that is heated with an electric fan heater.

The heating fan is stands on a small piece of wooden furniture, between the open kitchen door and Steve's work station. What was odd that Steve has also central heating radiators inside the house that made me to formulate questions about space heating technologies (such as energy efficiency). Therefore at the beginning of the video tours my questions are focused around the room temperature, air flows (such as opening/leaving open doors when studying) and air quality (such as morning after waking up and evening when working with radiators). For example, one of my planned question to Steve is do you know how a fan heater is working? Before addressing this specific question to Steve, 'in my head' I questioned myself about the working principles of a fan heater and I realized that my answer would be focused on the different modes of heat transfer (such as convection, radiation and conduction), because this is the way I know how a fan heater works. I know that a fan heater warm the air by blowing out convective heat. I know that a convection is the transfer of thermal energy from one place to another, through the movement of liquids and gases. The direction of the flow of heat within the air is turbulently upward, somewhat sideways but never downward. This is called 'free convection'. Thus, in convection heating, the blown warm air circulates upwards, it heats the space from the top down. I found this question to be less relevant as I am interested to find out together with Steve how this intangible and invisible flow is utilised and managed in everyday life. While in some cases the perhaps obvious technologies of windows and doors are key to managing flows of fresh and cold air, in Steve privately rented house this was not the case. Thus I ask Steve about the way he is heating his room with the fan heater; and he shows to me his thermometer (Image 5.1.) placed in front of his computer monitor, that is used for monitoring the temperature of the room: '*I got a thermometer, which*

I use and I tend to go religiously by this...so when I am heating up the room keep the doors closed until the cat decides he wants to run in or out, but I set the thermometer on the...I set the thermostat on the heater to try to correspond to the temperature of the room...so when the room gets colder I turn the heater up a little bit...but I try to keep the room temperature about 20°C'.

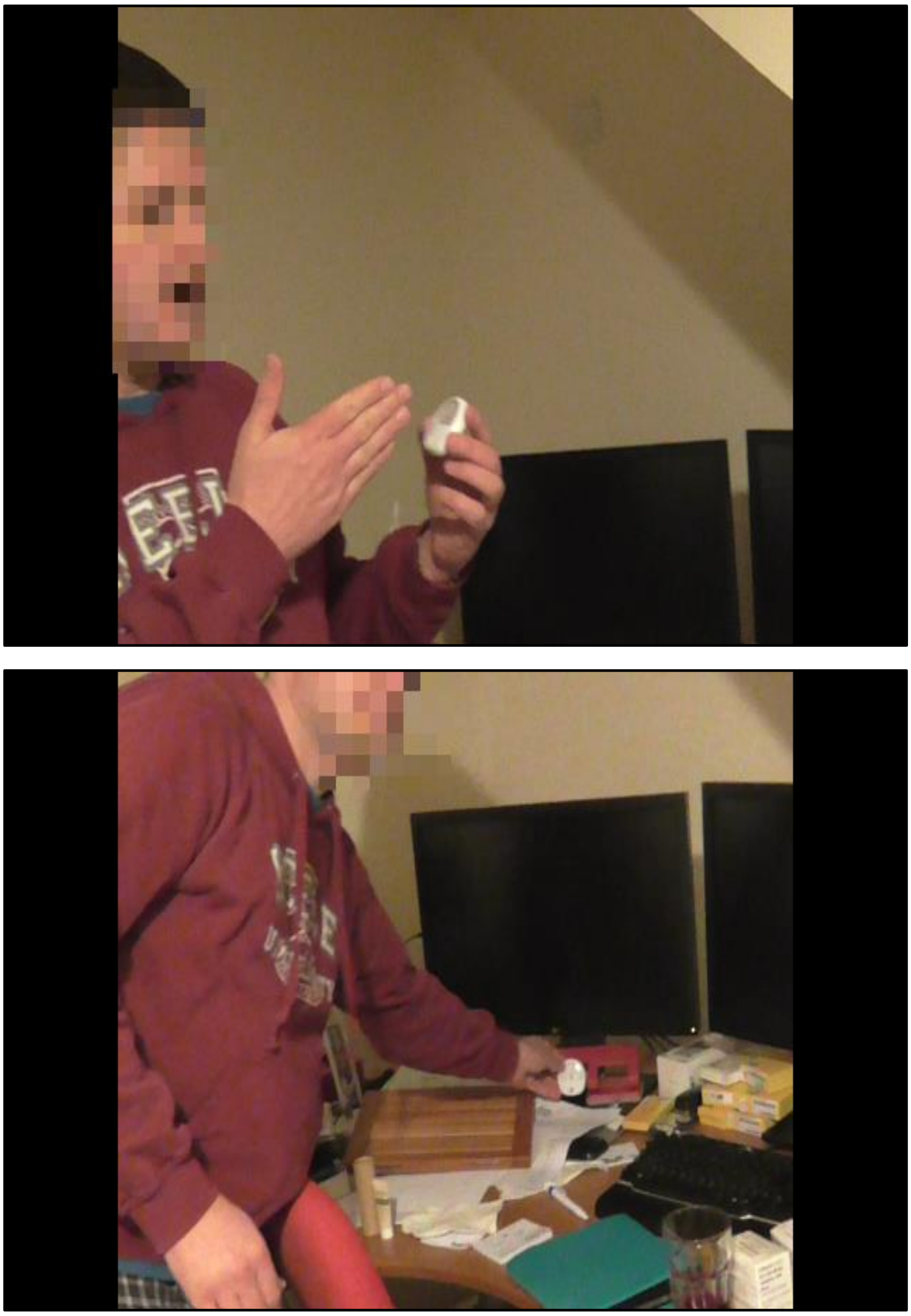


Image 5.1. Steve (House 1) explaining to me the way he is measuring the temperature of the living room

Steve shows me the way he is operating the fan. He turns the dial to operate the heater, that is a little bit noisy for me so I move closer with my camera and Steve moves his hand around the radiator fan to reassure himself that it works properly. He brings his fingers close to the heating fan and tells me that he can feel '*a nice stream of hot air, thus get the room warm very quickly.*' He generally works in the living room '*so I don't have like direct heat on my back, but it does warm, sort of general area of the room up.' He keeps the room temperature between '20°C-22°C, that 'is a comfortable working temperature any cooler then that my hands start getting cold working on the keyboard and things, any hotter than that, I get too hot and I find it uncomfortable.*' We are going upstairs and in his bedroom Steve has a similar radiator '*with the same power voltage and the same manufacturer, it is just an older model' with slightly different settings*. The bedroom radiator is standing on a plastic stool mould close to Steve's bed. When I ask Steve about what makes this heater to be different from the one in the living room he says: *'I find this more effective because when I put it on, between 3 and 4 on this one, the heat, keeps the heat of the room to a good temperature, the other one, the one downstairs even though using on the same setting all the time, I have to keep adjusting it up and down because the room temperature's changing, with this one if I put it between three and four it gets the room...you know...at satisfying temperature.'* This leads me to ask Steve how he knows the temperature of the room without having a thermometer inside his bedroom? Steve answers: *'Hmmm...I tend to find that I got used to it with the...the temperature...guage...and I sort on rely on that...so I don't never put that heater on number six or something, I would set it between three and four'*. He steps closer to the heating fan and starts to operate it by changing heater settings, he is moving his fingers around the heating fan to feel the different temperatures coming from the heating fan. The bedroom heating is also influenced by the presence of the cat '*...because it does like to get a bit closer to the heater so I need to make sure that he is not getting too close…I wouldn't leave it on with the cat around....no...I would switch it down to the freezer setting, if the cat is around, or off*'.

Image 5.2. Steve (House 1) is showing the way he is controlling the bedroom heater

The opening example suggests a number of elements of Steve home that can be considered as types of visible and invisible flow that is managed and utilised by Steve in heating the room. These include flows of air and movements of objects (such as doors) and other things (such as thermometer). Furthermore, Steve identified rooms as differing in their feel in terms of temperature, highlighting the coldest and warmest part of the privately rented house. This perspective allowed me to see and feel Steve engagements with flows of air around the home in everyday life. It was interesting to see that Steve ‘know’ what the living room and bedroom feel like when air flows are directed in a certain way, as well as the impact of these flows might have on the materiality of the home. Steve had his own tricks and techniques for managing flows of air that were designed to achieve specific and practical effects in the house environment.

As households increase in size, air flows are experienced and managed differently between different household members. This was the case in House 4 in this study. Emily (31 year, Environmental Sustainability & Green Technology student) and hers two housemates Mark (21 year, Biochemistry and Neuroscience student) and Steven (22 year, Law student), were renting this 2 bedroom mid-terrace flat, with the living room converted into a third bedroom. House 4 is located in a popular area close to Sainsbury's supermarket in Newcastle under Lyme. On arrival, I am greeted by Emily, who wears a jumper and a t-shirt. The floor has carpets and I experience the house as warm on my arrival. I took off my shoes and I followed Emily to the sitting room. Later, Mark, who wears a t-shirt and shorts, joins us and we start our guided tour from the sitting room. Before discussing the house heating system I ask the students to describe to me how they experience the outside weather. If for Emily today's weather 'was freezing' for Mark *'although it was cold, it was not raining or everything like that, so I think it still is a good day'*. When ask them to describe to me how they felt about their indoor environment on arrival, Emily sa *'When I was walking in I felt really hot... too hot' while for Mark it 'is quite warm… when I come back it gets even hotter'.* This is due the fact that the heating of the house runs on a programmed setting: '*...we always have the thermostat set to around 17°C-18°C, so when I come in naturally I can sit in a T-shirt and shorts and feel comfortable (Mark)'*. When I ask students if they made any changes in the sitting room, Emily tells me that they moved the furniture, because the sofa was absorbing all the heat from the radiator and they could not use the radiator to dry their clothes. Later she turns to Mark and asks '*...but have you noticed it's got hot, isn't?*', making Mark remark '*yeahhh, definitely*.'

We walk to the kitchen and Mark asks me if I feel the cold air coming from the laminate flooring: '*if you walk on without no shoe or socks on, it is really, really cold in the morning, or something...because it conducts the cold*', in contrast with the sitting room floor with the carpet '*even if it is hot or cold it is still comfortable to walk on...is hot…is same as the bathroom I think...*'. After familiarizing with the kitchen we walk upstairs to the students' rooms, where I experience the different air temperatures of the bedrooms. Mark has a '*powerful radiator...that I have on three...so it goes up to five...but I had a problem when I was sleeping, I left on five...and I got really hot and I wake up sweating too much and that kind of thing...so sometimes really bad actually...I put this one five...the top setting...open my window...so i am sleeping...with both...obviously wasting energy*'. During this time Mark touches the top of the radiator several times. The radiator behind Emily's door is '*down to two, normally, or off.... most of the day I turn it off and open my window*.' The heat difference is experienced by Mark who remarks: *Her room is quite cold compared to mine, isn't it? Can you feel it?'.* He would step closer to the radiator, lowers his body and puts his fingers on the top of the radiator, looks at the radiator valve setting and remarks *'yeah...and you have a draft... your room, I could tell you straight away, is colder than mine'* (Image 5.3.).

Image 5.3. Mark (House 4) touches the radiator to see if the heating is on

As the above example suggests Mark and Emily were concerned with managing flows between interior and exterior environments or within the home between the rooms. Furthermore, they treated windows, walls, furniture as boundaries through which air, heat and cold might flow and the video tours revealed a number of ways in which they let the outside air in, shut it out, keep flows contained in the home or disperse them (Pink et al. 2015, page 173). For example, furniture was moved around not to obscure the heat flows from the radiator that were crucial to the drying of laundry inside the house. For Mark allowing fresh air to flow through his room was part of his ongoing activity through which he made his room ‘feel right. This was achieved through routinely opening windows (such as after waking up in the morning and smelling the stuffiness of the air), or to get the air moving in order to get a better sleep.

A scientific explanation of this phenomena would be that the body perceives radiant heat differently from convective heat. While radiation heats people directly, transferring energy in one straight-forward direction, convection heat is more ‘convoluted’. Thus, heater fans transfer heat to the air which in turn transfers heat to the people in the room. This is less efficient process. On the other hand, in Mark and Emily case, where one person is always cold than the others radiant heating needs to be compromised. They need to find a temperature that works for both of them, but that may be less comfortable to them.

The temperature is set for the cold person and Mark needs only to open a window to get a cooling breeze that won’t affect the cold person's comfort level. As the radiant heating system is not reliant upon the temperature of the air, heating air by opening the window and leaving the radiators on wastes lot of energy that increases emissions of carbon dioxide in the atmosphere.

These findings about the way students heat their rooms imply that home heating is not a single custom practice and it goes beyond direct interaction with the heating control settings. Thus, as the above examples suggest, how students had different options for managing windows or doors to achieve the right feel for the house, and also applied embodied knowledge in making these decisions (Pink et al. 2015, page 174).

5.2.2. Anticipating hot air flows

The second way we learned more about how students manage flows in their indoor climates emerges from the way they regulate their heating system, and the forms of knowledge that they draw on when doing so, including the use of controls (such as turning heating on and off and the use of thermostats). Students interacted with a series of controls to regulate their heating systems to produce different qualities of air flows. For households with gas central heating systems, these included the use of multiple thermostats and timers; for students with electric heating systems, this involved interactions with portable heating fans and storage heaters. Basically, turning the heating on and off was achieved in many ways: through use of the thermometer, use of the timer or directly from the boiler. We were interested to find out how students are anticipating the appearance of the heat flows? As we were knowing that House 7 and House 8 heating is managed by students (respectively Keele Estate staff) with a heating programmer we scheduled the last two guided tours based on the houses heating times. While in House 8 we could video record the anticipation of the heating, in House 7 this was not possible.

Students living in House 8 admitted that they use a heating programmer that allows them to specify when the heating comes on. Catia (23 years old Biomedical Science student), Kendeel (25 years old Pharmacy student), Omar (21 year, International Relations student) and Bolu (23 year, Human Biology) lives in a two bedroom house, close to Keele University Campus. Bolu tells me that the heating of the house is running on a programmed setting '*so it is not adjusted every time you want*'. The heating normally comes on '*always at 6 o'clock in the evening and 'goes off at midnight'* (Bolu) but also '*is operated [manually]at 8 o'clock in the morning when we mostly wake up'* (Catia). In general students consider that the use of the heating programmer '*is ok and we generally adjusted to this*' (Bolu) and if during the daytime '*the house is cold, especially as it's 'getting winter*' they move from their room to the kitchen and turn on the oven that is '*gas operated and gas that produces a lot of heat'* (Bolu). In discussing the way they decided the heating hours, they are telling me that they decided based on their academic time tables, 's*o we don't have meetings, so because nothing we have now the heating is not turned on and that is energy sustainable'* (Bolu). As it was getting to 6 o'clock I could learn how students are anticipating for the heating to come on. Catia first looks at her mobile phone and she tells me the exact time, second, touches the top of the radiator with her fingers to feel the hot air flows coming from the radiator and finally draws her blind. Rushing to Bolu's room to video record the way he is anticipating the hot air flows I observe that Bolu's window is also opened '*to get some air flow*'. First, he closes the window, draws the blinds and finally he checks the radiator setting that needs to be on number four, the highest setting to speed up the flow of hot air from the radiator.

Campus accommodation heating systems are usually operated based on heating hours and this is the case of the heating system of House 7. During my PhD studies I attended meetings and communal meals in House 7, but this time I wanted to learn from the residents the way they are using the heating system. Markus (22 year, Politics student), Ayesha (21 year Environment and Sustainability student), Maria (21 year, Applied Environmental Science and International Relations) and Chandni (21 year, Environment and Sustainability student) guided me through their house.

The floor has carpets, but the house is chilly. I ask students if the heating is on, and they are telling me that the heating of the house runs on a programmed setting and normally comes on at 2 o'clock and goes off at 3 o'clock. It comes on again at 8 o'clock in the evening and goes off at 11 o'clock at night. Students are keeping all the radiators turned on and are adjusting the accommodation temperatures from the thermostat located in their living room. As this is their first winter in this house they are still experimenting but: *... when the heat is not turned on it can...it gets cold, very, very quickly, but right now I think is an OK temperature...I was living in Horwood*[3] *last year... and I remember I was feeling*

[3] Horwood Hall is a hall of residence on Keele Campus.

always hot with the amount of heating they had... it was always turned on really high... I think this is like a normal-ish, comfortable temperature' (Chandni).

We start our tour from the entrance door that leads through the carpeted hallway to kitchen, bathrooms and bedrooms. Near the main entrance, there is a radiator used by students to dry their shoes. However, the corridor is drafty because the single glazing of the door that makes the carpet to feel cold in the morning. In telling me this Markus suddenly turns around opens the door, put his fingers on the door glass, looks at Maria and Ayesha who step closer and touch the door glass. The '*kitchen gets warmer then the rest of the house because there is the boiler over there'* (Maria) and it heats up so much that sometimes when they are cooking they need to open the window. Ayesha occupies the largest bedroom that has two large windows on two sides and two large double panel radiators that were turned on. Upon entering the room I can feel the temperature change, the bedroom is colder than the kitchen and I noticed that the bed is positioned in the middle of the room, between the two radiators. When Ayesha moved in she tried to move her bed near the radiator but at night she *'would hear people walking in front of the window'* and she could not sleep at night. Ayesha would never adjust her room radiators because of the heating hours and she also uses the heat of the radiator to dry her clothes. Maria finds her room *'to be a little bit cold, but colder than the other parts of the house'*. The main reason of this is the poor insulation *'especially that my radiator is under the window.'* Her desk is in front of her radiator and when working from home she can feel the draught coming from her window. Therefore, she would always have two layers of clothing on when working inside her room. She has always her radiator turned on because of the heating hours and she would not adjust it, because she needs to pull the desk away from the radiator every time when she wants to reach the control. Chandni moved around her bed, '*I used to have my bed right next to the radiator, because I was thinking it is really-really warm...not at all...I thought like it was even worse...almost...it was warmer on this side of the room than next to the radiator...I don't know how does that works...but this is how it seems'*. In Chandni room I observe a radiator reflector (or a 'protective layer'), a thin foil behind her radiator and I wanted to learn if there are differences in heating radiator reflector or not. In answering to my question Chandni shows me: *'at the back is a metal sheet like thing...I think that one is in every single room because the insulation is so bad they put in that…it was like the heat back into the room...but it does not work as well...I don't think...I don't feel any difference when the heating is on...especially when the heater is right under the window…'* As she has her desk in front of the radiator, she would never adjust it.

The findings from the two privately rented student houses whose heating is controlled with timers have indicated so far that home heating is more than a mundane everyday routine described by the interaction with heating control settings; rather involves a series of processes and elements coming together (Pink et al. 2015). Thus, windows and doors were closed to keep in warmth and stop air flows. In House 7 case the age, design of the radiators was responsible for the inefficiency along with issues of insulation. Although in both houses the management and the interpretation of the way warm and cold air flows around the home was based on students' everyday life, this was managed differently by students and was combined with other activities (for example the use of lights) and was often negotiated with competing activities (for example fresh air heating versus safety concerns in the case of Ayesha) (Pink et al. 2015, page 172). Other sources of warm air that went beyond heating systems were experienced and utilised by students. For example, cooker/ovens, the sun, showers were used to in making warm air flows.

The other students who participated in this study considered the use of timers as managers of hot air flows restricting and they preferred turning on and off the heating system when required. In many student households the thermostat is set between 15°C and 22 °C, although when students were cold and wanted the house to warm up quickly, some reported turning the thermostat up to a higher setting. For example, when questioning Mark (from House 4) '*What is the first thing that you do when you feel cold?*' he answers: *'I always go check the thermostat and turn the heating up and that kind of thing, I do...*' Furthermore, houses with gas central heating had thermostatic radiator valves (TRVs) on most of their radiators.

Most participants had the TRVs on different settings in different rooms, depending on: how warm or cold that the room feels at any given time (for example the TRV in House 4 kitchen is normally set to maximum because students are drying their clothes inside the kitchen) or the activity that is planned for that space (Bolu from House 8 turns up the TRV in his room when the heating is coming on). Although several students reported never altering the TRVs, during the video tours these all were set on maximum settings. In the next subchapter we will discuss the ways flows constitute the home (Pink et al. 2015, page 174) and we will examine how the management of the flow produces particular outcome for the students (Pink et al. 2015, page 174).

5.2.3. Managing the membranes/flows

The above examples highlighted the way students are managing flows between indoor and outdoor environments or inside the home between rooms. In this context we follow Pink and Leder Mackley (2015, page 173) conceptualization of the home as changing and transitional, and as emplaced (with permeable membranes) within and in relation to the outside world (2015, page 173). Framing the home this way will highlight the way students managed the boundaries of the home and negotiate natural light and flows of air to dry laundry.

A number of ethnographic studies (Wilhite et al. 1996) have investigated the lighting across different cultural context, and the findings suggests that quality of light is socially or culturally constituted and not inherited by the technology (Jensen 2013). Currently, according to Energy Saving Trust lighting accounts for 18 per cent of a typical electricity bill which suggests that significant savings can be made by being aware of the importance of energy efficiency. Despite assuming that consumers might be aware of these issues even they are keen to save energy, other priorities can dominate (Pink et al. 2016). As such, atmospheres offer a route through which to analyse how such priorities play out (Pink et al. 2016). Students distinguished between different kinds of light and applied more or less successful strategies in managing and directing light flows.

In physics, light (or the luminous flux) it is a type of radiation, part of the electromagnetic spectrum that we can see. Unit of light intensity (or illuminance) is measured in *lumens per square meter* or lux. While illuminance can be measured, light from some sources (such as the sun or a lamp) falls on a surface. Thus, the human eye does not perceive illuminance but the reflection of the light from a specific surface. This is measured in *candelas per square inch* and can be perceived as light or as glare. Daylight is a diffused source of light that tends to illuminate surfaces more evenly in all directions: up, down and sideways. In contrast, electric lighting typically illuminates in a certain direction, such as on horizontal or vertical surfaces. In architecture, light is perceived as a fluid gas or liquid that occupies all the external space and enters the indoor spaces. Clearly, it is in the 'nature of light' to penetrate everywhere unless it is deliberately shut out.

During the video tours students told me that light - both natural and artificial - influenced their experiences of comfort within their domestic environment. Touring the privately rented houses, we observed many types of artificial light fittings (such as ceiling lights and table lamps) and classic fairy lights. Students used table lamps and candles when relaxing in favour of ceiling lights, as these were perceived to be a harsher type of light (preferred by students when multitasking). The use of natural light was found to be regulated by students using windows, blinds, doors and curtains. Students also considered natural light as providing additional thermal comfort. In the following we will present findings from the video tours to demonstrate to demonstrate the ways in which the management of flow produces a particular outcome for students, and the ways in which the flows constitute the home (Pink et al. 2015, page 174).

House 9 is located on a residential street on a brand-new estate. Part of the roads leading to the estate have not been asphalted yet, and I could observe that many of the properties were still for sale. House 9 is a 3 bedroom semi-detached house, located close to Knutton town centre. I am greeted by Samara (22 year old, Medical Chemistry and Biomedical student), by her two sisters -Yasmin (23 year old, Pharmacy) and Nadiya (17 old, Newcastle under Lyme college student), by her cousin Shammi (20 old, Economics and Mathematics student), by her mother Aisya (35+) and her father Aahmed (35+ old, Doctor). They joined my project because they just bought the property, and as they are ‘a large family’ (Aahmed) and energy is expensive, they would like to keep their eyes on their energy consumption.

The floor had no carpets and I am feeling chilly. We are touring the home together and we start from the kitchen that had an open concept design to feel more spacious and is fitted with 12V halogen light bulbs. Shami is telling me that the way the kitchen lights are used depends on ‘*what kind of work we want to do. Say, one of us...if we are eating we prefer to have more light, so sometimes we turn on both...the light bulb [pointing to the corridor light] and the six bulbs...if we are studying it is the same because we don’t have enough light to read and write, but if just working here in the kitchen we turn on just one of them*’. When asking the parents, Aisya shows me ‘*I am ok with the lighting...usually what I do...I use the Hub...and I don’t use that light only when eating in the kitchen...so instead of using six bulbs, it will be two bulb usually...when we are eating than I usually turn on that one [pointing to the six, 12V halogen bulbs] ...lighting is ok for me’*. The living room is the biggest room in the house and is *‘getting lot of sunshine and we don’t need the light during the daytime’* (Aahmed), they would turn on the ceiling lights afternoon '*most of the time I am sitting here I am doing some reading job, and the corner lamp is not enough, so we have to use it'* (Aahmed). We go upstairs to bedroom number 1 that is 's*mall and warm so we don't need to use the radiator*' (Samara) and the room is '*getting lot of sunshine and I have never had to turn on the lights during the day*' (Samara). Moreover '*in the afternoon when there is a lot of sunshine is too warm, sometimes I had to open the windows of this room and the one in the opposite room*' (Samara).

The 'opposite room' is used as study room where I could observe an ironing table, bookshelves, study desks and a 'naked' light bulb hanging on the ceiling. Samara is telling me that the girls '*study here using only one bulb or individual LED lamps, so they don't need to turn on the lights in different rooms*' (Samara). The use of the ceiling lights of the study room is conditioned by the number of people inside the room: '*if we are only one of us here we tended to use these lights [pointing to LED lamps] and turn the other [pointing to the ceiling lights] off*' (Yasmin). Yasmin switches on the LED lamp and would remark '*it quite bright, you know...it is more than enough*' that makes Aiysha to remark '*they have the laptop also so they have both source*'. Bedroom number 2 is slightly hotter than the study room '*for obvious reasons: the warm air comes up and plus we are getting sunshine in the morning*' (Aahmed). Shami and Samara would rarely turn on the lights of this room because they are spending most of their day in the study room or watching TV in the living room. As I am guided to the master bedroom I would observe on the corridor a motion sensor light or night-light that is used '*when we go to sleep we turn this [pointing to the night-light] one, so what that does...you know when...in the middle of the night you want to...you know….come to the corridor...we wouldn't have to turn on the actual light we can use just that*' (Yasmin). We enter the master bedroom, the only room with a carpet on the floor, again ceiling light without shade, that is lighted with bedside lamps that are mostly used because '*I am reading before sleeping*' (Aahmed). Aisyha shows me that by switching off the side lamp and living just the bedroom light on is impossible to read in the bed '*specially sitting over there [pointing to the right side of the bed] you can not read.*' (Aiysha).

Thus in House 9 lighting is not a discrete practice but is it relational to and interwoven with other activities (such as studying) and processes of home (Pink et al. 2015). Light can involve light flows from laptops, TV or other devices carried through the house (such as mobile phones). The fact that warm air rises was acknowledged by the householders who feel the bedroom number 2 hotter than the study room. At the same time, householders made sense of the flows of air in their homes, with regard to the position of the home in relation to the sun. In House 2, Arthur described the need to light the house as contributor to his mood.

House 2 is located in Madeley town, not so far away from House 1. It is a one-bedroom mid-floor flat with an open lounge and kitchen and a bathroom without shower. The heating is managed with storage heaters. Arthur is a 23 year old Pharmacy student who did his research project on students perception of their greenhouse gas emissions, and he specifically focused on carbon dioxide. As the SEDM 1 and SEDM 2 display in real-time time, the carbon dioxide emissions per unit of electricity used, he joined my project to monitor his home carbon footprint. Arthur tells me that he spends most of his time working from his desk. His desk is close to his large window but when he is working he would face the living room, sitting with his back to the window. During afternoons he tends to have his desktop lamp on and '*yeeahh..my kitchen lights...that my rubbish kitchen light...ahhh... I don't usually have this open actually [pointing to the window blinds] ...quite often I have closed which is based because I have to put that on [pointing to the ceiling lights]...but this is a terrible light [pointing to the ceiling lights].*' Arthur jumps up from his desk and turns on the ceiling lights to show me that '*...everyone laugh on this one...because it makes no difference...but I suppose at night it makes a little..tiny bit of light, changes the colour of the room, so it feels warmer I suppose*'. Arthur turns on these lights '*every night, pretty much...but sometimes I just use the side ones because it makes it to feel a little bit cosy*.' Later he is telling to me that after moving in he moved the working desk around '*when I moved in I did not had a sofa here, I had two big chairs, it is a little bit ugly the room, obviously I decorated it...and as I spent more time here, I realised what I wanted to do...were I like to sit and what I need to do ... so I eventually I reconfigured it to sort to suit my needs the most...you know nice window behind me and...I used to have my desk over there [pointing to the sofa]*'. As Arthur blinds are opened I could observe that it is still light outside, so I ask Arthur if there is any difference of having the side-lamp on when still light outside or after it gets dark. Arthur is telling to me *'it doesn't make a difference [and he would switch the lamp off to show me] I still see what I am doing...but it feels nice of it to have that [and he would turn on the lamp]...is like a fire isn't it...it warms a little bit, isn't it?*' (Image 5.4.).

Image 5.4. Arthur’s (House 3) desk position after moving around the furniture

Arthur’s bedroom has large windows with blinds on it, that are always closed. For Arthur ‘*because I got my own place you know...this is just a sleeping room...this is the hibernation chamber...and is there is the main room...so I suppose if I would live in a house with other people like I did in first year...sort of you are living in your bedroom, don’t you?*’

The above example highlight the way lighting and studying routines can become interwoven with each other in the making of the atmosphere of the home (Pink et al. 2016). Lamps are used to make the interior cosier and safer. Furthermore Arthur’s large window not only reduced the need for artificial lighting but equally acted as a sunny spot in the house.

In House 5, students used different technologies for producing and managing flows. These included bedside lamps, string lights or candles. Their evaluation of the use of the different technologies is useful for investigating and exploring the different and innovative ways in which technologies are being used in making and managing flows.

House 5 is a three bedroom semi-detached property, located close to Silverdale town centre. Before the meeting we researched the energy performance of the house but we also wanted to find out more about the infrastructure of the house. The heating system runs on central heating. There is a gas boiler in the kitchen and an electronic thermostat in the kitchen downstairs. Melanie (23 year old, Environment and Sustainability), Julie (23 year old, Physiotherapy) and Paula (23 year old, History and Politics) were renting the house. Our meeting is scheduled for late afternoon and everybody is expected to attend the meeting. After arrival I observe two entrance doors of the house: one leading to the kitchen and one leading to the hallway. The main entrance (the one leading to the hallway) had a spot light controlled with a motion detector sensor that turns on, on my arrival. I am greeted by Melanie who invites me inside the house, closes the door that had a thick curtain on it to keep the heat in. After closing the main door she draws the curtain and puts a draft stopper at the bottom of the door to stop the cold air from coming into the home.

Paula occupies the ground floor bedroom that is close to the main door. Her curtains are closed and the ceiling light is turned on. In her room I observe different side lamps and candles. When discussing the way she is uses the lamps when inside, she is telling me that '*I am using this one [pointing to the ceiling lights], like the majority of the time and that one [pointing to a desktop table lamp] very sporadically when is very dark*'. She also got some fairy lights *'yeah...I got some over there [pointing to the fireplace] but is battery powered*' and *'that light [pointing to the bedside lamp near her bed] but that is not functioning'* Moving with my camera closer to the fireplace I could observe that the fireplace is stuffed with candles and with a string light that is powered by battery. When she is using her laptop she would have her ceiling light turned on, that *'takes a little time to light up, to get a proper lighting, but it's alright'*. At night she '*would turn those on [pointing to the fireplace fairy lights] and I would light my candles and that kind of things...and I would put on that little light [pointing to the bedside lamp near her bed]*' and turn this off *[pointing to the ceiling lights], but at the moment I can't do that, so that is probably on [pointing to the ceiling lights]* (Image 5.5.). The reason why she is lighting her room differently is because '*that one [pointing to the bedside lamp near her bed] is much more an ambient light kind of thing where this one is kind of a harsh light [pointing to the ceiling lights], obviously light up the whole room rather like than the corner in that I am sitting in, so I rather have like a little light on, but at the moment I am kind of stuck with that one.* '

Image 5.5. Paula (House 5) fireplace decorated with candles that create a specific smell and feel when 'chilling out' inside her room.

Melanie occupies the largest bedroom upstairs. Her window curtain is drawn, she has her ceiling light on and a string of lights were also lighting the room. When asking about the way she is lighting her room she is telling me about the '*the fairy lights that connects into a plug behind the chest, or draws whatever it goes...they look around over the window and then there is the main light in the middle of the ceiling...and that's it'.* While the main light *'gets the job done and lights up'* the room, during the daytime she would not use it, she would use the sunlight from outside but when it gets dark she would shut the curtains and turn the main light on. But when she is getting ready for bed, she will turn off the main lights '*when I get change and I am using just the fairy lights and when I am actually going to sleep I am turning them off*' (Melanie). In discussing the 'actually going to sleep' meaning Melania will approximate *'the fairly lights are on for ten minutes max.'* Melanie experiences the fairy lights to be *'more weaker than the ceiling lights, not as brighter than the main lamp...I feel light it sets..it lights up the room enough...so before you are going to sleep you don't want a bright light.'* (Image 5.6.)

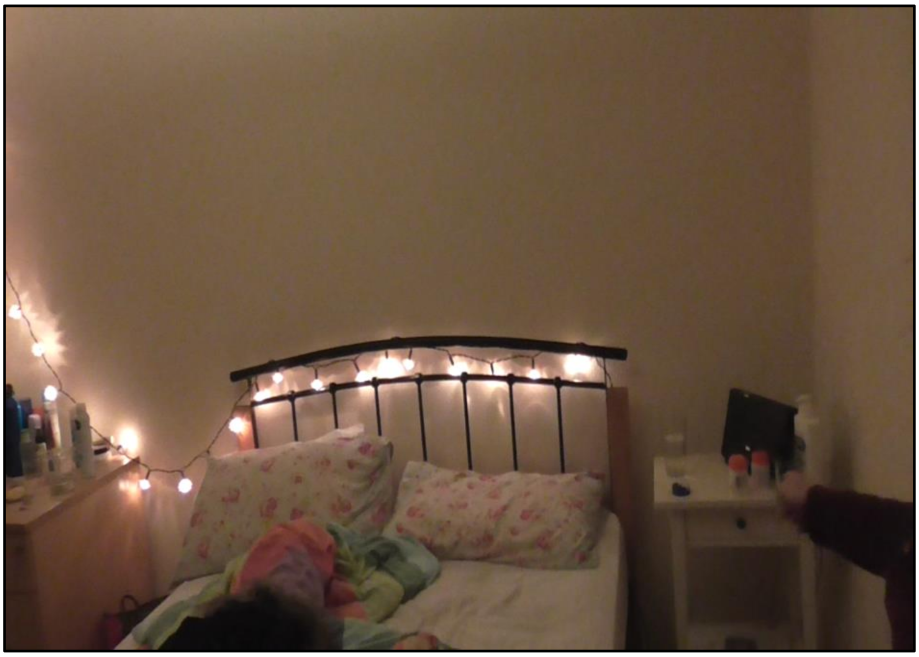


Image 5.6. Melanie (House 4) is showing the way she lights her room before going to bed

For Paula the bedroom is well lit when all the available lights (such as bedside lamps, ceiling lights) are switched on. The main justification for turning on all lights are '*related to wanting to see'*. As she explains, the management and interpretation of the light flows inside her bedroom is based on everyday and individual contingencies (Pink et al. 2016). For example, Paula's candles enabled flows of air and light that changed the smell and feel of her bedroom. In this sense, Paula accounted for light as a scent flow to achieve a specific atmospheric lighting (Pink et al. 2016). Curtains and blinds were also used to make the bedroom safer when lighting the room and Melanie (House 5) explained to me the way she developed a sequence of bedtime activities which involved management of different light flows in relation to everyday activities (such as going to bed).

While the students from House 5 were financially committed (by their energy bill) to low their energy use, this commitment was often negotiated in relation to competing priorities (such as lighting with open curtains versus safety concerns). While in House 5 indirect lights (such as candles or string lights) were preferred during night-time, in House 4 Emily and Giulia were directing the light with adjustable table lamps.

I asked Emily to show me the way she is using the lamp when she is doing her 'Uni' work. She would have her curtains shut, she sits in front of her desktop computer and she uses an adjustable desk lamp. She positions her desk lamp on the top of her PC speaker, with the 'head down' and looking to the middle of the working desk. This way the light is directed to the working desk, making the PC keyboard visible. While the directed light made the PC keyboard visible, I could experience the darkness of the left-hand side of the working desk that is close to her bed. Most of the evenings, before going to sleep, she is reading something, while lying flat in the bed. In doing this she moves the lamp from the top of PC speaker, close to her bed. Furthermore, she adjusts the head of the lamp to direct the light exactly on the surface where he needs it. When she goes to sleep she leans out of the bed and switches off. I ask Emily if she uses her room ceiling lights, but *'If I need more light...I can make more light...I can switch this on [pointing to the ceiling light that she will switch on] but I don't like it very much because I think is too bright...I think a bedroom should be a lower light...occasionally I use a candle...but that only if somebody comes around and we are just talking and I got music in the background I turn the lamp off and I put a couple of candle on.'* (Image 5.7.). While Mark uses his room ceiling lights to light the room this is not the case of Giulia (32 old, PhD students) who moved in after Mark left for an internship in Japan. During night time Giulia is using two lamps to 'light her room' as she considered that the '*general lamp [referring to ceiling light] is too strong' and she needs a softer light that is strong enough 'to light the space'.* In order to *'get the perfect light for the room'* (Giulia) she positioned her lamps in two opposite corners.

She would turn on both of the lamps inside room, *'to lighten different areas of the room'* (Giulia) but when she watches a movie just one lamp would stay on because she doesn't like to stay in darkness and she *'won't enjoy the movie' (Giulia).* I ask Giulia to show me the way she experiences the so called '*very-very-very soft light*'. Giulia will show me that before going to bed she adjusts the head of the table lamp, directs the light from the working desk to the dark coloured blinds. As dark colours absorb light rather than reflecting it, Giulia will experience a '*very soft light'* (Giulia, 32).

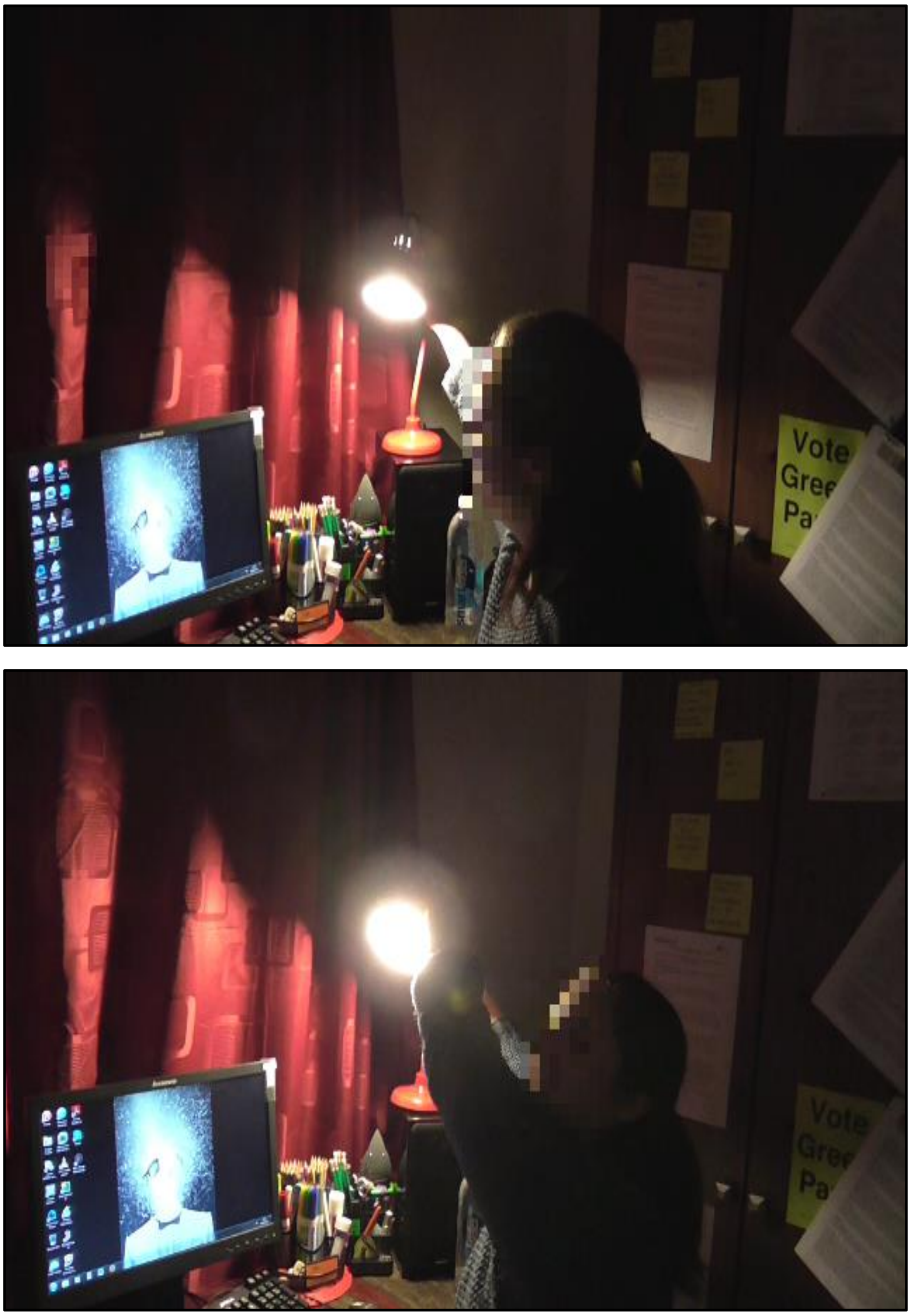


Image 5.7. Emily (House 4) showing me the way she directs the lights inside her room at different times of the day

Taking the concept of flow as a key analytical unit the video ethnography highlighted the way Emily and Giulia managed and directed light flows in their everyday life (Pink et al. 2015). The above example suggests that for Emily and Giulia flows of light have different qualities and affordances, and can be managed in different ways. Perhaps, most importantly these flows are not solid tangible materialities that can be held or moved around, but 'are manifested through their relationships with material objects (Pink et al. 2015, page 170)'.

In what follows we give examples of the way students previous experiences and 'practice memories' (Maller et al. 2013, page 147) resurrected and/or were incorporated into management of flows.

5.2.4. Practice memory: steaming clothes and dealing with drafts

Many researchers continue to equate creativity with multiple forms of intelligence and talent. However, during the guided video tours we learned that creativity and the ability to improvise is not a magical force, a born gift or an uncontrollable entity –creativity is located in the mundane and it is created through the way people engage in their everyday activities. In this sense, Maller and Strengers (2015, page 147) argue that mobile populations (such as migrants) carry embodied practice memories about how to perform everyday activities from their country of origin to new locations. A practice memory is defined as *'past enactments of practices that are embodied in their performers, leading to their resurrection in new and modified forms'* (Maller et al. 2013, page 244). This implies that '*a record or trace of [a practice's] history [is] preserved and reproduced the bodies which carrying it* '(Maller et al. 2013, page 245) as well as in the materials involved in carrying it out. In this sense, memories how to manage and direct flows never truly 'die' or become '*fossilized*' (Shove et al 2012, page 34), but are '*preserved in a cryogenic-like state' until such conditions emerge which lead to their potential resurrection or modification'* (Maller et al. 2013, page 245). Here we will exemplify the way practice memories of steaming clothes and dealing with drafts can resurface after moving in to a new location.

During the guided tours I could learn that female students do more ironing than male students and ironing is related to dressing code and presentability. This was the case of House 9 in which all female residences were wearing a 'hijab' or a 'headscarves' that was part of their muslim identity. Samara is ironing her 'hijab' daily on an ironing board with an iron that '*goes to standby after two minutes and turns off automatically'*. Emily (House 4) also showed me her ironing board and iron as Alison (22) who is hiding her iron from Sandra under her bed '*it got it from downstairs it was in the house when I came'*. But how male students do the ironing? During the first interview session Steve (House 1) would tell me that he is ironing his uniform every Saturday morning, and he would show me his iron. Well, in the case of Arthur (House 2) ironing is interwoven with sensory, emotional and environmental dimensions of bathing practices.

Thus Arthur lives in a house without shower and washing machine. He takes baths and uses the Campus laundrette to wash his clothes. Ironing was an issue for Arthur, '*because on a placement in a hospital, or in a pharmacy, and you have to look smart*' and he had to figure out a method that will remove the wrinkles from his clothing fast. Arthur's uncle Stephen, likes to take steamy baths it used to hang the wrinkled clothes on a shower rod. Stephen would start the water that he will put on hot and close windows, doors so the steam can get out. It takes around 15 minutes of steam to get the wrinkles out. Arthur is showing me this method and he hangs one of his wrinkled shirt above the bath (Image 5.10.). Well, above Arthur bath, is a little tiny hole, that meant to be there. It is not like someone knocked a hole in the wall, and Arthur remarks *'I have no idea what it would have been, but is perfect for putting the bit of a clothes hanger in there, and suspending my shirt over there. I would not do exclusively just for the shirt I make sure I do it when I am having a bath, I am not just going mental like that…*'

While telling me this he hangs his shirt over the bath, he makes sure that the door is closed, to be '*really steamy here*' (Arthur) and '*somehow, I don't know how it works but that [pointing to the shirt] it completely strains out...becomes presentable.* I want to learn how to produce the steam that makes the shirt presentable. Arthur shows me '*so what I do normally in the morning I put both on equally'* and Arthur turns on the cold and the hot water tap, and shows me the way the water is flowing from the tap. But when he needs to iron his clothes '*I will put actually a little bit slower, [Arthur turns on the hot tap showing the flow rate of the hot water] I put just the hot on, I put quite slowly, so uses the hot water slower, so...so...the temperature of the water in it would be hot because..so it slowly rise [showing me this while moving his fingers up and down] and it will be always nice and hot and producing more steam, but then again just...just my sort of idea, how may work, I don't know, I have not done a test if it works as well with the other option...this is just my hunch.]*

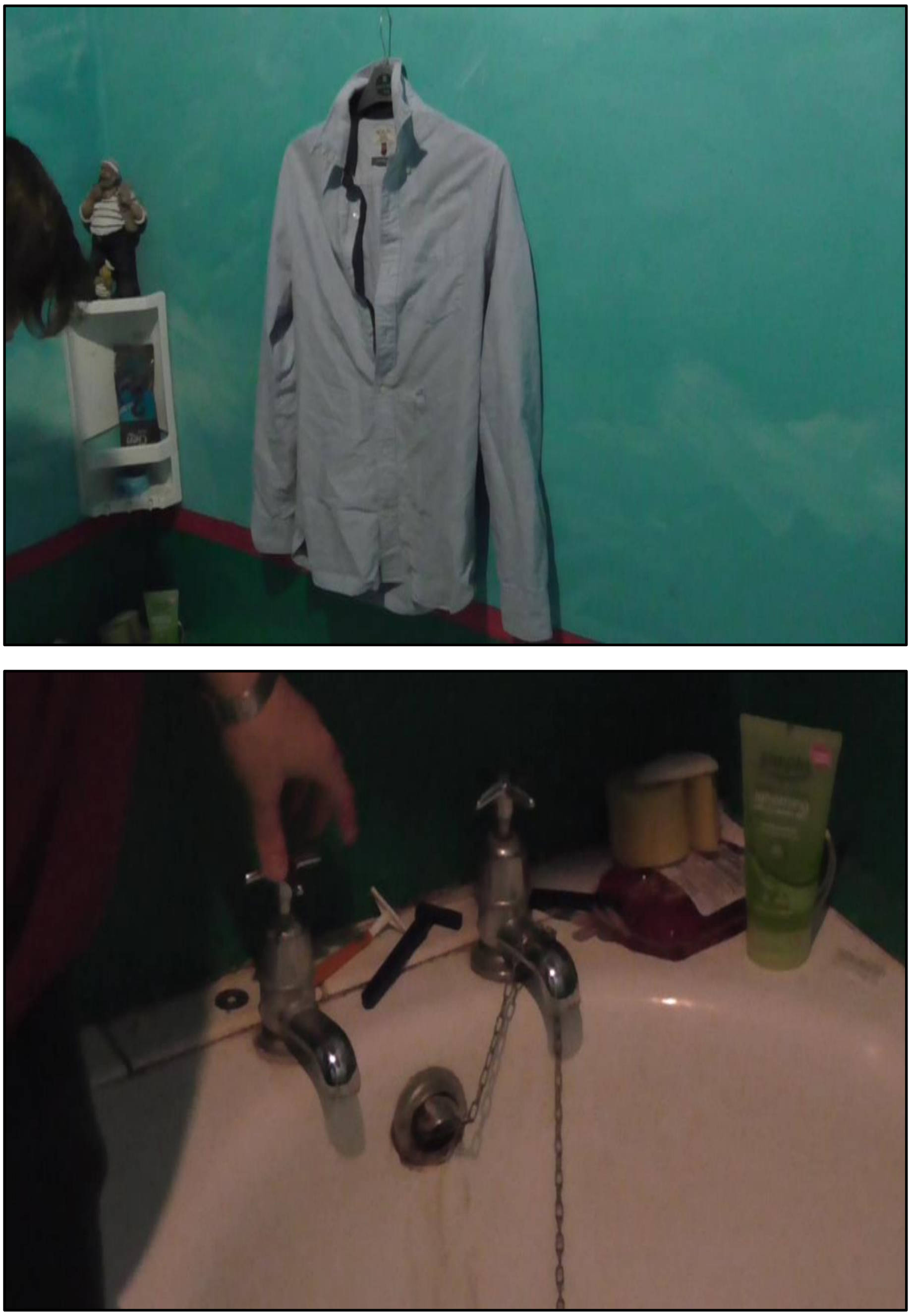


Image 5.10. Arthur (House 4) showing me the way she irons his clothes while bathing

What Arthur is witnessing is the condensation of the evaporated water - what he calls steam- tiny, white droplets of (liquid) water that are suspended in air. The easiest way to explain the evaporation phenomena is to think at the molecular level. For example, I imagine a single molecule of water, sitting on the top surface of Arthur's bath. This lonely molecule vibrates with a certain kinetic energy, and collides with other water molecules surrounding it. The collision might allow one of the molecules to escape the surface of the liquid as vapor in the air above (or hot air rises). This process is called evaporation and it can be observed on the macro level as water slowly disappearing (actually transitioning into invisible water vapor). In a closed system (such as bathroom door, windows closed) this process will reach an equilibrium when the collision rate is less than the rate at which the liquid releases molecules. It condenses, turns opaque, and becomes visible water vapor (or steam) that Arthur's observe.

The reason while the ironing works is that the majority of clothing's act as thermoplastics. In other words, the material of the clothing become soft when heated, compared to thermoset, which becomes hard once it cools, and no amount of reheating can undo it (for example kitchens laminate countertops). Thus as Arthur's wrinkled clothing has to undergo a plastic deformation, and he needs to heat the shirt up its glass transition point, to smooth out the wrinkles. When the fabric cools down, Arthur's clothes should be relatively wrinkle free.

In the above example Arthur described the resurrection of past practices of ironing, although the specific make-up of the ironing practice is not performed exactly as it was in his uncle house. The inclusion of new material elements, such as the bedroom wall for hanging the clothes above the steamy water, demonstrates the way the practice memory responds to the local availability of elements as it is resurrected (Maller et al. 2013, page 153). On the other hand, this example suggests how energy wasteful activities can be resurrected as well.

In three houses we observed that students are using draft-stoppers or door curtains to keep the heated air inside the house. While House 5 landlord installed a large commercial curtain on the front door that students were using regularly, House 7 living room door had a door curtain that was '*thiny, polyester or something, that will not gonna insulate anyway.'* (Markus, House 7)

During the guided tours Emily's (House 4) complained about her drafty windows and about the '*big gap*' under her door and we wanted to learn how to trap the hot air inside the room and keep out the corridor lights (Image 5.9.). When the room it's drafty Emily puts '*either thi*s' pointing to the piece of clothing hanged on the door, '*that is a dressing gown, or big towel like that, close the door and lay it* *in front...'*. As I don't really understand the method I ask kindly Emily to show me exactly the way she fits the towel to stop the cold air entering her room.

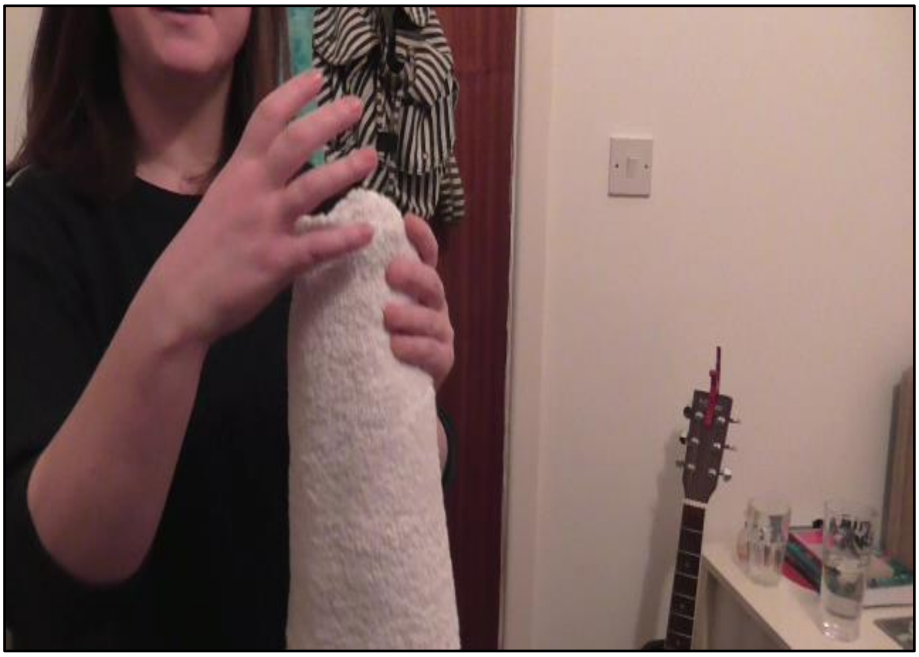


Image 5.9. Emily and Mark (House 4) showing me a way of blocking the gap under the bedroom door

She closes the door and starts to roll up a big white towel while telling me: '*In my old house I use to have tights...*', but she is interrupted by Mark who ask Emily '*Is your gap big as mine*?' and he starts to take measures whit his figures of the gap under Emily door. Emily is not impressed she replies with '*Yeah*' and continuous with the rolling up of the towel and continues her idea by telling me *'...women tights fill them off with old women clothes and then tide the end... like a big sausage cause my old house is really drafty and then they were already made…*' and crouches down with the rolled up towel that she lays in front of her door. Mark checks if there is any draft coming under the door and crouches down and he puts his hand on the towel, that makes Emily to remark '*I don't think you can..it's quite good'*. While Mark considers that 'do the towel' is useful he would never use this technique because is more '*effort than the draft what was causing*.' and is faster to turn up the radiator.

In this case the gap underneath the bedroom doors primarily assists the airflow throughout the house. Thus, outdoor air (or the depressurized) is supplied through the corridors and it enters the bedrooms through the gap under the door. Blocking the gap under the bedroom room not only reduces the airflow entering into the room but also the air flow through the house. The trapped air pressurizes Emily's bedroom. This positive pressure forces conditioned air out of the bedroom through the drafty windows or force into cracks in walls or ceiling. One simple lesson that I learned from building science research is that for every cubic foot of air forced out of a building, a cubic foot must be drawn in from outside to replace it. Thus, an equal amount of air is drawn into the house through the drafty window to replace the forced-out air. The gap under the closed bedroom door does not obscure the airflow, limits heat loss that makes Emily to feel the room warmer during the winter. Otherwise with the drafty window and the gap under the door the Emily's room will be less comfortable, she would adjust more often the radiator and health problems could proliferate.

Emily's example suggests that sustainable forms of practice can be resurrected from dormancy encouraging a range of energy conservation actives such as innovative methods of blocking the heat leaving the room. Emily's example also suggests how the duration and intensity of doing the practice had ensured its continual and unchanged performance (Maller et al. 2013, page 154). Importantly, Emily's and Arthur's example suggests that practices and their elements can be 'remembered', although the links between the elements are loosened when they are not actively performed (Maller et al. 2013).

5.3. Conclusions

The video camera could not measure indoor environment conditions such as humidity level or air temperature, but we did record students' reflections on the invisible elements of the home and their facial and bodily expressions in managing home environments. As exemplified in this chapter flows of air, light and sound were frequently associated with the use of appliances and systems that generate temperatures, light and sounds and consume electricity, gas and (possibly) other power sources (Pink et al. 2015).

During the home visits, we observed that some of the students made their own improvisory interventions based on their own knowledge of their homes, including the direction and management of flows. We observed that these improvisations are part of their everyday movements students made as they moved through their homes without really 'thinking about it' consciously (Pink et al. 2015).

Yet, by conceptualising householders as managers of flows, we highlighted how they ongoingly make interventions in the management of their homes as part of everyday life. In this chapter we exemplified that the way students managed and directed the flows of air, light or sound was based on their embodied experiences as well as their sensory-aesthetic making of home (Pink et al. 2015). Furthermore, looking at the domestic environments through the prism of flows, enabled a way to situate practices and to start looking into energy managing practices which involved a focus on how energy in consumed through specific everyday life 'practices' and not practice.

We also exemplified the way experiences and memories can lie dormant and can resurface in times of disruption, bringing an opportunity to resurrect past skills in carrying out practices and, for example handling energy (Maller et al. 2015). Energy Saving Competitions are good examples the way energy saving practices temporarily resurrect practice memories, although as argued by Maller et al. (2015) just for a short period of time. Practice memories also suggests that sustainable communities (such as Campus communities or Eigg Island, Chapter 2.7.) where practice memories lie dormant in a large number of carriers are potential sites of resurrection (Maller et al. 2015). In the next chapter is will discuss how practices-that-consume-energy hang together and to show how these different types of connections matter for each other.

Chapter 6: Looking into comfort and cleanliness practices-that-consume energy

In the previous chapter we investigated what students do, how they move through, know and sense their privately rented homes. Furthermore, we exemplified the way students improvised in making and managing their privately rented home to feel right (Pink et al. 2012). Furthermore, we suggested a new methodological approach (Macrorie 2012) for investigating systems of practices that focus on the actor doings in everyday life.

As our aim in this thesis is to identify where (and how) SEDMs might be incorporated in the ways of living, in the following we are interested to find out more about the composition and organization of comfort and cleanliness activities. For example, showering and laundering may be characterized as practices that are part of the same bundles of practices (Shove et al. 2012), as conventions connected to cleanliness are a strong element in both practices. Wearing ‘clean’ clothes presupposes that you are ‘clean’ yourself, and these practices therefore need to be conducted sequentially. Staying clean is a very concrete accomplishment that people work towards.

In this chapter we are interested to find out how these combinations of activities hang together and/or why do they stay the same? We start our analysis with the energy profiles of different households pointing out the strength and problems relying on the smart electricity display metering data. This we will followed by a discussion on the compatibility and utility of the energy metering data in researching energy, managing practices (Naus et al. 2015) and their inter-connections. In the final part we zoom in (Nicolini 2010) on the elements that shape domestic energy consuming practices (Gram-Hanssen 2010) while focusing on the temporalities in and around the multiplicity of object relations (Jalas et al. 2013). The chapter ends with a critique on the dominant talk-based methods employed by practice researchers in investigating mundane practices (Martens 2012).

6.1. Monitoring performances of practices-that-consume-electricity

Smart electricity displays monitoring data provided an entry point for investigating the connections between technology and other elements of practices-that-consume-energy. Moreover, through monitoring technological usage, the aggregated monitoring data provided a way to measure the performance of practices. While the SEDMs provided data on students' energy consumption, it is not the practice that was measured, but the by-products of a student performing practice that consume energy. A similar approach can be found in Gram-Hanssen's (2011) investigation which used space heating and appliance energy usage data to investigate the importance of practices (relative to improving technological efficiency) in lowering domestic energy demand in Danish households. Influenced by Gram-Hanssen's (2011) investigation Foulds et al. (2016) used building monitoring data (such as temperature, humidity, air quality, electricity, etc.) to examine whether energy use changes by moving home and how building monitoring data can be used in understanding individual's everyday practices-that-consume-electricity.

Although in these studies practices are the central unit of analysis, there is little guidance on how to bound (or look for) practices-that-consume-electricity using building monitoring datasets. One (of the many) reason is that practices co-evolve alongside each other, that makes it difficult to match the logged energy usage with everyday practices. While the building monitoring data cannot be directly translated into factors that shape everyday life it can inform the researcher about the everyday organization of practices in time and space. This is suggested by Morley et al. (2011) who used monitoring data as an investigative method to highlight descriptively that differences do exist in the performance of everyday practices. Morley et al. (2011, page 2046) call for more detailed energy monitoring, reflecting on '*variations both in practices and in overall energy consumption. Average consumption values fail to represent highly diverse groupings, and they obscure detail from our understanding of energy demand, which for example might help identify particularly intensive varieties of practice. Further, at a time when sustainability motivates energy demand reductions, the variation in energy consumption is in itself significant since it reflects the distribution of an increasingly contentious and expensive resource. This calls for consideration of whether variation in itself should be a target for change.'*

While aggregated energy consumption data provides little understanding into the daily rhythm of householders, many behavioural studies use the aggregated data to headline their findings (McCalley et al.

2002, Benders et al. 2006, Darby 2006). For example, Darby (2006) shows a 5% reduction in energy consumption but does not explain how and why the changes in the performance of everyday domestic practices occurred. According to Fisher (2008) consumers pay more attention to the disaggregated data that could yield higher savings than the aggregated energy consumption data. Building on Fisher's (2008) findings, Bates et al. (2012) disaggregated total energy consumption by end-use demand to determine the role of specific domestic energy services in homes (such as lighting), while Kelly et al. (2016) quantified the energy consumption of specific appliances and devices. Although these are insightful studies, their default position of primarily using qualitative interviewing or video data to explain variations in quantitative monitoring data is adopted.

While monitoring is a very reliable and precise with regard to timing of changes in energy consumption, monitoring alone cannot provide any useful information about why changes in measurement happened. Thus, requires the richness offered by qualitative data to understand what changes in measurement means (such as regarding emotions, aspirations, etc.). Put simply, in this investigation data is used for more exploratory purposes, for example we use the data to examine how time structures the performance of practices.

6.1.1. Making practices-that consume electricity visible

In investigating the effect of the SEDMs on students' energy consumption we had to meter their normal energy consumption prior to usage of SEDMs. Later we used this monthly consumption as a baseline to compare with the energy consumption after using the SEDMs. Thus, after the guided video tours (Chapter 5) in every student household we installed SEDM 1 that recorded at one minute interval the power consumption of the house. As we did not want students to use to the SEDM 1 monitor, we sealed the monitor (Image 6.1.) in an envelope and we wrote my phone number on it, asking students to contact me in the case of power shortages when the SEDM 1 needed to be reset.

One month before the first interview sessions we visited all student households and downloaded the energy monitoring data and changed the batteries of the meters. It was nice to catch up with the students. It was interesting to note the changes that had occurred since the last meeting highlighting the dynamic nature of student everyday life, adding to the complexity of this type of study. These visits were an opportunity to say goodbye to Mark (House 4) who was moving out, to find out from Paul that Abel (House 6) left the University and moved home, to find the SEDM 1 transmitter in House 8 was without batteries or to chat with Markus (House 7) on his social media posts on carbon offsetting. Also during the home visits Aisya (House 9) asked me to use the video camera inside their house and Abigail, Jake (House 3) girlfriend, told me that she would like to withdraw from the study.

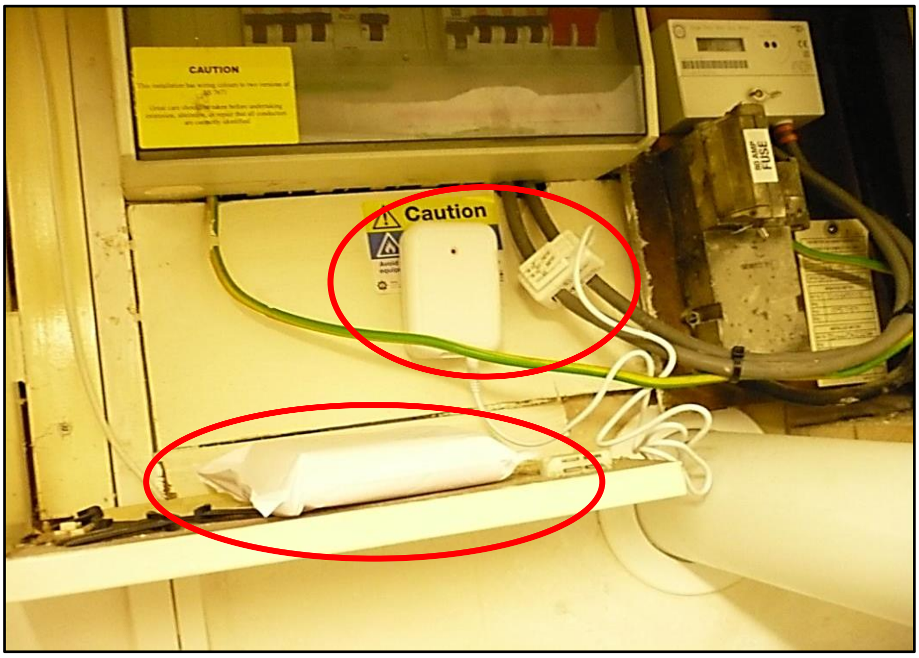


Image 6.1. House 4 SEDM 1 monitor sealed in an envelope (green circle)

Using the guided video tours, photos taken during the home visits and the collected electricity consumption data, we started to prepare for the first interview session. While the guided video tours helped me to understand the way students were using (and managing) their privately rented home, the building monitoring data recorded the time and energy consumption of a specific activity.

Existing empirical smart metering and monitoring studies recognises the importance of appliance signatures in understanding everyday electricity consumption (Powells et al. 2014, Kelly et al. 2016). There is a general agreement in the research that certain appliance signatures may provide information about the state of the appliance(s) which contributes to the total load (Powells et al. 2014). For example, on Figure 6.1. we can identify Arthur's (House 2) storage heater that makes use of the Economy 7 tariff (the yellow spikes between 00h00 and 04h30) or Steve's (House 1) '5 minutes' irregular showering routines (blue spikes between 08h10-08h22)

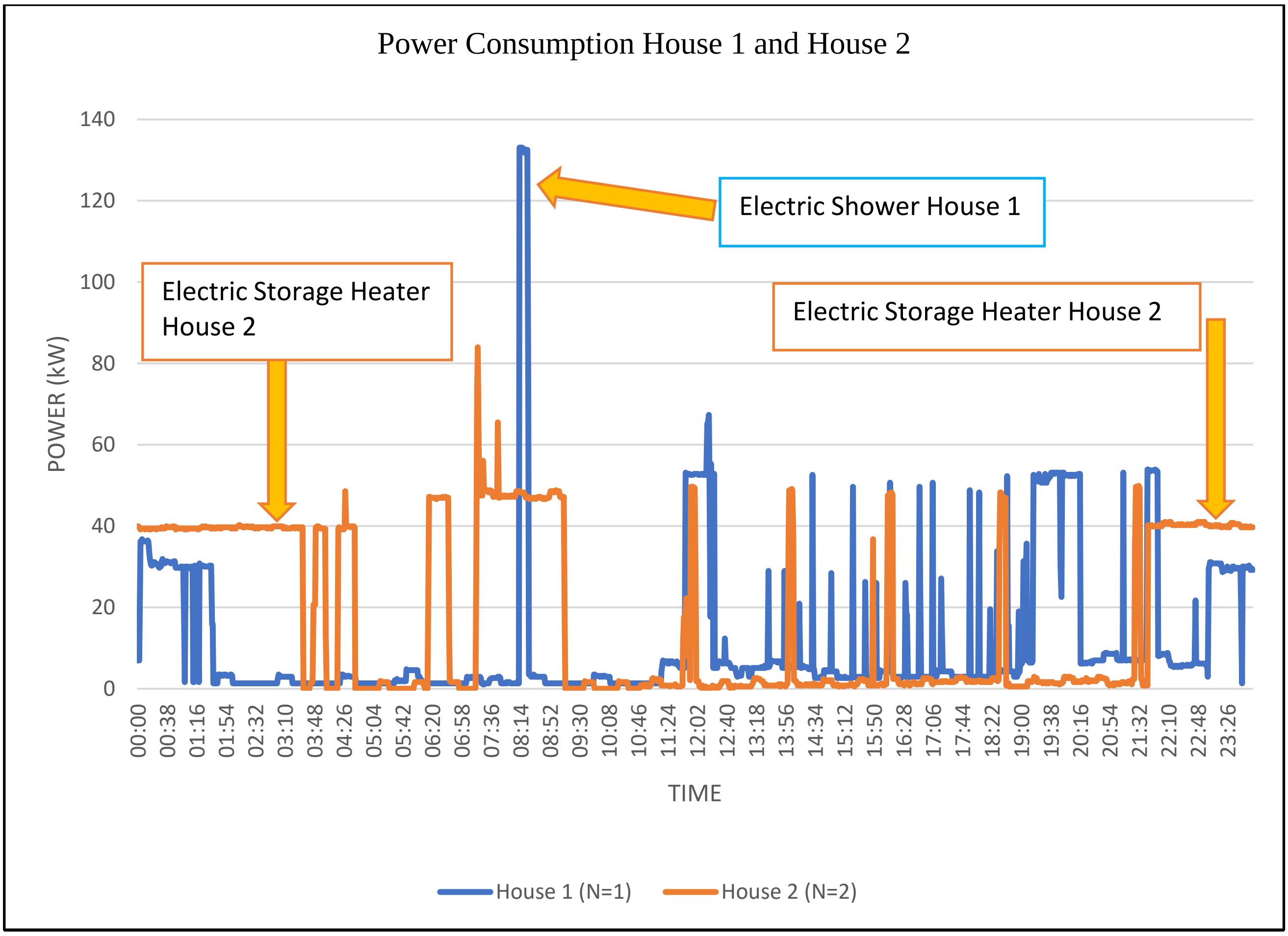


Figure 6.1. Power Consumption of House 2 (N=1) and House 1 (N=1) the day before our interview session

Although these spikes and troughs do not tell the whole story, they do reveal information on everyday energy consumption and help in preparation for the interview sessions. For example, the size of the blue spikes and the timing of the blue spikes is different. This raises questions and leads me to investigate why and how students shower?

Aggregating household data the day before the interview session (Figure 6.2.) smooths out the graph somewhat and reveals high peaks in the morning and evening. Zooming on these periods of time during higher energy use reveals more detail on the energy consumption practices inside the homes.

The first thing that we noticed on the smoothed electricity consumption graph was the area under the line that is significant from an energy consumption point of view. Although the electricity consumption graph may show an increase in the amount of energy being consumed, this is not necessarily significant unless it goes for a long time or happens frequently. In order to, understand the source of this energy use we prepared questions on the way students use standby power inside their privately rented homes.

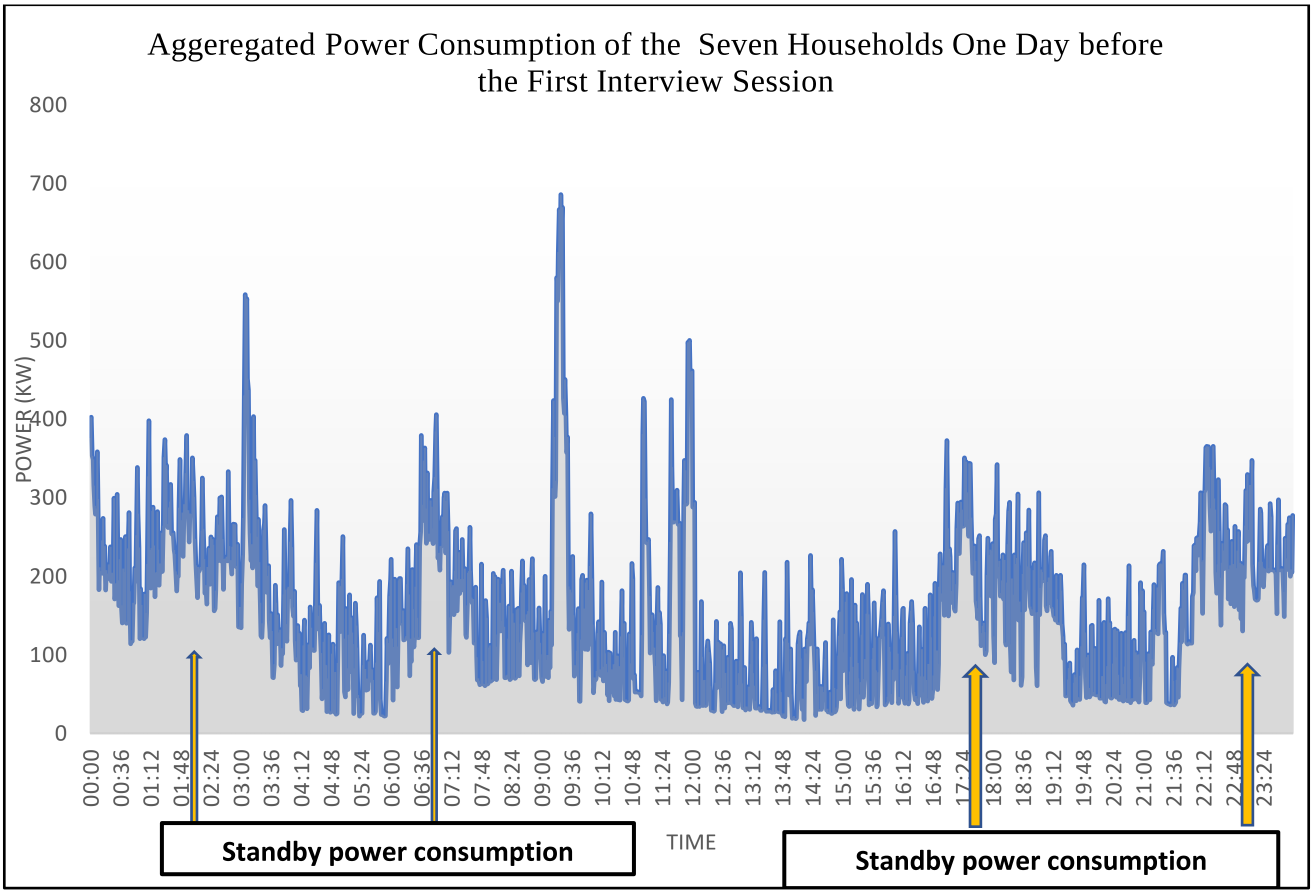


Figure 6.2. Aggregated power consumption of the seven households one day before the first interview session

During the guided tours we learned that students use multiple electric appliances in performing different practices. When measuring whole house electricity data, it is extremely difficult to differentiate between different appliances unless they have recognisable cycling patterns or use a lot of energy. Appliances such as tumble dryers, electric showers, washing machines and cookers have higher energy use can be more easily identified based on their specific signature with SEDM, however even these can be lost in the noise of the appliances being used (Kelly et al. 2016).

While the video recordings and the photos taken during the first home visit allowed the preparation of a dinner to be observed and recorded (practice which would have been invisible if only the energy data had been collected), the energy logging data have allowed me to interrogate the time and energy consumption of the specific practice.

Although it was difficult to match the energy data with the guided video tours, it revealed several interesting facts about students' energy consumption. Firstly, there is a significant and largely unexplainable base load (House 7). Secondly, there are energy-use practices going on which are not actually using energy at the time, such as the tablet being used on a battery. Thus, practices using rechargeable appliances complicate matching energy-use practices with actual energy use. Thirdly, even though the consumption spikes are mostly visible, there are still invisible practices going on, such as the use of the multiple appliances with complex signatures together, e.g., the lights, cooker hob light, microwave and computer. These all suggests the fact that metering alone cannot make practices visible, just as video recording practices cannot reveal energy consumption on its own. Fourthly, it is evident that some practices remain invisible mainly because they are performed in students' rooms. In this case the interviews provided additional insight into the way it is consumed behind closed doors. Finally, the guided tours and the energy profile of the households revealed that the period of active occupancy is quite long.

Clearly there is a high degree of speculation in this analysis, but the aggregated and the disaggregated hourly data allowed the identification of general movements of students inside the house. Moreover, the aggregated data provided a strong indication of the active occupancy levels, but has less potential to reveal appliance use. Thus while the smart meters could be designed to provide higher resolution data whilst maintaining privacy through appropriate data selection or processing techniques (Chapter

2.3), they still fail to explain those moments or 'times' when many students are doing the same thing at the same time.

Therefore, in the following we will present the way SEDMs data was used in co-investigation of the practice bundles/complexes and their interconnections. In seeking to understand the organization of bundles of practices-that-consume we turn to Southerton (2006) seminal work on domestic time management to show that comfort and cleanliness practices in students households '*hang together by the virtue of their connections across a number of temporal scale'* (Blue et al. 2017, page 6).

6.2. Co-investigation: presenting yesterday monitoring result back to students

Even after getting to know the students, some trends in the monitoring data could not be explained without students' assistance and specific discussion about a period of time (such as morning, afternoons, etc.). As we mentioned earlier without needing to collect the metering data, we would not have had the opportunity of speaking with students, and we would not know that during the Christmas break the House 6 landlord bleed the radiators and a new tenant is moving in, Steven (House 4) girlfriend moved in for a couple of weeks or Aahmed (House 9) was telling me that they had an electrical safety check and the technicians were concerned with the smart meters overheating problems. However, we tried to explain them the difference between SEDM and smart meters they decided that metering with SEDM is not convenient to them and withdraw from the study. Similarly, because of the impossibility of collecting the SEDM metering data and due to the unavailability of the students we had to remove the SEDM from House 8, and continue my research with the remaining 7 students houses (N=18).

These were some of the temporary disruptions to practices, caused by technological breakdowns or in some cases by overstaying (or moving in) house guests which made the understanding of quantitative energy metering data difficult, more specifically not representative of the daily performed energy consumption practice. This suggests that attempting to understand the energy monitoring results without students' assistance is fraught with a serious risk of misinterpretation of data. For example, monitoring data could have been used wrongly to justify that students are performing certain energy consuming practices that produce directly a certain comfort levels, such as use of electric blankets. On the other the monitoring data revealed insight into the temporal organization of the energy consuming practices.

Therefore, for the first interview session using students' previous day electricity monitoring data (Chapter 4.13) and their house plan (Chapter 4.14) we planned a discussion on the day before the session, a randomly chosen weekday and weekend day energy consumption activities. Discussing the monitoring data directly, the students helped me to uncover some of the invisible features of daily electricity consumption practices in ways that the video recordings, photographs failed to do. The building monitoring data helped in discussing the mundane (Catney et al. 2016), to bring into discussion the abstract features of daily energy consumption activities and their temporal organization. For example, Steve (House 1) spoke enthusiastically about the spikes and thoughts of his afternoon energy consumption when he was taking a nap. But there were many hilarious comments on house electricity consumption, for example Emily (House 4) at one point remarked: '*Oh God, seeing that makes me think I was doing a lot of things on Tuesday but in my head I was just sitting at my desk going; oh I want to die…*'. During the sessions we felt that the focused nature of the building monitoring data, metering energy consumption per minute, made energy consumption more real than for example a discussion on an estimated energy bill but most importantly it helped me to bring everyday rhythms to the fore (Foulds et al. 2016). In line with Foulds et al. (2016) who underline the untapped potential of the building monitoring data (and of the other technical data, such as thermal imaging) this research will explore the usefulness of the technical data in understanding daily electricity consumption and in understanding the temporal organization of the daily electricity consumption activities. Nevertheless, it was surprising to see how interested most of the students were in the diagrams, in seeing the others consumption while they were away from home: '*What the hell? I wasn't home. I was in the library [monitoring showing high peaks when Alison (House 6) was at the library]*.', '*How does energy work? Like, how does the consumption work? When you switch something on does it peak and then come down? [Kerry seeing the continuous spikes on the House 7 diagram]*'. In this research students were interested in the energy diagrams created by the researcher and this could suggest the possibility of using monitoring data to incentivise participation and enrolment.

6.2.1. The potential use of the building diagrams and floor plans for understanding the temporal structuring of comfort and cleanliness practices-that-consume-energy

Examining the temporal structuring of comfort and cleanliness practices-that-consume-energy implies a need for different methods that range from long-term monitoring everyday energy consumption patterns and material objects to the capturing and recording of tension or pressure and boredom (Jalas et al. 2016). While Southertons's (2006) seminal work based on participant observations and in-depth interviews offers a method to understanding the active coordination between people, in this part of the study we are interested in the socio-technical structuring of time and draw on various sources of data. Firstly, 3 semi- structured interviews and 4 focus groups sessions around the day before electricity consumption revealed details about the organization of electricity consumption practices such as when, by whom or in conjunction to what other activities electricity consumption practices were performed. Secondly, 3 semi-structured interviews and 4 focus groups sessions on the way students are using their home, that revealed students' orientation inside the house and on the way they experience time. Thirdly, 17 semi-structured interviews during which students were asked to provide a description of change in their heating, lighting, showering, cooking, laundering, ironing and hoovering practices after moving home. Finally, in order to capture the emotional state and boredom we video recorded *in-situ* the performance of different energy consumption practices.

All interviews, focus group sessions were transcribed and thematically coded using NVivo focusing on the temporal structuring of the practices and circulation of practice elements in the natural (or normal) situation. Following this process, the interviews with SEDMs diagrams were coded (Southerton et al. 2005, Jalas et al. 2013) from the point of view of the temporal structuring of lighting, heating, showering, hoovering, laundering, cooking, working and ironing. We found a little guidance (Halkier et al. 2011) on how to use practice approach to code my data meaning that we had to rearrange (and sometimes recode) and restructure codes (and coding systems) in analysing practices. Furthermore, we found extremely difficult to distinguish the boundaries of practise or where they begin and end (see Chapter 3.5). Therefore, we focus my analyses on summarizing (and not quantifying) the ways that students operate heating, lighting, showering etc. systems, cope with the related demand and achieve comfort and cleanliness in everyday life.

6.2.2. Temporal structuring of comfort and cleanliness practices-that-consume-energy

The focus sessions with the building diagrams and floor plans served two different roles in this analysis. Firstly, we used the data to extract details of the organization of comfort and cleanliness practices within students' households that was not available through the energy performance certificates or electricity bills. These details included the question of when, by whom and in conjunction to what other activities comfort and cleanliness activities were performed. As such, the focus group session with electricity consumption diagrams and floor plans enabled me to explore practice arrangements (Schatzki 2010, page 130) and thus served as a proxy for participant observations. Secondly, the focus group session with electricity consumption diagrams and floor plans revealed students views on the experience of time when performing comfort and cleanliness practices. In the following we introduce the temporal structuring of everyday life (such as sequence, periodicity, tempo and coordination) that will be followed by examples of the temporalities around the use of electricity in comfort and cleanliness practices.

6.2.2.1. Tempo

Tempo indicates the rate or speed of the activity. For example Steve (House 1) will recount the way he is prioritizing his morning activities: '*The bathroom, come downstairs, iron my shirt, iron my trousers. May have switched the computer on, I don't know, can't remember. I don't think I did this Saturday. I don't think I needed to look at anything this Saturday… [...]...So I may have had my breakfast down here, may have had it back upstairs in the bedroom. I probably have the heater on in the bedroom during that time, potentially. You know, the little fan heater. Take the chill off. So that I'd be warm enough as I get out of the shower… [...]… Come back in, get dressed while it's still warm in there, turn the heater off, and then leave for work.'* Thus his well-established morning routine helps Steve to leave the house on time. While in his research on professional chefs, Fine (1990) claims that days with too few demands were frustrating to chefs, because on these occasions the 'cook stops '*thinking' and may make foolish mistakes*' (Fine 1990, page 106) in this research students describe the way they enjoy the slow days (such as weekends or term days without lectures) by watching TV, browsing the net or taking napes.

For example. the girls from House 5 will confess to me that during weekends '*It is a lot more TV….';* Arthur (House 3) will tell me that non-academic days lack of structure and he will describe these days as: '*What I do in the morning is because I didn't have to be up at a certain point, I would have woken up, turned on my hot water, so that would have been right at the beginning, yes. And then I'd have waited an hour or until I wanted a bath. I probably was lazy yesterday and left it a few hours, and then had a bath when I was ready…[...]...There's not really much structure to them. It would tend to be just I might have something planned for the evening, I might be seeing my mate or seeing Claire, or I might just be in on my own. That really... I don't really have much to describe.'*

6.2.2.2 Periodicity

Periodicity refers to the frequency of reoccurrence of activities. For example Jake (House 3) will prepare a special breakfast on weekends '*It's something… Bacon, sausages, mushrooms, toast, hash browns, baked beans. So a English breakfast…[...]...No, because we don't really have time to do that in the week. Maybe I'll make an egg sandwich in the week or a bacon sandwich, because it takes five minutes. But this takes a bit longer; maybe, well, half an hour or so. Might have fresh coffee as well. We don't really have time for that in the week. So…'.*Paul (House 6) will be cooking ' *I cook normally on the weekends. I cook on the weekends or I just cook small, small stuff. But then like I'm hardly home to eat apart from breakfast because I take food to campus sometimes...'*

While the convenience of the showering/bathing system contributes to flexibility and allows longer periods of shower, this characteristic also creates demands (Shove 2003). For example, Steve (House 1) describes his showering as: '*I need to take a shower today, actually I haven't showered yet today. But I do shower every day. Once a day really. I haven't been out for a long time now. If I was going out an evening for a meal or something like that I may take a shower before going out and change clothes and put something different on to go out. But my shower... Yes, I just... Just get... It's generally just before I'm leaving. So, I'll have had my breakfast, I'll have a shower, and I just wash my hair, shower myself. If I'm going to have a shave, I'll shave. And then just swill the shower curtain round* *and swill the bath round afterwards, that's it really.'* While for Steve (House 1) the use of the electric shower tends to be part of his personal appearance for Arthur (House 6) bathing is 'form of restoration' and relaxation: *'In the morning. Very, very occasionally I won't have time in the morning, because I might wake up, forget to put the hot water on before I go back to bed. Like if I'm really tired, I'll just wake up and go back and get back into bed. And then I'll wake up and be like, no, and I'll have to have one in the evening. Sometimes I'll have two a day. If I'm not well, it's really nice to get in the bath, or if I'm going out at night, like some people might have a shower, I just have a quick bath or something. Just to get nice and fresh and something. I really enjoy it as well. It's just really relaxing.'* Similarly, Marcus (Home 7) will describe the enjoyment of a long, steamy and relaxing bath: *'Yes. I generally have baths as opposed to showers. I mostly have baths just to relax and nurse a few of my chronic injuries. Like, I've got chronic back pain at the moment and I find that just relaxing in some hot water generally helps them along and the same with my right knee as well. I've got a little bit of chronic pain that's developed since the summer, in my right knee.'*

Speed, immediacy and convenience of the water and electricity as materials acts as a buffer that allows students to pay more attention to their personal presentability and body odour, as well to prioritize and plan their daily activities. On the other hand, showers and baths are not always used to get the body clean, there is a variety of other meanings that showering is imbued with such as relaxation. As the above examples suggests showering is a habitual everyday practice influenced by practitioners desire for the enjoyment of spending that time engaging in cleanliness practice, regardless of its resource-intensiveness outcome.

Laundering was largely determined by what was considered to be dirty and smelly that influenced how quickly the wash basket or carrier bags were filled. In some cases sheets and towels were done separately from other clothes mainly because they tended to make up loads by themselves they were more likely subject to rules. For example, Paula (House 5) will launder her beddings '*Once every two weeks. It depends if I am here or not. I am at my boyfriends a lot but once every two weeks.'* General type of laundry (such as underwear, socks, t-shirts) was treated more flexibly and was done 'as the need arose.' Priority was given to gym stuff, uniforms (such as t-shirts, blouses and socks) or to particular clothes needed washing and drying even if there were other clothes available to worn. The traditional phases of laundering are the follows: first, the smelly and dirty clothes are gathered in baskets or carrier bags inside students rooms or left on corridors, second the piled up bags, baskets were transported to the washing machine were - sometimes - the laundry is separated based on colour intensity and fabric, third the laundry is loaded into the washing machine together with different type washing products (powder/liquid detergent or fabric softener), fourth the laundering program is selected and the washing machine is turned on, fifth at the end of the laundering program, the clothes are dried in a tumble dryer, on racks attached to the radiators, or on horse clothes, sixth the dried, wrinkled clothing is folded or left hanging and seventh the clean laundry is put away. The different phases of the laundry with its different set of technologies has the capacity to influence the timing and the energy consumption of the laundering process. The washing machine Eco wash setting was used in a couple of homes. In House 1 the washing machine and the tumble dryer were connected to timers to schedule the laundry cycle so that it would finish at a convenient time.

While the House 5 washing machine had a ‘delay start’ button, students did not used this time delay setting instead they were switching the machine(s) on manually. Paul (House 6) reported seeing the washing machine instructions manuals at some time, when they moved in, but he did not had the time to read it. While in House 4 Giulia will ask Emily's advice on how to use the washing machine, the majority of the students are following their clothes label instructions that demand a particular setting to be used.

In almost all student houses the washing machine helped to reclassify the meaning of the dirt. Thus, cleanliness is more about the whiteness and freshness of the clothes and clean was considered whatever was taken out of the machine. Even though using the tumble dryer was not seen as an energy efficient solution, students indicated that they prefer to dry some items with the tumble dryer. Thus towels and sheets were softer if dried with a tumble dryer than if air-dried, energy conservation were overruled by ideas about how linens should feel and how long does it take to air dry.

6.2.2.3. Synchronization and Coordination

Synchronization and coordination primarily relate to the level of coordination with other activities. For example Emily and Giulia from House 5 reports non-academic days as to be ‘*more of an odd job days*’ when they have time for the ‘time-filling’ jobs (Jalas et al. 2013): *‘Actually, this week it didn’t happen on Saturday, it happened on Sunday and since both my and Emily were at home without doing anything* *we decided to clean the house'.* The hoover, iron and the washing machine gets used on these days: '*Hoover is more efficacious and you definitely need the hoover if you have carpets. You can't, in my opinion you can't use brush of course, on carpet. And if you have to clean something very quickly, like something crashes into the kitchen or something like that, you can use the brush of course, but if you have to properly clean I prefer to use hoover'.*

Heating practices were always connected with other tasks. In general, of all the tasks related to electricity consumption practices heating is the one most often carried out as an orchestrated and planned activity (Fine 1990) and the only one that seems to require the use of the calendar and fixed appointments between students (Southerton 2006). Inside the student houses, lighting is one of the prominent conjunctions in which heating co-occurs. The small heater fans inside students' rooms (such as House 6) are turned on and off as a routine activity with little elaboration about, but more specifically to create a nice temperature, during the cold days. In the case of the central heating (such as House 5) or the pre-set heating systems (such as House 7 where the heating is controlled by a third party) however, the logic might be reversed: after the heating comes up, a particular course and selection of activities follow. For example, Melanie from House 5 will tell me that '*I hardly turn the heating on. When it is turned on it is turned on from five o'clock to seven o'clock. It does heat up quite fast. I don't know feel like it affects my work.'* The use of central heating can span three day rhythm: of first keeping warm the body with blankets, jumpers, hot drinks or hot baths, second heating the house and third allowing the heat to attain a level to suit everybody.

Thus before heating Julie (House 5) dresses up as '*It got to the point I had my jumper on and my blanket and I was still cold and I had a hot drink so I wanted heat.'* and Marcus (House 7) will take a hot bath to warm up *'...that's a part of it. I do like warm baths and I do like coming out of the bath, being nice and warm.'* When the heat comes up Paula (House 5) will close the curtains *'Generally it is a good temperature however the windows are a bit poor sometimes, they let the heat out. They let cold in and heat out. I turn my curtains a lot when the heating comes on.'* Kerry from House 7 will dial the thermostat to the *'The highest, 30 degrees. [...]...Tolerable. Like, it's not warm, but it's okay'* and Julie and Melanie from House 5 after turning up the heating will *'...watching the TV and chatting together about the day.'* In reaching the right temperature, or cooling the room students would open their windows *'sometimes too warm actually. So then I open the window (Sandra, House 6)*'. These are just some examples of the ways rooms are being transformed into comfortable spaces: a mixture of interactions with different type of heating devices and engaging in series of practices ranging from drinking hot drinks, staying in one room near a heating fan, shutting windows and doors and wearing extra clothes to stay warm.

Heating meshes with the various needs or situated benefits that indoor heat yields. Heat is needed to dry clothes and to get clean. Thus while Alison (House 6) will use a rack attached to her radiator to dry towels and gym stuff, Steven (House 7) and Steve (House 1) will use the heater fan to warm up their cold bedrooms while they are showering. Furthermore, in Paul (House 6) case heating can be described as an act of love: '*It's not too dark usually, so I never really turn the lights on. But I always turn the heater so these girls will be nice and warm.*'

While there are exceptions controlling the central heating (such as House 1) for students is a burden. For example, controlling the central heating is problematic in terms of synchronization for Giulia (House 5) *'I cooked until 6:30pm and then I decided to turn on the heating, but I'm not sure that I was successful because sometimes it, I don't know how it works. I don't understand so…';* or for Chadni (House 7) '*I don't even know what's going on any more like, it doesn't feel like the radiators are on, but I don't know if they are*.' In the best case heating is controlled from the radiator valves or from the thermostat as described by Melanie (House 5): *'We have just a normal boiler, with a dial thing and then a thermostat in the hallway but we keep that always set on the same temperature, 22 or something.'* The choice for measuring the room temperature is divided between students Kerry (House 6) will tell me *'No, I've never done that….To measure the temperature? No, just as long as I feel warm then that's all that matters.'* while Steve (House 1) will show me his thermometer that is using to monitor his room temperature: '*I keep my eye on the temperature reading.'*

6.2.2.4. Sequence

Sequence is primarily related to ordering of events. *'I know exactly when I need to leave'*, '*gone at that time'*, '*I haven't got time'* are just a few of the many articulations of the time spent by students while preparing to leave to Campus. All of which we argue fit under the umbrella of 'self-monitoring time'. For example, Steve knows exactly when he needs to leave the house: '*I know exactly when I need to* *leave, yes. So I'm on a schedule. I have to leave by ten to eight generally, although it's usually nearish eight o'clock by the time I leave.' (Steve, House 1)* or *Jake* (House 3) knows that he has time to play some Xbox while waiting on her girlfriend to get ready *'After that usually when I have breakfast I come in here and maybe I play some Xbox. Because I don't take very long to get ready. My girlfriend does; so I will have time to play, maybe 20 minutes.*'

While students recount spending around ten minutes preparing to leave the house a multitude of activities take place involving the use of mobile phones, fan heaters, lights or kettles. We would argue the use of these devices is influenced by students' time management strategies but also their individual way of living (Southerton 2006). For example Kerry (House 7) plans her morning after her supervisor email: '*My supervisor normally sends me a mail about what I should be doing. During like, from 09:30 until 11:30, my two hours of working, so she kind of, normally sends me a list of things that I should be doing, so I kind of, just look at my email and then plan out what I'm going to do and then I went…'* While some of these technologies help students to keep up with the time, they also have the effect of ratcheting the resource intensity of daily lives.

In some cases morning and afternoon schedules are ordered after institutionally scheduled events. For example, the start and end times of the term day create routines for students, and set times for breaks. This was the case with Giulia's skyped conversations that created the opportunity not only for preparing and eating food but also for laundering: '*The washing machine was working for a lot, two hours maybe, three hours. I don't remember actually. So while the washing machine was one I ate my pizza and I had my computer here but it wasn't in charge…. I was in a Skype call with my friend. '*

6.2.3. Conclusions

It is evident from the findings presented above that a typical day was arranged with respect to fixed practices (such as showering, cooking, shopping etc.) (Southerton et al. 2006), around which malleable practices organised themselves (such as browsing the net, watching TV) and within which time fillers slotted in (such as reading, studying etc.). Furthermore, the above examples suggest that the temporal aspects of energy consumption cannot be reduced to individual intentions or attitudes, but rather underline the challenge in understanding how practices-that-consume energy are coordinated and ordered within everyday life. As argued by Southerton (2006) changing practices-that-consume energy in order to address sustainability issues, requires looking beyond the individualistic behavioural models and paying closer attention to the interdependencies, connections and configurations of practices-that-consume energy.

The above examples also suggested if a practice happens regularly (such as showering, laundering) it might be defined as a normal practice and so hard to change (or shift); if it starts to make competition on other important practices it may feel rushed (such as Emily's example of 'cooking big' while writing essay); if it takes up a lot of time (such as bathing in House 2 and 7) it will be difficult to move to another time-slot, in another part of the day and sometimes seasonality will make shifting practices more difficult too (such as drying clothes).

This section so far suggested that time is more about minutes and in the following section I will explore with examples the relationship between time and practices-that-consume-energy focusing on: time as a resource, time structured by the temporal demands of practices-that-consume-energy and time as a construct arising out of performance of practices-that-consume-energy.

6.2.3.1. Time as a resource

Practices-as-performance take time (Shove et al. 2012, page 129). According to this conceptualization, time is a resource and practices-that-consume-energy must compete for it. For example, laundering time was conditioned by the amount of clothes needed to be laundered and by the availability of the washing machine in students' houses with more than one student: '*When I have enough clothes to full the washing machine, and I want to just wash two or three things. I want to wash a lot of things altogether. And then I use the washing machine when it is available because since we are three people we have to share of course, the use of the washing machine. So when it is free and there's nobody else who wants to use it I do that.'* (Giulia, House 4).

For Arthur (House 2) academic days were less structured and practices-that-consume energy curved the available time around everyday demands: '*What I do in the morning is because I didn't have to be up at a certain point, I would have woken up, turned on my hot water, so that would have been right* *at the beginning, yes. And then I'd have waited an hour or until I wanted a bath. I probably was lazy yesterday and left it a few hours, and then had a bath when I was ready.'*

For Steve (House 1) practices-that-consume-energy on weekend-days were influenced and prioritized according to his part-time work commitment: '*So I put the fan heater on in my bedroom. I may have put the one on down... No, I don't know whether I did put the one on down here. I came down stairs, ironed my shirt and trousers, and had my breakfast. Took a shower. And then I left for work around about eight in the morning. And then I would be away all day then until about six or seven. Then I'd come back, put the heater on in here, and put the lights on.'*

Meeting with supervisors, friends etc. suggested that certain practices-that-consume energy had to be done at a specific time of the day. For example, Chadni (House 7) will tell me: '*Normally like, I have an internship thing that I do on Monday mornings but I kind of... She normally sends me…. My supervisor normally sends me a mail about what I should be doing. During like, from 09:30 until 11:30, my two hours of working, so she kind of, normally sends me a list of things that I should be doing, so I kind of, just look at my email and then plan out what I'm going to do and then I went… After I planned what I was going to do at like, 09:45 I went to brush my teeth.'*

Another form of escalation of the impacts of practices-that-consume-energy is through multi-tasking (Røpke et al. 2007). For example Rosie (House 6) is describing me her evening as:' *and carry on using my laptop doing work. Maybe use my printer to print off work for the next day. Lecture slides and things. Watch TV while on my laptop. Maybe turn the light on because it's got dark by then. And yes, that's it really. I go to be around... Oh, I use the bathroom right before I go to bed.*'

Procrastination on a certain task in a favour of desirable (or must) tasks is another way to highlight the way practices-that-consume energy compete for time. For example Marcus (House 7) will tell me: '*I kind of work and don't work. Like I work and then I play guitar for a bit and make some lunch but I generally keep the computer on during this whole time. '*

As a conclusion, where time was interpreted as a resource, competition between practices-that-consume energy emerge and the result was that students felt harried and hurried (Southerton et al. 2001). In line with Southerton (2006) findings the above examples suggest that time is arranged around a fixed particular point (such as showering). This makes change difficult because shifting demand involves other householder member, and sometimes has a long duration (such as laundering).

6.2.3.2. Practices-that-consume-energy have temporal and rhythmic characteristics

In section 6.2.2. we exemplified the way time in students' households are structured by the temporal characteristics of practices-that-consume-energy (Shove et al. 2012). One significant example is the timing of meals*: 'After that, maybe about seven o'clock, we usually come downstairs to the kitchen to cook dinner. And it really depends what dinner I'm cooking. Sometimes it takes 20 minutes, sometimes it takes two hours. We usually eat at nine o'clock. So sometimes I go into the kitchen later to cook. Because sometimes it's seven, sometimes it's maybe 7:30, sometimes its maybe eight o'clock.'* (Arthur, House 3). Thus, for Arthur preparing a meal is appropriate and meaningful at a time of a day, but also the time at which cooking is carried out gives a particular meaning to practices-that-consume-energy. For example, Arthur explains to me the difference between a week and week-end day breakfast as: '*No, because we don't really have time to do that in the week. Maybe I'll make an egg sandwich in the week or a bacon sandwich, because it takes five minutes. But this takes a bit longer; maybe, well, half an hour or so. Might have fresh coffee as well. We don't really have time for that in the week. So…'*

Furthermore, in section 6.2. we exemplified that specific practices-that-consume energy needs to be done at a particular time of the day in a particular sequence and duration (Southerton 2006). For example, Sandra (House 6) explains to me the way she is finding her way to her room after returning from campus: *'When I enter I'll turn on this light just so I can lock the door, and then I'll turn on the kitchen light just so I can …Turn it on and then I'll walk through the living room in the darkness, and I'll turn on the corridor light for upstairs. I'll walk up the stairs. And then I turn it off again. And then I go through things like into my room.'*

Sequencing of the day was broadly similar for most students: *'Wake up at 10:00, bath, and same routine as always. Bath, I usually go to my computer, switch it on… o, the same stuff I always do. Procrastinating, playing games, watching YouTube videos, playing a bit of guitar, so the amplifier is on with the computer as well.'* (Marcus, House 7). In some cases, the continuous repetition of practices-that-consume energy provided a rhythm (Higginson et al. 2016) that allowed a certain pattern to emerge: *'No, they don't stay overnight. Or not anymore, anyway. My friends probably would have left at about 18:30 to go to a Green Party meeting. So it would have been just myself and maybe a couple of other people in the front room. And we probably cooked in the kitchen for about maybe 18:00, maybe 19:00'* (Marcus, House 7).

The building up of repetitive practices (such as cooking with friends) were highly valued by practitioners '*If it was that Tuesday, my mate who gives me a lift, he came in with me. So he might have charged his phone…I think he was sitting on the sofa for a couple of hours. He was get... Because he had the same lessons to teach in the afternoon, so he probably had his laptop with him. And he would have been sitting for a couple of hours. I would have been sitting there for a couple of hours doing things. When he left, I probably just stay there, like …' (*Arthur, House 2). When asking Arthur (House 2) if he would charge his neighbour for charging his phone inside his flat: '*I'm sure it does, but I don't like care enough about it for... To like charge, him to use.'*

As a conclusion, time was structured around practices of cooking, showering, heating or lighting and sequencing of the day across students' households was broadly similar. It was interesting to see how repetitive patterns (such as cooking with friends) allowed certain patterns to develop over time.

6.2.3.3. Practices-that-consume-energy take and make time

A practice approach acknowledges that practitioners experience of time results from participation in practices as time is constituted by practices (see Chapter 3.6.). However, time is differentiated by practices that fill it: *'So like, you are… Saturdays are usually like… You are much more… How to say? Like, you go into a time, you're conscious about the time, or less conscious about time'* (Ciadni, House 7). This suggests that time is not only integral construct of practices-that-consume energy but also is the way the experience is made. In Chapter 5 and Chapter 6.2.2. I exemplified the way practices-that-consume energy are managed and organised in students' households.

Thus in managing their times some students were using gadgets, timetables, etc: *'I can check my phone, I'll have a look at like my messages and things, see if that will jog my memory. I've not got a fantastic memory (Arthur, House 2)'* or *'Honestly can't remember. I wish you'd have told me you'd be asking* *me all these questions, because I'd have made a note of what I was switching on and off perhaps. But never mind.'* (Steve, House 1).

The difference between the ways time was structured in practices-that-consume energy was best by described by Arthur (House 1) in explaining the difference between an academic and non-academic day: '*There's not really much structure to them. It would tend to be just I might have something planned for the evening, I might be seeing my mate or seeing Mel, or I might just be in on my own. That really... I don't really have much to describe'.* In some way or another this would also suggests that the way the day is organised creates the day: *'Not really. At the weekend there's not really ever usually a plan. There's things that we have to do. So I will have to this week I have got lots of reading to do, so I'll make time for that and maybe… So…'* (Jake, House 3) or '*It is a lot more TV on the weekend'* (House 5).

As a conclusion, coordination of practices-that-consume-energy with SEDMs may seem to be necessary to help students in monitoring energy consumption. From smart metering point of view more coordinated households allows a degree of predictability (and modelling) to energy use.

6.3. Investigating the elements of practice

In the previous section we highlighted the way SEDMs data can be used in investigating the temporalities and connections between energy managing practices (Naus et al. 2015). However, from this analysis is missing how comfort and cleanliness practices came to have temporal features in the first place. In other words, why does showering have a particular tempo or periodicity? In the following we will present how we utilised the monitoring data in investigating the interconnections between elements of practice as in practice related performance of comfort and cleanliness practices.

The analysis followed Gram-Hanssen's (2010) elements which shape the performance of the practice that consume energy. The four elements are: technologies, institutionalised knowledge and explicit rules, know-how and embodied habits, and engagements. Particular focus of the interview session was to identify the way moving house transformed practices. While it was impossible to investigate students practices before moving home it was possible to re-enact and discuss previous practices. For example, we were interested to find out if they were using fan heaters or fairy lights before moving home.

6.3.1. Technologies

Building monitoring data recorded the date and the time of the electricity consumption of different electronic devices. At the initial stage of the research, the data collected from SEDM 1 was thought as a reference point to the potential use of the domestic technologies inside student households. For example, SEDM 1 not only recorded the monthly aggregated energy usage of students' homes but indicated which, when and to some extent how technologies are used. However, monitoring data failed to explain why technologies were used or failed to identify the cultural components that influenced everyday electricity usage. In order to understand reasons behind the technological usage we decided to investigate the connections between technology and other elements of practice (Gram-Hanssen 2010). Such an analysis could identify competences and meanings (Shove 2010) needed to perform a practice. How technological changes are influencing the other elements of practice and the performance of practice will be discussed in the following subsections.

6.3.2 Institutionalised knowledge and explicit rules

While it was not possible to start monitoring students' electricity usage from the move-in day, the guided video tours indicated landlords' intervention and involvement during the moving in. Arthur (House 2) provided me an example of landlord involvement when moving in the house: *'I have never... I don't think I've ever read a manual. It might have... The reason that I... I mean I don't even know how this works, but the reason that I have a slight idea of, you know, that heating up and stuff during the thing is probably because my landlord explained it to me on the day that I moved in. He would have given me some idea of how it works.*' In other houses however, the landlord is involvement lacked impact on students' electricity consumption. When discussed further in interviews, this was only reinforced: '*There's always a leak somewhere. Upstairs there's a leak in the toilet, so the landlord came out today and put an empty bean can underneath and was like I'll come back in two weeks and fix it. The bath doesn't drain, I tried to fix it. There was leak there* (Emily, House 4). One of the consequence of the landlord's low involvement on the moving-in day was that the institutionalised knowledge and explicit rules played a minor role in students learning how best to interact with their homes.

Jake (House 5) and Paul (House 6) had consulted the washing machine instruction manual before using it: '*Why did I look in it? I looked at it because… Well, just to make sure that I knew what settings there were on there, and what they were for, and how to use it and, you know, where to put the washing powder. Because there's three drawers, so washing powder goes in the left and the thing in the middle. And I think, to be honest, when I get electrical products I tend to read the instruction manual anyway. Even if it's something that I've used before; just to know and make sure…'* (House 3, Jake). What is interesting in Jake (House 5) case that he learned to control the washing machine based on the instruction manual. This would suggests that institutional knowledge can be transformed to know-how over time, as technology becomes routinized into the practice: '*For instance, with the washing machine, it's got a timer function. So, I can set it to come on later… [...]...Yes. So I set the washing up in the evening; so maybe about nine o'clock. Well, maybe not… Maybe ten o'clock, before I go to bed. And then you can set it to delay the finish of the cycle. So I have the cheaper electricity from 12 till 6:00am. So I usually set the washing machine to come on maybe four o'clock, 4:30, so it's finished before six o'clock.'* While institutional knowledge can be transferred into know-how over time, accidents and errors may disrupt this transfer, making practitioner to 'look back' or to 'look after' institutional knowledge and to consult instructions manuals to find out what went wrong. For example Steve (House 1) is telling me that the reason for using deionized water and not tap water when ironing is result from: *'Just from science over the years and things and the mistakes I've made by not using deionised water. And ironing my shirt and then having a big black mark across the shirt, and it's the last shirt you've got, that you haven't got any more shirts in your wardrobe so you know that, yes, really shouldn't do that. I've bought deionised water for the iron now. '*While Jake (House 3) is consulting instruction manuals to learn how to launder in House 5 the dishwasher itself is considered to be the source of knowledge on how to wash dishes: '*So dishwasher has a couple of settings and we always put it on eco. And we just put it on when it is full up really. We also wash quite a few pots and pans by hand because it ruins the quality if you put them in the dishwasher too much.* (Melanie, House 5).'

The institutions that students therefore attempted to rely on were more informal (such as friends and family, rather than formal landlord advice). For example Steven (House 5) who last year was using the campus laundrette would ask guidance from Emily (House 4) on how to use the temperature setting of the washing machine: *'Because I wanted to start doing my laundry because the settings were different than the ones on campus. The ones on campus you just put in colours or whites or whatever. This one is more specific to the temperature.'* Giulia (House 5) would also rely on Emily's (House 4) advice in finding the programs that fit her needs: '*I mean, actually I just wanted to be sure that a certain kind of programme corresponded to my idea of that product, and this is because of the language because maybe I can interpret things in a different way. So, I just wanted a confirmation from an English speaking person I think, because it was quite easy to understand.'*

While institutional knowledge had the potential to influence energy consumption it was not always taken seriously by students: *'I don't follow the instructions to the t, but I make sure I understand what they're saying. So like, if it says, don't leave in your hair for too long, rinse out immediately then I will rinse out immediately. If it says keep in your hair, massage into your hair for two or three minutes then I'll do that.' (*Kerry, House 7*)* or '*It depends on the stains of the different clothes. Like for my whites, I usually put two tubs because I want to maintain the brightness of the shirt'* (Steven, House 4). Even where ignoring the instruction manuals or safety regulations had caused damage, the practice may be undisrupted: '*Tap water, so I get all the crap coming out the iron because it's not ionized water. Highest setting because the iron is not as efficient as it should. So when I do iron I put it on three cottons, only for very delicate things will I turn it down* (Emily, House 4).

Even students from the House 7 which could be described as an environment where institutional regulations have more authority over heating, lighting or laundering admitted that they read the university accommodation regulations but admitted at least partly ignoring them: *'During the winter I did have an electric blanket thing that I put under my bed because it was really, really cold. That was my sister's, that she gave to me, so I put that on like, two or three hours before I went to sleep and then I'd switch it off when I go to sleep, yes.' (*Kerry, House 7*).* In other case Marcus (House 7) who was committed to reduce his carbon impact by hand washing his clothes would confess about the difficulties faced in doing this without machines: ''*For the past couple of weeks, I washed most of my clothes in the bath, in the bathtub and then for my last round of laundry, I went to the laundrette to drop it off at* *the Circuit laundry washing machines… [...]..Clothes that I washed by hand takes a lot longer. It takes a lot longer to dry as well and it's a lot more effort than just simply sticking it in the big, industrial washing machine.'* Similarly Ayeha (House 7) would complain about the ineffectiveness of the broom when cleaning the house: '*Definitely go for a hoover because it's so much easier to use as well. If you use a broom it takes like, a lot of effort and actually time as well to properly clean it, so I would definitely go for a hoover'.* These are just a few example suggesting that institutional knowledge may be less effective in changing practices that can be done without the use of technology.

6.3.3. Know-how and embodied habits

Harold Wilhite (2012, page 89) suggests that there are two sites or sources of embodied knowledge: the body and artefacts. While the artefacts (or technology) was discussed in Chapter 6.4.2 in the following we will discuss the way knowledge becomes embedded in the body (Wilhite et al. 2012) while performing comfort and cleanliness practices. Wilhite (2012, page 63), discusses the role of embodied knowledge to explain how individuals perform actions, and he argues that when people perform an action often, predispositions for next performances are embodied, and this embodiment happens due to the immersion of the individual in a certain cultural field. For example, the video recording of Paul's and Sandra's cooking revealed that Paul who spends more time inside the kitchen has a different routinized bodily activity than Sandra who mainly preheats prepared meals or takes the food from the freezer and defrost it in the microwave.

While some of the know-how can be transmitted through communication (such as instruction manuals); often know-how is embodied within physical routines and habits; for example, drawing the curtains at night, adjusting radiator valves or closing the doors to keep the heat in. This is fundamental to Wilhite et al. (2012) who call for attention to the body within energy research by exploring the role of experiences in the development of know-how around energy consumption (Royston 2014). In the following we will reflect on how experienced-based know is developed and used in managing comfort and cleanliness practices.

Sensory experiences is one way that know-how develops: feeling, seeing, hearing or tasting are important ways how students learn their homes, especially when performing practices (Royston 2014).

For example, while Steve (House 5) was using a thermometer to visually monitor the temperature of his room, Kerry (House 7) would describe me the way she was feeling the room temperature through its skin: '*My fingers tend to stay warm because I keep moving them it's… And I normally like you know, keep them… I keep moving and I guess, touching them to like, keep them warm because my palms are normally warm so I keep doing this when I'm working on my computer. It's my feet because now I've started making the habit to cross my legs so that my toes keep warm but otherwise I used to have my chair… Like, feet hanging from my chair so they're just kind of, hanging and they had no cover, so my toes would get really cold.'* When it comes to turning on the lights when working on PC students generally do not consider only the amount of light needed to illuminate their desk, but also the brightness of the space around them: *'Yes. That light wouldn't light up. If you can see, if I turn this off, it doesn't provide a lot of light really. So when I'm needing to read notes, when I'm having to make notes or read notes, hand written, not so much on the computer, but if I'm making notes, if I'm reading books and things, I need to have the lights on really, just to give general brightness of light, so... To help with that' (Steve, House 1)* or *'Because one is too less and the general light on the roof, it's too much. So two little lamps is a good compromise for me in terms of light' (Giulia, House 4).*

Nevertheless, know-how about the temperature or about the light intensity develops as students gradually 'learn their home'. For example, students could tell me not only which parts of the house are the coldest or the warmest but also the time of the day when they are experiencing different temperatures. Draughts can be felt as a breeze or coldness coming under the doors or windows. They can be made visible by curtains blowing: *'When it gets really windy, from the windows. My curtains will move, because the wind comes in. (House 7, Chadni)'*. In another case the coldness of the bathroom is used by Steve (House 1) to describe its desire for change in lifestyle:' *But then it's... It's not a struggle, but when you go to the bathroom and icy cold it just reminds you that, you know, this won't be forever.'*

In addition, feeling the cold metal at the top of the radiators, hearing the gurgle of the pipes or seeing the spark of the gas-fire are all sensory clues on when and how the heat is generated and transmitted by the heating system. As well, everyday interaction, engagement and sensory experiences may help in the identification of the faulty appliances: '*They smell fine but have you noticed that a washing machine smells really bad if it's left for a few days? It has a sewage smell and that's why I checked the* *filter really, I've checked it a few times. But maybe that's just a leak on the pipe behind it. (Emily, House 4)'.*

Another form of experienced based know-how relates to finding the best place for portable heaters or lamps. For example, Giulia (House 5) will brief me about the atmosphere that she creates when using her lamps: '*Because it means that I have a relaxed atmosphere in my room with soft light but strong enough to enlighten the space, the whole space of my room. This is why I have in two different corners of my room, so that the whole room can be enlightened without being too strong.*' On the other hand, Steve (House 1) describes me the way he masters the lights of his room when working on his computer: '*The general light will give me light for around the room, moving around the room, but these lamps are more for studying really. So if I'm not studying I'll switch these lamps off. So if I'm just watching something on the computer I'll switch these three lamps off and I may put these side lamps on just to give the room a bit of light and turn the main light off.'*

What we found interesting were improvisations or 'cheap tricks' in temperature management. Examples of methods that have been developed included using the oven to heat the kitchen (House 6); taking a steaming bath: *'to have a plain shirt for some reason, because if it were already crinkly, then it would just be hanging up in there, and steaming it'* (House 2), placing tinfoil behind the radiators (House 7) or using the dressing gown as a draught excluder (House 4). These improvisations are the result of the acquired know-how through experience (Royston 2014). Another form of know-how which influenced comfort and cleanliness practices was theoretical knowledge. For example when discussing with Marcus (House 7) about cleansing materials he would tell me: *'... I've not washed my hair in a month….Just to reduce my consumption of manufactured chemicals, I guess and I assume that any kind of synthetic, manufactured chemicals typically has a very damaging impact on the environment. So, I usually just use soap just to wash my body and that's about it'* or Chadni (House 7) will tell the reason for buying an energy saving bulb '*Just amount of kilowatts and then it just said energy saver and environmentally friendly, so I just went for that choice. I think it was a little bit more expensive than the others though'.*

As well, as through the sensory experiences know-how can be formed/transformed through collective experiences or through shared participation in practice. For example, Melanie (House 4) learned the maintenance of the washing machine while working for *'Beko, which is an appliance company, and I was in the customer service department and I used to have to advise people about how to use their washing machine environmentally friendly. Essentially that's where I got really… Apart from using them in life but I know how to maintain a washing machine',* Jake (House 3) learned to cook at an early age, from its parents and brother: '*Well, I suppose it's at my home; at my parents' home. So I learnt things from my mother. My brother, who's a chef as well; so that's his profession. So he taught me a few things when he was at home. And I think, yes, I just picked things up from my mother mostly; and then once I moved away to university, I took the opportunity to learn and practise things. So I had lots of cookbooks and I do actually sometimes use the internet as well to find videos on, you know, how to do a certain technique or something like that. So...*' While analyzing the shared know-how (such as what it means to keep the home warm) in different student households we observed that certain students in the study had a wider range of knowledge and skills or they were carrying out the same practice but in a different way. These students tended either to be older, or to have different experiences of the domestic technology upon which the other students had come to rely and so they could perform their practices in a more sustainable way. This echoes back to Strengers et al. (2012) suggestions that '*policies should prioritise infrastructures which provide adaptive opportunity'*.

In short, this brief exploration suggests that know-how is a temporally complex process influenced by experiences and 'practice memories' (Maller et al. 2013) as well as life-course moments and wider transitions in social practice (Royston 2014).

6.3.4 Engagements

Student engagements in energy saving practices existed but were not prominent practices. The motivation associated with efforts to conserve energy was best described by Jake (House 3): '*Usually, I think that, in terms of energy saving, or of the energy saving that I do, it's usually down to a financial aspect. So we don't have the heating on much, not because I want to help the environment by not using so much. It's purely because I don't have the money to spend, you know. If I was a millionaire, probably I would spend… I would have the heating on more.'* In House 1 and House 3 the performance of comfort and cleanliness practices was influenced, though not exclusively, by the electric bill (Gram

Hanssen 2010). This suggests that frequent billing has an effect on students' energy consumption and it can be used as a support in analysing everyday electricity consumption practices.

The make-up of comfort and cleanliness practices of students' households who had their energy bills included in their rent, was different from the other households, and this is evidenced by the building monitoring data. For example, the energy bill payer such as Steve (House 1), was keen to save more on his energy bill by 'timing his laundry' with timer plugs: '*I did not know how much electricity the tumble dryer was using once the dryer would finished…so I was concerned it might be using a bit more…you know…more than I wanted to use'.* Steve (House 1) had no idea if this was actually saving any money at all, but he planned to extend this solution and attach a timer plug to the router because during the night '*he is not using the internet at all'* and '*nothing important is going on during the night*', but '*that it is always on*'.

Furthermore Steve (House 1) was keen to control the temperature of his house by turning of the central heater and heating the house with portable heaters: '*...don't want to have the heating going on all the time... So what I did was I decided to then just heat one room up that I was in by having one of those fan heaters. I only bought that one this year. The other one I bought years ago. And I'd just have that fan heater with me down here. In the living room when I was in the living room, and then take it upstairs with me at night. And have it warm my bedroom up.'* As the gas is about a third of the cost of electricity per unit of energy, turning of the central heating and heating with portable heaters contributed to higher electricity consumption and higher electricity bills. What was interesting that the engagement that 'could be' saving money seemed to influence an array of domestic practices thereby producing different heating, lighting, working or showering related practices which increased Steve (House 1) electricity bill.

On the other hand, students whose bill was estimated by landlord were less interested in controlling energy usage: *'Before you started talking to us about electricity consumption, which obviously will bring to life how much we are using… I think I would say, apart from your heater which I didn't know about, I think we are quite low energy consumption. Even with that potentially… Compared to most people, because when I got to people's houses I notice that there are a lot of appliances all working at the same time and people have TVs and things and obviously we don't'* (Emily, House 4). From talking to the students whose bills were estimated by their landlords, it seemed they were less motivated in saving energy and more about their comfort level. For example Giulia (House 5) will describe the setting of the temperature of the house as a result of a compromise between householders: *'The temperature is good because it's warm enough but not too hot. I mean, there is not that much waste in my opinion, but you can enjoy a warm house in any case. So it is a good compromise I think'.*

Social expectations had engagements associated with what was regarded as clean and comfortable. For example in House 6 rooms needed to smell fresh and Sandra (House 6) was using air fresheners to keep out the '*smell of the kitchen*' while Rosie (House 6) considered the air fresheners '*an extra*' added to the atmosphere of her room. Clothing needed to smell fresh even if it does not look dirty: ': *'I have never left my clothes long enough to smell damp but I have smelt other people's clothes that have been hanging around too long and I don't want my clothes to smell like that* (Melanie, House 5). The freshness of the cooked food was judged based on its colour: *'You can see by the cauliflower will start going brown or black. You know? The broccoli will start getting very limp.* (Steve, House 1). As freshly cooked food could not be stored, this meant a large quantity of food was wasted: *'There's a lot of waste there because I've switched over to fresh vegetables recently. Before that there was never any waste because I'd have a microwave meal and it would go in, all the meal would be eaten. Now I find that if the veg is getting a bit old I can't stomach it. Because if I eat it and it's a bit old it goes through me'* (Steve, House 1).

Other practices that had engagements associated with social expectation was home making. The guided video tours and the building monitoring data highlighted that these practices increased electricity consumption. For example, Arthur (House 2) lamps were used in the creation of a cosy atmosphere: *'But it's not pleasant or cosy. It's suddenly... The moment you get this on and you got these side lightings, it's a bit nicer. That tends to be now the one that I keep on the most. And often I just have that one on. If I'm watching a film or watching videos on my laptop and not drawing, it's that one now, because it feels nice... [...]... It's not about those kind of lights. It's probably just it feels homely and things like that. That's what I mean by cosy.'* Misconceptions about the central heating controls, which was deemed to not provide enough heat made students to turn the heating up to the maximum and when it gets too hot to open a window. Anomalies recorded by the monitoring data prompted a detailed investigation on this subject that revealed differences in engagements with the heating: *'Well I mean* *it's not up to me. Like each room is slightly different, temperatures and stuff, and we all like different temperatures, so I'm not going to tell them off really. But I guess it is using a bit more electricity than… [...]…But it's less energy than turning the whole system on.' (Paul, House 4).*

Hosting guests' practices, moving in practices or preparing for the arrival of a new tenant have had clear engagements associated with societal expectations. For example, Giulia (House 5) moving-in demanded tidying up the house as well as *'getting stuff out the freezer for Giulia in case she needed a room because I freeze things. So I've been defrosting things, cooking them, making more space. So yes, I've been cooking a lot over this week. I can't think, though, what…'* (Emily, House 5). Paul (House 7) allowed friends to prepare meals during home visits: '*So, Lawrence prepared just a basic pasta dish, just cooked up some onions, garlic, tomatoes kind of, sloshed it all together and yes… Pasta. That involved the kettle, that involved the cooker and…'* Arthur daily hosted his neighbour who frequently charged his phone during visits that seemed not to be problem for the good host Arthur: '*I'm sure it does, but I don't like care enough about it for... To like charge him to use.*'

In short, the above examples suggests that engagements have a little to do with the machine itself and more to do with societal conventions. Strategies to achieve energy saving in higher-education therefore be better advised to deal with the conventions of the student residences rather than the machines itself.

6.4. Looking into performance of comfort and cleanliness practices

Lydia Martens (2012) remarks that interviews yield better understanding the organisational dimension of the practice (or practice-as-entity) than the activity dimension of the practice (or practice-as-performance). One of the reason of this is the utilization of the 'imprecise language' (Martens 2012) in interviews, '*the obvious inconsistency between talk*' (Martens 2012) and doings, and the interview context encourages '*performance-related silences*' (Martens 2012). Thus as suggested by Martens (2012) practice-as-entity can be is discussed with a semi-structured interview but the analysis of practice-as-performance requires a more dynamic approach that can help in understanding how comfort and cleanliness practices are '*constituted in and through their performance*' (Martens et al. 2016).

Following Martens (2012) after the semi-structured interviews on practice-as-entity we video recorded the activity dimension of specific practices. In the following we will exemplify the role of the video recordings in researching materiality, the way video recordings prompts talk about the performance of doings. By looking into the performance (Martens et al. 2014), we aim in discovering how Steve (House 1), Melanie (House 4) and Paula is (House 5) laundering, are constituted in and through their performance; what tasks are bought together in doing the laundering (Martens et al. 2014); how doings are sequenced, in what sense the performance of laundering has a routine quality (Martens et al. 2014); and how infrastructure, objects and bodies are used in the laundering process (Martens et al. 2017). The frequency of the laundering was influenced by the amount of clothing needed. Furthermore, the size of the loads dependent on the amount of clothing and types of clothing needed washing. As the clothes need a certain amount of room in the washer to move around, Steve (House 1) is laundering with a 'three quarters full', while Emily (House 4) makes sure *'the clothes not touching the top...there is some space'.* In explaining this Steve (House 1) and Emily (House 4) are making different kind of hand gestures (such as touching the inside of the washer) to help me to understand the way the washing machines are filled in. If this rule is not respected and the washing machine is overloaded the machine can cause physical problems: *'you can damage the drum...also your clothes will come out as dirty as it went in* (Steve, House 1). While during the interviews Steve (House 1) mentioned that he has a cold-filled washing machine, this time he will speak about the efficiency and the benefit of having a cold-filled washing machine pointing to the boiler: *'it's a cold filled washing machine...so it does not drain all the hot water from the hot water tank which I find more affective.*' Spinning speed is also important for Steve (House 1) as he expects to save something on drying costs if the laundry is spun faster: *'...it's a 1400 spin on the washing machine as well… so when the washing comes in...the washing is very-very-very dry. I had an old washing machine that was going up only to 1200 spin and the washing would be dripping as you are taking out from the washing machine. This is more effective spinning at a higher spin to dry a little bit quicker.* '

Image 6.2. Steve (House 1) showing to me the 'three quarters full' loading with his hands

On the other hand faster spinning creases the clothes and House 5 washing machine had an anti-crease button. During the interview session when discussing the ironing practice Paula (House 5) told me that '*We have an iron but I don't think we have an ironing board, and I do it as needed.'* When looking into the performance of the laundering practices while recording it she would routinely turn on the washing machine and press the 'reduced creased' button saying: '*.if I got like loads of shirts like that I put on reduce creased thing that turns this thingy down'*. When asking Paula (House 5) about what is that 'thingy that went down' she would tell me *'I just figured it out as I went along.'* Basically the 'reduced creased' option decreased the spinning speed from 1600 rpm to 800 rpm to help reducing creasing.

Image 6.3. Paula (House 5) showing the way she sets the washing machine temperature

While the clothing labels may stipulate the wash cycle temperature selection, when looking into performance of practices the washing cycle temperatures selection was based on the number of items loaded into the washer. For example while Paula will show me the way she selects the 'mini staff' cycle: '*...If I got only a few things…like say a few towels or whatever I will put on the mini staff [SHE PRESSES THE MINI LOAD BUTTON],* Emily will show me the malfunctioning of the 'mini-wash button' on House 5 washing machine: '*...although there is a mini-wash here but when I use that it goes around-around and around...and those that...I don't know why?...obviously it the fault with the machine…[...]...but the mini wash doesn't work just keep going and won't stop, I had to cancel the program, rinse, actually manually drain, spin and drain, so...*' . Steve (House 1) was using 'express wash' (or quick wash) option '*if the clothes are not too dirty and they need to freshen up I use the express wash button'.* Before the interview session while researching Steve (House 1) washing machine settings we found that the 5kg Bosch Maxx 1200rmp 'express wash' program is also called as the 'quick wash' program and was designed to wash a small amount of lightly soiled clothing (such as two pairs of men jeans). All three students mentioned washing cycle programs that they never used: extra rinse, pre-wash, rinse, delicate or wool cycles.

While instruction manuals define the type (such as liquid or powder) and place where the detergent needs to be placed, the amount of the detergent used is correlated not only with the freshness of the clothes but also with the quality of the detergent. For example, Steve (House 1) tended to use cheap detergent but after a while he observed some colour loss and colour fading on his t-shirts he decided to buy and use more professional detergents: biological for whites and coloured for coloured clothes. He will show me the brand and the quantity of the washing machine used when laundering. As Emily (House 4) was a smoker we wanted to find out the way she gets rid of the cigar odor. Thus, during the interview session Steven (House 4) would define clean clothes as *'If they don't' have stains or smell like cigarettes or…'* When looking into the performance of laundering practices Emily will show me the quantity - only *half of the cap of the detergent* that she uses mainly because '*Sometimes I get eczema, so I worry that it's the detergent.*' Thus for Emily (House 4) it seems that laundering products are seen as overpowering and it may be necessary to use less: '*Yes, I use it according to instruction but I use a little bit less because I think detergents can affect my skin.'*

The washing machine incorrect maintenance can result smelly clothes, leaking and even breakage. Instruction manuals give indication on how to properly clean and maintain washing machines. While Paula (House 5) did not read the washing machine instruction manual when looking into performances she would show me the way she cleans the washing machine after use. Firstly, she tends to leave the washing machine door open, in order to let in air '*so it does not kind of smell or whatever...'* and prevent germs from breeding. Secondly, '*sometimes I will put to wash own its own'* meaning she will run the washer on hot wash empty to get rid of the *'ill smell'*. As soon the washer stops Paula (House 5) will load the clothes into the dryer but before that she would make sure that the filter of the dryer to be clean. When asking Paula (House 5) to show me the filter of the tumble dryer that '*is probably not clean because I just used it...[...]...we do it when we need it'*. During the interview session Steve (House 1) would tell me that he always tumble dries his towels to make them fluffy and soft:' *If you dry them in the tumble dryer it tends to soften them up and makes them nice to sort of dry yourself on. I don't like drying myself with them, with like sandpaper'* and later when looking into performances she would show me the way he does this. While House 5 was using a vented tumble dryer in House 1 Steve was drying clothes with a ventless dryer that was consuming more electricity and required proper maintenance: '*I empty the condenser out, clean the filter every time...so I clean the filter so it isn't filling in with lots of things less effective...and also clean the condenser box regularly as well... '*

Image 6.4. Emily (House 4) showing amount of detergent she uses when laundering

The implications of these video recordings is profound and start to show how *‘language and talk form a resource and an obstruction when we want to think about mundane practices in scholarly ways* (Martens 2012, page 3)’. Firstly, while the camera does not record the invisible elements of laundering (such as warm air coming from the dryer or the smell of the detergents), it does record students’ reflection on these invisible elements and what they say about these, their facial and bodily expressions of the laundering practices over time. Secondly, while during the semi-structured interviews students were eager to articulate ‘what matters the most’ in doing a practice (Martens 2012) when video recording specific comfort and cleanliness practices students narratives followed a different line of explanation that included the use of their bodies in illustrating size, volume, length or area that mattered to most to them. Thirdly, the video recordings help in reaching and grasping the dynamic nature of comfort and cleanliness practices as it occurs rather than producing additional talk and text (such as CCTV recordings). Fourthly, in terms of how laundering practices are done by students and how laundering is explained by students, how I observed students laundering practices and the way I write about their laundering practices there is an obvious inconsistency (Martens 2012). In line with Martens (2012) this ‘*discrepancy would not have come to light*’ from the semi-structured interviews, as they disregard the naturally flow of everyday life and the material surroundings (Jalas et al. 2014). Finally, as suggested by Martens (2012) the language on how to do practice is situated in terms of understanding of a standard. For example, Steve (House 1) will tell me that he regularly dries her towels in a drier:'*... it tends to soften them up and makes them nice to sort of dry yourself on. I don't like drying myself with them, with like sandpaper'.* Thus Steve (House 1) does not explain to me the way he controls the drier or what type of drier he uses while drying towels. Instead relying on his own judgements of good and bad that are rooted in everyday experiences, tries to describe to me the wider conditions and consequences of tumble drying the towels. This has two implications: this mode introduces the public eye of a 'generalised other' and secondly, this also suggests that leaning on language '*would lead to accounts that do not grasp the element of materiality of practice*' (Jalas et al. 2014).

Some key questions arise some the above analysis: what do we need to know to talk about students' practices and how we should talk about the activity of practices (Martens 2012) '*knowing that our practice-based language it is stepped in standards and politics'* (Martens et al. 2017, page 10). The language used by students in analysing the structure and social organization of comfort and cleanliness practices were distinct from their practical-performance in which comfort and cleanliness practices were embedded. As argued by Martens (2012) practices may be made understandable through talk but the performative aspects of practices are less amenable to talk-based methods (such as interviews) as these practices only rarely subject to self-conscious verbal reflection by research participants (Martens 2012). Mixed methods might add further depth and insight to the analysis, as when building monitoring data, situated video recordings generated with the participants, are combined with interview data, allowing participants to explain the importance they attach to different practices and how they consider them to be meaningful (Martens 2012).

6.5. Conclusions

The aim of this chapter was to highlight the interconnections between energy managing practices using the smart electricity monitoring data. In this chapter we demonstrated that practices-that-consume-energy have different temporal features with more or less malleable position within sequences of activity in students' everyday life. This description of how practices-that-consume-energy connect in time is important because it shows the way certain characteristics of practices matter for the ways it can be link with others. Furthermore, by zooming in (Nicolini 2012) on specific practices-at-consume-energy, we specified why certain practices-that-consume-energy have a particular tempo or periodicity. This investigation helped me in discussing the relationship between the connections that hold practices-that-consume-energy together.

Practices-that-consume energy are clearly connected through a range of temporal connections. For example, timing of hair washing depends only in part on the Giulia's hair condition; it depends more on the scheduling and coordination of parallel activities (such as preparing to 'go out') that themselves depend on the day of the week (such as academic day or week-end day) or time of the year. This would suggest that the position of hair washing practice within the socio-temporal order is more about the organisation of patterns of practices and hence time in the home as a whole (Stanley et al. 2017). Furthermore, the temporal order of practices-that-consume-energy in students' households defines the organisation of everyday activity. For example, Julie and Melanie (House 5) are watching TV serials together (such as Grey's Anatomy or The Simpsons) on a specific time of the day.

Perhaps most importantly the findings of this chapter suggest that any energy saving intervention in comfort and cleanliness practices-that-consume-energy need to look beyond domestic technologies. Zooming out (Nicolini 2012) on energy managing practices (Naus et al. 2015) could offer a method of understanding the way comfort and cleanliness practices are interconnected and spread contributing to a range of resource management problems that the governments with the roll out of smart metering tries to solve it.

In the final part of this chapter we underlined the importance of the home energy visits that revealed different aspects of doings and saying of practise-that-consume- energy. If in Chapter 5, we argued that the video ethnography brought to the fore different elements of the home that could be conceptualized as 'flows' (Pink et al. 2015) that are managed by students in this Chapter 6 we used my camera to video record the saying and doings of different energy consumption practices. As we argued when performing domestic activities students were able to describe verbally and to show me the organization of the practice-that-consume-energy (Martens 2012, Martens et al. 2017).

Chapter 7: Looking for change in comfort and cleanliness practices-that-consume-energy

If in the previous chapter we were interested to find out how practices-that-consume electricity hang together, in what follows we are interested to find out what caused (or if not made) energy managing practice (Naus et al. 2015) to change. Specifically, this chapter examines the impact of SEDMs as form of intervention on energy managing practices (Naus et al. 2015) by exploring continuities and ruptures in practices-that-consume-energy. We start my discussion with highlighting design issues of the feedback studies carried out to quantify the effect of the immediate smart metering data on residential energy consumption behaviour. This will be followed by reflection upon receiving and using smart metering data for preparing for the last interview sessions. We will present findings obtained from using such mixed methods to investigate the cause of the change in energy managing practices (Naus et. 2015) that consume electricity.

7.1. The efficacy of energy feedback in halls of residences: limited evidence

In chapter 2.5.1. we reviewed trials that applied tailored information, goal settings reward and real-time feedback in students' halls of residences with the aim to increase energy conservation and energy knowledge. These studies suggest that a practical approach for inducing energy conservation in students' halls of residences is to monitor electricity consumption and to provide real-time feedback to the students. In addition, studies that metered the effect of the immediate, real-time energy consumption on students' energy consumption behaviour report savings up to 55% (Petersen et al. 2007) depending on study design (such as use of control group) or to use of different methodologies. The most important factors influencing the results of a feedback studies is halls of residences is summarized in Table 7.1.

Design of a good feedback study	Pitfalls
Sample size	Small sample may prevent the findings from being extrapolated. The smaller the impacts are, the larger sample is required.
Control groups with or without before-and-after comparisons	With a control group the impact of general issues can be controlled for (such as moving home).
Participant enrolment and selection of control and treatment groups	Voluntary enrolment self-selection bias can take place. For example consumers with interest in technology (such as timers, smart meters) more likely self-select and join the study.
A combination of several feedbacks and other information and incentives	Applying variety forms of treatments makes it difficult to accurately detect the effect of the treatment.
Duration of trials	A short period trials may result in-significant results. Long term impact require a long observation.

Table 7.1. Factors influencing the result of a feedback studies. Adopted after Zvingilaite et al. (2015, page 14)

Indeed, Emeakaroha et al. (2014) suggests that from a methodological perspective less robust feedback studies without controls yielded higher energy savings (Petersen et al. 2007), whereas more robust feedback studies that used control group yielded lower energy savings (Bekker et a. 2010). Other issues influencing the inaccurate metering of the real-time feedback effect in halls of residences are concerned with the duration of the trials (these studies lasted 2-5 weeks or less) and the combination of several feedbacks (such goal setting) and other information and monetary incentives within a single treatment condition. Evidently, these research design flows make it difficult to ascertain whether the effects of real-time energy feedback persist in the long term and to identify the circumstances under which real-time energy feedback had the greatest impact.

If there is interest in real-time energy feedback, it appears to result primarily from the financial rewards of the energy competitions with environmental motives featuring second (Emeakaroha et al. 2014). Thus, there is evidence suggesting that framing reductions in CO_2 emissions rather than in energy usage (Bekker et al. 2010) could increase energy reduction in halls of residences, but further research is needed on the effectiveness of such an intervention.

One of the ways in which energy feedback works in halls of residences is by recruiting students into a limited number of energy-saving actions. For example, actions that students can take in relations to real-time energy feedback are: (a) unplug devices (such as mobile charger, laptop charger, etc.) and (b) switch off devices (such as laptops, desktop PC, etc.). While real-time energy feedback may encourage students to conserve energy, the literature suggests that not everyone has the inclination or expertise to conduct such investigations. For example, a study by DECC (2013) identified that consumers with no formal qualifications reduced their energy bills by 41% while consumers with A-levels reduced their energy bill with 72%. Perhaps this would suggests that understanding smart metering data involves certain numeracy skills and analytic competencies that not everyone may have and this is critical to unlock the potential energy reduction capacities of SEDMs (Buchanan et al. 2015). Others have noticed that the effect of immediate real-time energy feedback varies widely within and between household (Murtagh et al. 2014, Van Dam et al. 2010). For example, in their study, Murtagh et al. (2014) characterise the energy consumption distribution between households as 20:60:20 split or as monitor enthusiasts, aspiring energy savers and energy non-active.

In conclusion, the findings of the energy feedback trials suggests that the effect of the real-time energy feedback is largely dependent on students action potentials that in term are influenced by living circumstances (such are privately rented properties) and by personal finances (Buchanan et al. 2015). Therefore, if the real-time energy metering data from SEDMs is to effectively reduce energy consumption there is a clear need to design a feedback that goes beyond the existing kWh, £ and CO_2 information and that require consumers time in energy in understanding, evaluating and reflecting on everyday energy usage.

7.2. Receiving smart metering monitoring data from students

One month after the first interview session we emailed students asking them to forward to me the smart metering data from SEDM 1. Basically, students had to connect SEDM 1 to their computer via USB and transfer the data using a Windows utility program which outputs a CSV file. However not all students managed to download and forward the smart electricity metering data. The first and common complaint was related to the pairing the SEDM 1 with the computer: '*Sorry I am quite rubbish with computers! I think that you need to come to show me how this is done as I do not have a cable and I* *am having to go out for the day now. I am sorry to be useless in this case!!!' (Emily, House 4).* Another complaint was with the data transfer process, for example Melanie (House 5) will email me *'Julie has not been in the house for over a month and has therefore not used the electric meter devices and so has not affected her behavior in anyform. I experienced troubles when downloading the OWL data last time and was wondering if it would be possible for you to download? If that is no problem for you, please let me know a time'.* In the best case the file was downloaded and forwarded to me, but without using the SEDM 1 software package that would diagram hourly, daily and monthly the electricity consumption: '*I have downloaded the data to excel as a CSV file. I hope that this is the format that you wanted - I wasn't sure what to do with the software' (Steve, House 1)* or *'Attached is the .CSV file for the electricity meter. Please let me know if that has worked properly.'* In order, not to lose the data we would visit and download myself House 4 and House 5 metering data. While Arthur (House 2) and Paul (House 6) promised me several times that they will forward to me the data, they fail to do this and the data gets overwritten and lost.

Using the monitoring data received from the students we started to look after change in energy consumption. An apparently simple analysis in investigating change in students energy consumption would be to compare the aggregated electricity used by households before and after receiving SEDMs. However, this is problematic in a number of ways: the days are not comparable as some fall in the early summer (after receiving SEDMs) and some in the winter (before SEDMs), the number of occupants and occupancy patterns were different in different households and the numbers and types of electric appliances differed widely too.

For example, Figure 7.1 shows Steve (House 1), who is leaving alone has the highest electricity consumption before and after SEDMs, while Jake (House 3) who leaves with her girlfriend has the lowest energy consumption before and after receiving SEDMs. On the one hand, looking at the aggregated energy consumption before students received the SEDMs (blue bars) suggests that students whose bill is included in the rent (House 3) have a lower energy consumption than students whose energy bill is estimated by the landlord (for example House 4). On the other hand, the after SEDMs (orange bar) data suggests that the cost of the energy is not the main factor in defining energy consumption. Furthermore Figure 7.1. suggests reduction House 3 energy consumption after receiving the SEDMs.

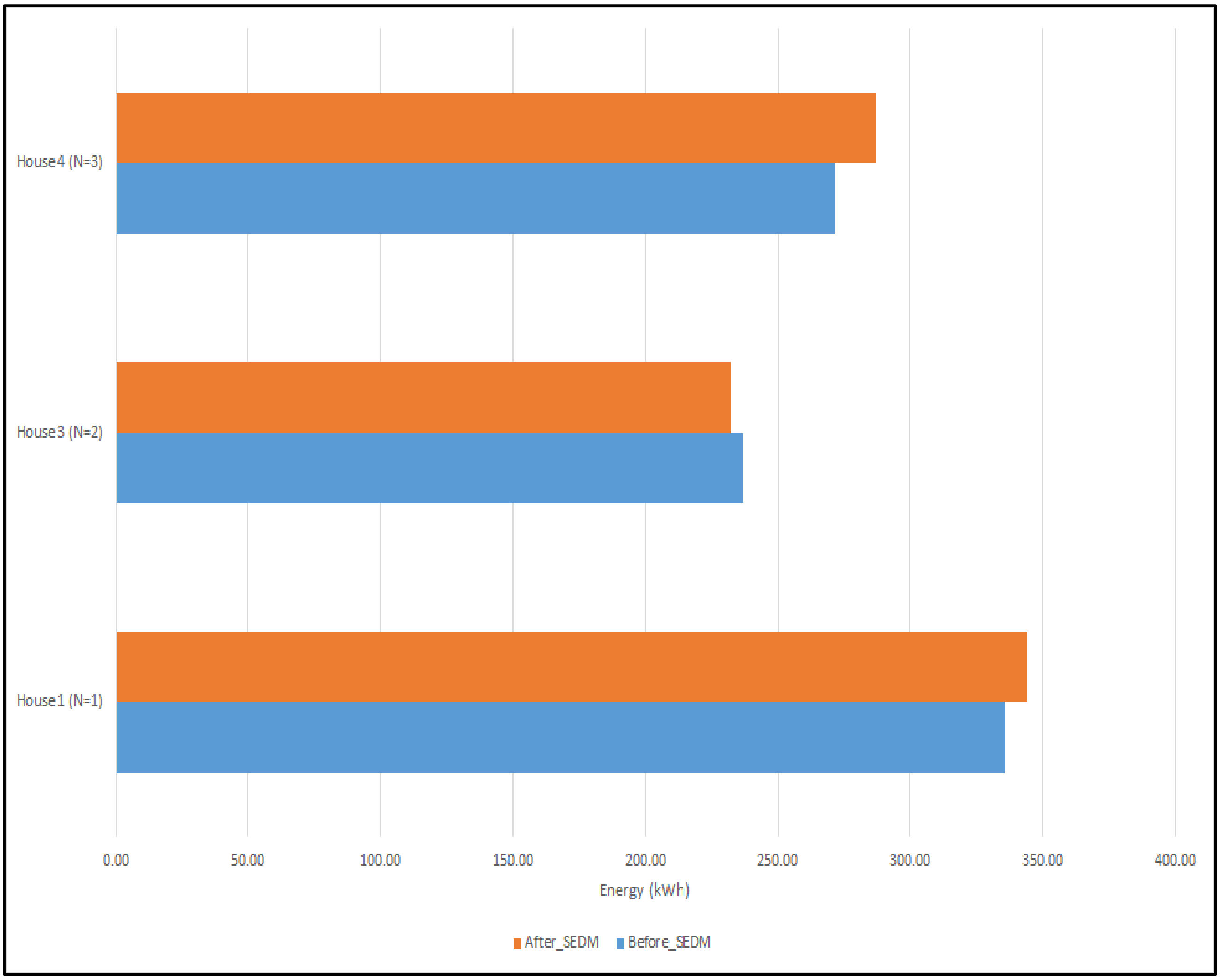


Figure 7.1. Aggregated energy consumption, House 1 (N=1, 28 days), House 3 (N=2, 26 days) and House 4 (N=3, 25 days) before (blue bar) and after (orange bar) SEDM 1

The disaggregated data suggested that the EDF EcoManager Transmitters plugs (SEDM 3) were randomly deployed by students throughout the home.

Although it is difficult to identify the cause of the change in energy consumption, the energy monitoring data revealed several interesting facts about students' energy consumption after receiving SEDMs. Firstly, the SEDMs recorded energy reductions in students aggregated energy consumption after receiving SEDMs. Secondly, the SEDMs recorded reduction in standby power. Thirdly, the appliance signatures suggest change in patterns of energy consumption (such as showering, laundering).

Therefore, for the second interview session we decided to diagram students electricity consumption (such as one diagram presenting the monthly electricity consumption with SEDMs, one diagram presenting the weekly electricity consumption before using SEDMs and four diagrams presenting the weekly electricity consumption with SEDMs and to discuss with them the role of the SEDMs in their everyday life. But before this we asked, every students 'kindly' to prepare for me a video diary on their way of living with SEDMs.

7.3. Living with the SEDMs

In total 10 video diaries were submitted by the students, before and after the final interview session. This activity involved use of a small video camera – such as laptop camera or mobile phone camera – during the preparation of a cup of tea, charging of a mobile phone, playing with Xbox or other electricity consumption activities. Students were asked to describe and to reflect on the way they consumed electricity during different activities and what is the role of the SEDMs in these processes.

we reached the idea of developing this method when, looking back at video recordings and at the materials that resulted from my fieldwork, we arrived at the topic of resource management (Strengers 2013). It seemed that some motivations but also contradictions on the way students were talking about their everyday activities that consume electricity were related to the attribute of being a student in a privately rented house. Another motivation for the video diaries was that most of my materials were related about domestic practices-that-consume energy, with only a few insights about the way electricity is experienced behind closed doors or when some of the household members were not at home. What we found interesting in these video diaries was the moment of reflexivity about the importance of the electricity as a commodity in daily activities.

7.3.1. Fiddling with the SEDMs

The disconnection between energy data and practices-that-consume-energy was highlighted when students were asked to meter their energy consumption using SEDMs. Thus, as a result of the difficulties in understanding and connecting the SEDMs data to their everyday practices-that-consume-energy, many students discussed why they no longer felt the need to use their SEDMs on everyday basis. In the literature, this phenomenon is interpreted as a cognitive problem (Kidd et al. 2008) that can be solved by providing meaningful information to the energy consumers (Abrahamse et al. 2005, Darby 2006, Fisher 2008).

Sandra (House 6) video records (Image 7.1.) how much energy she is using while charging her iPad. Interestingly, in doing this she will use the transmitter plug of SEDM 3. The transmitter plug is part of the SEDM 3 that can be controlled wirelessly from the SEDM 3 display. So, the relative running costs and CO_2 emissions of each smart plugged appliance is displayed on SEDM 3 monitor and not on the transmitter plug itself. This is observed by Sandra; '*you can see the lights on, but it does not show me how much I am using or how much is costing to me to charge iPad alone'*. Later she is telling me 'if *I am being honest...I don't really understand what is happening...and obviously I just switched on and the red light...but it is not telling me how much I am using or how much it costs...so I am really not happy with it at the moment...so I don't think I really want to use it...I don't really like how does it looks...there are no settings on it...nothing that tells me how to adjust it or...'* After a while Sandra will conclude that '*I really I don't know what to do with it'*. She would try to *'put it in a different socket...but I really don't know what to do with it...it doesn't monitor at all...doesn't tell me what I want to know so...'*. She will end the video telling me that she didn't really like them: *'...I don't really like complicated things or complicated gadgets...but is simple...but is a little bit too simple, it is just switching on and off button, what I would prefer something visual, maybe something with numbers, telling me the cost or how much I am using'* or '*how much this little thing...charging costs in my electricity bill'*. Alison gives advice to *'people who created them that this particular monitor is too simple, is not helpful at all'*; and she would rather use a gadget' *that would make a 'sound when going over the budget or something…at this point this is a useless gadget and I am not really happy about that, I don't like the gadget and I don't think that I will use the gadget'*.

Image 7.1. Sandra (House 6) video showing the fiddling with the IAM

Alison’s (House 6) concern is finding out the electricity consumption of the SEDM 2 itself. She starts her investigation with the question: ‘*how much actually does it cost to run the meter?*’ and ‘*how much electricity does it consumes itself?*’. In reflecting on the importance of having a SEDMs inside the home she is saying that her interest in joining my research project was to receive the SEDMs to lower the household electricity consumption. She is turning on SEDM 2 and is describing the display as ‘*so* *far the cost for the meter is 6.83, but I don't see anything for energy...and yeah...let me see what else I can press*'. Later she is correcting herself: '*ok the energy is...I think is...6.83 kW...I don't understand it...the meter without actually nothing plugged in...helped me to give an overview how much it cost to run itself….after me the meters are not so efficient...I don't think that they are all that great...I don't see the point of it...it costs too much to buy them in the first place and they are telling us…what an electricity company can tell us'*. Reflecting on the settings of the SEDM 2 Alison says: '*even though this one looks, particularly easy to use...I am not a big fan of the meters...if I'm gonna tell the truth really'*. She ends the video recording *'it is waste of 6.83 of energy, but at the end of the day I see no point in it...but I think if you are looking to be really energy efficient and you are really about saving the environment and like that stuff...maybe helpful for people who really are into that...but personally for me, it's' not that I don't care for the environment...I care about it...I just not really...like my priority is not the environment...I do other things to help the environment...but electricity wise...I do personally the best to reduce costs, but I don't think that I need a meter to tell me...this is how much energy you reduced...or this is how you are saving the environment or whatever'.*

7.3.2. Managing and monitoring electricity usage with SEDMs

Students who did some monitoring with the SEDMs would show me (or describe to me) their motivation for metering electricity inside the home. While these video diaries identify the context in which electricity metering occurs making references to the activities performed before and after metering occurred, they offer little understanding of the transformation made in their energy consumption because of the SEDMs data.

For example, Steve (House 1) is using the SEDM 3 (Image 7.2.) to manage the power consumption of his PC and other items (such PC monitor) connected to it. He is showing me the way he is controlling his PC with SEDM 3 '*…I am just* going *to bed right now so I am plugging in my charger to recharge my tablets…here we go…we are going to isolate the computer…at the mains on Eco-Manager* (SEDM 3), *so…I am expecting some emails in the morning so normally, shut down my broadband as well…but I will leave the broadband on in the case I got an email in the morning, so…I just gone shut down…so* *my computer is isolated, there is no power going into the computer just power going into the broadband at this moment downstairs…and I wish you a good night*'.

In the morning Steve is reflecting on the data displayed on the SEDM3 monitor *'….I am using 29£/month…how much I am using per week…would it tell me? 3.13£/day…now I am going to switch on my main computer…pressing and holding number 2 button where my computer and other items are connected to…press the on button…and watch the monitor…'*.Steve (House 1) observes the initial increase in energy consumption when the PC is turned on *'…so while initially starts up there is a little increase on the cost thing…I am using 28W of power, 3.29£/months that is 10.5 cents/day…so when I don't have my computer switched on…you know…I am actually saving something...when isolating my computer from the mains. '*

Jake (House 3) submitted his video diary a couple weeks after finishing the study: *'It is a couple of weeks that the study finished and I really observed a difference in… kind of a …awareness…I think this is the main thing that the monitors did for me…it raised my awareness with regards how much each appliance used…but also when I am not actually …hmmm…using the appliance…so for example the standing use of electricity in the house was something like 1.6 pence/hour…and…I could see that as my base rate…and when I know that I am not using anything I could see if that base rate was higher than the 1.6 or not…if it was it meant that probably I left on something on standby'.* Remembering the functionalities of the meters Jake explains: '*So in terms of study benefits towards myself I found that definitely it made me more aware…with regards to the monitoring and feedback…from the different settings of monitoring…it was interesting to use the single appliance monitor* (SEDM 1*)….just to see how much each of appliance used…I wasn't really sure…you know the TV used more than the Xbox or whatever '*. When it comes to the data displayed by the SEDMs Jake describes: *'In terms of feedback I really…I just used the cost/hour…I don't have to much....understanding or experience using kWh, etc. or looking at $C0_2$ produced that doesn't make to much sense to me on a daily basis, where as in the financial cost/hour…really raised…ahhh…caught my interest because I look at my electricity consumption'*. Jake ends the video diary with a reflection on the importance of the SEDMs in his everyday life '*when I look at my electricity consumption…I look to lower it mainly because of the financial…kind of incentive rather trying to be green or trying to help the environment…that kind of things.'*

Image 7.2. Steve (House 1) video diary showing the SEDM 3 display before turning down his computer.

Emily and Giulia (House 4) decided to share together the use of the SEDMs in their everyday life. In doing this, first Emily describes the way they are consuming electricity in everyday life '*So when we had the monitors in the house…so the fact we are both responsible tenants…the way we are using electricity is already quite responsible…I don't think that the monitors necessarily changed our behavior…we are both quite responsible anyway…we try our best to conserve energy and to waste it*'. Giulia gives me a different explication of not using the SEDMs: '*in a certain reason we didn't really care about our consumption and our cost because our bills are already included in the rent…so it didn't really mattered from an economical point of view and I think the economic reason is the most important at the end of the day.*' In reflecting on the applicability of the SEDMs in a real-life context Giulia is telling me: '*…but if you were a family and you really need to take care of your cost…I think this method of the meter where you actually you can see your consumption your costs could be really-really useful. If I was living in my house where I need to pay my bills definitely I would buy one of these meters'.*

7.3.3. Environmental reflections after using SEDMs

Some students considered being identifiable as an 'green citizen' and considered displaying these actions to roommates as important. Different visible signs were posted inside (in some cases outside also) the homes that indicated their commitments to the environment and some of the students were excited to show part of their environmental skills during the video recorded guided tours. In this sense, while some of the environmentalists reflected on the benefits of having SEDMs inside the household to reduce carbon emissions others mentioned the environmental impact associated with the meter fabrication processes (such as mining and extracting minerals).

Paul (House 6) overall considers that people using SEDMs will save the environment: *'I find it interesting because I study Environment and Sustainability...and so everything starts to become ingrained in me now that everything I need to do has to be...with awareness of environment and living a lifestyle that is not in any way degrading the environment of excessive...excessively using energy and resource...like that.*' Without using SEDMs in the recording Paul tells me '*that meters not only...you know...think about the environment...but also looking after your money, because they can save you a little bit of money but only if you know what you are doing'*. Paul explains what problems they had with the meters: '*we did not know how to use the meters...because …we are kind of…you know...very busy people...so we got a little push on said of it...so really think about how to use it properly...where to find advices or something like that'*. In principle for Paul the advice on how to use the meters is welcomed: '*on how to use the meters would be beneficial for us...I think' also 'thinking about bills...so things...getting used to that'* is helpful. Paul 'blames' the lack of time for a lack of engagement with SEDMs, and *'next time I would like to know more on how they work, how to use them most efficiently and what to look for in order to...you know...help...support the environment and save money as much as I can.'* As her roommates *Paul* suggests optimizing the meters that would involve '*different senses...having lights… [...]...so give you a little bit of warning about if your electricity consumption is too high or...something like that...that is easy to spot, because the thing is that with these tiny screens plugged into walls...with small digits...you know...it is not on the daily agenda.*' Furthermore, Paul is interested about how SEDMs are made, about the different parts of the meters, resource used to fabricate the device and he would be interested to know if they are '*sourced sustainably because that is important as well…and if they are affordable*'. Paul considers looking into the meters when he will live alone as a '*way of counting down your action…[...]…I could pinpoint where I need to cut down...or even, often doing okay'*. Paul concludes with *'these meters appeal more to people looking at the environment and looking to save money, I am definitely the first of those, so if it spreads awareness it will benefit everyone'*.

Marcus (House 7) describes the wider implication of using the SEDMs in everyday life: *'really helped…kind of present …kind of physical awareness and an immediate awareness of what is actually is happening in the household…in the Bungalow…it really helped…to present a challenge what was going on because it became very-very-very immediately obvious for me to see just how demanding my own habits were…in terms of energy and resource use and then having the ability to calculate the amount of carbon…the amount of carbon dioxide I was producing because of my habit'*. In reflecting on the way, he made sense of the information displayed on the SEDMs he is telling me '*what I felt could it been a good solution …which was…let's take this information...let's put it in a carbon calculator through google…and see what CO_2 needs to be at… production be at'*. Reflecting on the usefulness of the SEDMs is telling me '*…the point I am trying to make essentially is that the energy meters helped to start looking into a solution and try to get to a more balanced level for production, I think that was the most important think that I take away from that….'* Marcus considers using the SEDMs in the future, in real-time context '*…I do have a solution…get some solar panels on what was once a garden shed and see what's happens from there…and this is largely due to the energy monitor and obviously being in the Bungalow having this kind of deep awareness.*'

7.3.4. Conclusions on video diaries

In summary, the video diaries helped me to zoom in (Nicolini 2012) on students' personal experience of using SEDMs and they revealed their personal and subjective experience in real-time and in contexts defined by the students. In this sense, later the video diaries would help me to zoom out (Nicolini 2012) and to look at the household comfort and cleanliness practices-that-consume-energy as a whole. Furthermore, the recording of the diaries were different as students moved (and directed) differently the lens of the camera in reflecting on their way of living with (or without) SEDMs. What we found interesting was the way they addressed me during the video recordings sometimes revealing their need to share their experience with the meters or something personal about the others electricity consumption. Students appear very authentic and trustworthy in these recordings, and they portray themselves both as a responsible energy consumer, but they also show their insecurity in managing their energy usage with SEDMs. Later during the second sessions finding from the interviews will be prompted and discussed with the students.

Perhaps most importantly for the smart meter roll-out, the video diaries seem to suggest that using smart metering data to change (and reconfigure) everyday practices-that-consume energy has serious limitations. The first indication of this is suggested by Steve (House 1) video diary that focus on reducing consumption rather than reconfiguring practices-that-consume-energy. Shove (1997, page 270) warns about this '*Whether we like it or not, these revealing processes in a sense constitute what counts as energy. And what counts is often what can be relatively easily counted'*. Thus, by ignoring the electricity consumption associated with comfort and cleanliness practices, the seemingly non-negotiable routines that are deeply engrained into the fabric of everyday life (Shove 2010), receives less attention as the focus is on everyday electricity consumption. Furthermore, Steve (House 1) and Jake's (House 3) video diaries revealed some of the actions that students intended to take after reading the SEDMs display. For example Jake (House 3) used the SEDM 3 as an energy-management tool, in monitoring the household standby power consumption and in defining a normative benchmark (Hargreaves 2010, Wood et al. 2003) on how much energy should be used to a specific time of the day.

While the representation of the data (such as appliance specific or aggregated data) is clearly important in engaging students in energy saving actions , Marcus (House 7) and Paul's (House 6) video diaries illustrate that the institutional context within which the data is provided may increase engagement with the SEDMs (Burchell et al. 2016, Simcock et al. 2014). For example Marcus who was living in on Campus accommodation suggested that the SEDMs prompted him to wonder how to reduce his carbon emissions and '*to think look into solution and to try to get to a more balanced level for production'*, while Paul who presented himself as an Environment and Sustainability student, argued that the SEDMs prompted him to think about the smart meter roll-out process '*because that is important as well…and if they are affordable*'. In broad terms, Marcus and Paul video diaries suggested that part of the energy saving actions are influenced by a broader set of social and political contexts (Catney et al. 2013) in which institutions (such as universities) are engaged, for example in saving energy.

7.4. Co-investigating change in electricity usage using electricity consumption diagrams

While the energy monitoring data suggested reductions in students' everyday energy consumption, the monitoring data could not explain the cause of the energy reductions. Therefore, for the final sessions I decided to diagram students' weekly electricity consumption (such as one diagram presenting the monthly electricity consumption with SEDMs, one diagram presenting the weekly electricity consumption before using SEDMs and four diagrams presenting the weekly electricity consumption with SEDMs.) and to ask them to identify any reduction in consumption after receiving the SEDMs. My initial aim with the diagrams was to analyse together with the students how SEDMs feedback is incorporated in identify practise-that-consume-energy.

While some students looked into the diagrams pointing out changes in energy consumption, others were just staring at the diagrams not knowing how or where to look after change. Furthermore, not all students fancied this approach, for example the diagramming approach was criticized by the Steve (House 1), who says after looking at the diagram: '*...there are still peaks...there is time when I am using the tumble dryer... [...]...I don't think this is the best way to see it... I can only see when I got peaks…so this could be when I was using the tumble dryer, the washing machine and where I used the heater fan perhaps or where I have the computer plugged in...'* While Steve was capable of identifying different energy consumption activities, he failed to show me when and where the energy reductions occurred. After receiving the historical data (electricity consumption one week before SEDMs) he will show to me '*what I notice is that my little bits...I don't know why are these little peaks there?...regularly...overall...there is less of residual background sort of...seem to be less residual current used...I mean...it seems to be a drop in the amount of electricity use...though there are these patterns and things...'.* When looking at the spikes Steve will tell me '*it would be nice to identify what are the main peaks are really, but...less than...but more consistent peaks...bigger usage...less than the amount of the other one...but is consistent...consistency means using lot of energy'.*

The responsible energy users from House 4 will tell me '*It seems we are using less here...This is less... I don't know why?*' Asking Emily and Giulia to be more specific in their interpretation they are telling me '*because there are more troughs than peaks...yeah the peaks are the high consumption moments* *that are less then here...and this sort goes right near to the top and these ones...we never quite exceed...*'. In comparing the electricity consumption between weeks, they are saying to me '*this is very worrying [electricity consumption with SEDMs]', because 'of the thickness of the usage and the highest of the spikes*' or '*because of the frequency of the high peaks*'. Asking about disruptions in everyday caused by the SEDMs they will say '*if any change came would it be unconsciously because of the meters. Maybe the meters had some conscious level...we realized that they were there ...but not knowingly...' and they did not consciously modified behaviour*.'

While the above excerpt, from the second interview session highlight a specific 'vocabulary' used by the students in identifying change in electricity consumption patterns they fail to name the energy-saving-action(s) that resulted this change. On the other hand the interview with the electricity diagrams revealed students motivations in reducing electricity consumption, was less connected to troughs and spikes and more to everyday contingencies. Thus, while the smart demand policies assume that consumers will conduct 'mini investigations' (Strengers 2013) in connecting smart metering data with everyday-practices-that-consume energy, the above examples suggest that not everyone has the motivation or expertise required to participate in such investigations (Buchanan et al. 2015). Indeed, the understanding and interpreting aggregated and disaggregated energy consumption data is not an easy task, '*that involves certain numeracy skills that are seemingly needed if consumers are to unlock the potential energy reduction capacities of IHDs'* (Buchanan et al. 2015, page 92).

On way in which SEDMs work is by recruiting householders into *a 'coherent package of energy saving-actions'* (Strengers 2013, page 78). In investigating what energy feedback seeks to perform in students' homes, we video recorded what students are doing and saying when using the SEDMs and later during semi-structured interviews we were trying to explore the similarities and differences between elements of energy-saving-practises performed using SEDMs in Steve (House 1) and Jake (House 3) household.

7.5. Change in flows management after receiving SEDMs

In this subchapter, we are looking at the cause of change in Steve (House 1) and Jake (House 3) energy consumption activities after receiving the SEDMs. In doing this, we are using the *in-situ* video recordings in which Steve (House 1) and Jake (House 3) were filmed and interviewed as they were performing everyday activities that involved the use of SEDMs, for example boiling the kettle. After receiving the SEDMs Jake (House 3) and Steve (House 1) spoke of different types of electricity (such as standby power) that was present inside their homes and of the different kind of strategies that they employed in managing different types of electricity.

For example, in House 1 controlling electricity flows through the house was part of Steve's ongoing activity which made his home 'feel right' (Pink et al. 2012). It was either achieved through the plug-in timers used on the washing machine and tumble dryer or through the SEDM 3 IAMs (the so called smart plugs) that were plugged '*behind the desk and to switch the computer on and off and I do know when the computer are even switched off, still residual power is going through the screens, speaker systems, through my external hard drive possibly, through the printer and other things like that….'*

Indeed, in Steve's house, controlling the electricity has been emerging as important to the drying of laundry and controlling desktop appliances. Remote control occurred as *'a reminder as I am getting in the bed there is right beside my bed to switch off the items, to remember to switch them off.'* The 'set and forget' timers were important for the scheduling of laundry in everyday activities. What we found interesting was the way Steve treated the SEDM 3 smart plugs as part of his home infrastructure (Pink et al. 2015, page 173) through which light and heat flows could be controlled. For example he is telling me that '*I go to bed at night, I usually, switch off the computer first of all when I got into the bed, leave on the broadband for a little longer so I can send emails, receive emails, look on Facebook, watch Netflix on tablet, such sort of things when I go to bend I usually switch off the broadband.'* Thus, smart plugs were remotely switched on in the morning to allow in fresh flows of sounds from the PC and radio and later before going to bed smart plugs were remotely switched off to stop the residual power flowing, or to keep out the noise. On the other hand, IAMs weren't always considered successful in managing and producing flows. For example, Steve is telling me about the difficulties in controlling the internet rooter with a smart plug: '*since I got this new EEbox, I had to have one of the plugs for longer period of time because this take quite a while to reset itself, once it was set on, but this is mainly behind the desk it would be easier to get access to it.'* Yet, the technical difficulties this did not discouraged Steve from using the IAMs, who contacted his phone supplier who suggested an improvement on his phone line. On the other hand Steve (House 1) engagement with the SEDMs did not surprised me as during the first interview session he would tell me about his project on 'rewiring' his internet router to reduce his flat standby power: '*I'm looking at rewiring that just so that's on a timing plug so that will switch off between maybe one and six or something in the morning. And then completely switching the power off on my computer and the screens and printer and what not. Because even though they're switched off, they're probably still having a little bit of trickle flow through.'* What surprised me was the fact that Steve (House 1) used only the SEDM 3 at a specific time of the day and not all three SEDMs in managing his electricity consumption. Thus, as the SEDM 2 is equipped with a digital thermometer. We were expecting from Steve (House 1) to replace his old thermometer with the fancy SEDM 2. However, as he was not heating with the radiator fans any more, the electronic thermometer displayed on SEDMs was not needed (Buchanan et al. 2015).

Jake (House 3) using SEDM 2 identified rooms as differing in their temperature, highlighting the coldest and warmest parts of the house: *'As you can see it's 21 degrees now but back in April time because we only really have the heating on in the evenings so in the daytime when I'm not usually here, sometimes when I am here I look at it and it's like 13 degrees and I think oh, it's actually quite cold in here. It made me more aware how cold it was, I hadn't really noticed before.'* These examples helps us to conceptualize Jake's (House 3) engagements with flows of air that are already part of the rooms and the way he manages these in making the rooms to feel right (House 3). Furthermore he was using SEDM 3 IAMs to meter his newly bought kettle electricity consumption: '*so the meter is here, I keep it here because it was easy way to having it here…and the other thing…that was plugged in was the kettle so when it's on could see what's is using right now…and if I click to the other one [TELLING ME WHILE BUTTONING SEDM 3] takes a while to catch up…yes…this is the Xbox one 11pence/month…keeps flickering back for some reason eventually does go down to zero taking a while to come back on*'. Again, in this case monitoring the kettle electricity consumption did not surprised me as during the first interview session he would tell me: *'Yes, yes, I drink a lot of tea and coffee. So in the morning I'll make one cup for myself and for my girlfriend. And then later on in the morning I will make another cup for me. And depending on how long I'm here, if I have to go to university early in the day, then no. But if I'm going later, I will have some more tea as well.'*

We would argue that the biggest advantage of using the flow management approach was in identifying the cause of the energy saving activities. For example, video recordings of Steve (House 1) flow management skills with the SEDMs identified activities that remained partly invisible during the first meeting (such as switching off appliances before going to sleep) a so called in-between practice (Pink et al. 2017, page 174): '*So before I got into bed, I'd look at it and think, oh, I've got that still switched on, so switch it off now, yes.*' Switch off activity is spread around his house as Steve is telling me: '*So once I go upstairs I switch everything off down here. I don't leave the computer going or anything, or the printer or anything. I make sure everything's switched off.'* Indeed, it was present in different practices-that-consume-energy, placed a set of constraints on the performances of practices-that-consume-energy by specific time during which different practise could be carried out (such as browsing the internet).

For example, Steve was describing me the way he leaves the house before going to work: '*Oh yes, I mean I switch the lights off before I go now. I mean, the winter sometimes I'll leave the lights on because I know that I won't be back before dark.*' In another case when focusing on lighting practice he would describe to me the switch on and off as: '*'I mean, I switch the bathroom light on and I may have the upstairs light. Depends on how light it is in the house. If it's a bright morning I don't really need the lights on. If it's a dull morning I'll put the lights on.'* When it comes to working practices Steve (House 1) is telling me: '*Well, I switch the computer off at the buttons and I switch the buttons off on the screen and things, but it's always plugged in.'* The *in-situ* video recordings of House 1 suggested change in practices-that-consume-energy caused by the switch off function of the SEDMs. As Steve was telling to me: '*The Eco-Timer [SEDM 3] is good for actually being reminded before I go to… Because I set it up beside my bed. So before I got into bed, I'd look at it and think, oh, I've got that still switched on, so switch it off now, yes. Even though I may have switched the computer down, I'd notice that it's still on, so I just switch it off.'* Later during a semi-structured interview with the SEDMs we would zoom in (Nicolini 2011) on the organisational dimension of the energy monitoring practice (or practice-as-entity) (Martens 2012). Key findings from the transcript are summarised in Table 7.2.

Know-how	In the below quote Steve describes to invisibility of the energy, or how he conceptualizes the energy flows: *'I mean there is all the… I mean, even though people think they've switched their computer off, computers have… Forgot the name of them… Transformers in them. Transformers, anything with a transformer on it… Things like your lamp, when you switch off the power, you're actually… You're breaking the circuit so there's no energy running through that. You could have lamps plugged in all over the house, as long as they're all switched off, they're not using any energy. Anything that has a transformer that transforms energy from, like, AC to DC, that it's going to have residual power running through it. Because even though you've switched off the item or it's not currently on, you're going to have residual power. Unless you actually, physically, isolate the power going to the transformer, you've always got a little trickle amount going through it. And then that amount of course increases when you switch on the electrical item that it's powering. '*
Institutional Knowledge	As I suggested previously (Chapter 7.1.) the capabilities of the real-time energy feedback to reduce energy consumption is largely dependent on students' action potentials that in term are influenced by living circumstances (such are privately rented properties) and by personal finances (Buchanan et al. 2015). *'If I was given the Eco Manager for free I would use it. If I had to buy it, I wouldn't. Because I didn't think spending £80 was sufficient to providing me with savings that would equal that within a short period of time. I'd have to be looking at saving that would be above and beyond what, you know, it's saving me within a short period of time, really. To sort of... I mean, even with things like those cells you can put on the roof, the… What are they called? The energy cells. A lot of houses have had those put on them but they're owned by another company and you just get a proportion of what they generate. The solar cells, the solar cells on the roof. To buy them outright, it's, like, £7000 or £8000 or even more, depending on the size of your roof and what they have to do. And I'm thinking, for £7000, how long is it going to take me to recoup that money? You know, I only… I use maybe 1200 a month, it would take me ten years to pay that back. '*
Engagements	In the below quote Steve explains his motivation in engaging with SEDMs that is related to his private economy and not so much to saving electricity (Gram-Hanssen 2010, page 161). *'They highlighting when I've got things plugged in, more so, and… So not so much my electricity… I mean, I need to use the computer when I need to use the computer, that's it. I'll use the computer, I won't stop using the computer to think, oh, I'll save electricity. I need to use the computer, so the computer's on. But it reminds me after I've finished using the computer, and even though I've shut the computer down, to isolate the mains on the whole computer system. So the computer, the external hard drive, the screens, the printer… My lamps won't be using anything, once I switch the plug off on the lamp, it won't be using anything anyway but, you know…'*

Technologies	In the below quote Steve explains the way his technologies are placed and connected in different rooms, suggesting that the energy monitoring practice is not only influenced by individual devices but also by electricity infrastructures, broadband networks that shapes standby consumption (Gram-Hanssen 2010, page 162). ‘*Yes, you can observe what's plugged in. I mean, if I had all the items around the house plugged in and they're all set up on these things, you can observe, you can see very quickly what things are currently plugged in, what's currently using power and that sort of thing. Whereas, you know, I only had three plugs. So I made most… I made the most use, really, of it on the three main things that I use in the house, which is my radio upstairs… Apart from my fan heater that I plugged in to the other device, my radio upstairs, my Wi-Fi and my phone booster box, and then my computer on a separate plug. So I was able to, you know, be aware of, you know, switching them off and things like that when I'd finished using them.* ‘

Table 7.2. Examples from Steve (House 1) transcript when discussing the energy monitoring practice with SEDMs

7.6. Change in practices-that-consume-energy (without using the SEDMs)

Change in practices-that-consume-energy doesn’t have to evolve a SEDMs or a smart meter. Thus, energy feedback is only ‘*one among many forms of feedback that are integral to everyday practice’* and thus to energy use itself (Strengers 2013, page 92). Strengers suggests three forms of feedback: social, material and embodied sensory feedback (Strengers 2013, page 87) that are already embedded in practices-that-consume-energy. Foulds et al. (2014, page 20) develops this argument further by incorporating other modes of feedback that involves: cognition, sensation, materiality, sociality, policy and politics, and theory and research. Later he would argue for the exploration of these different modes of feedback process (or feedback loops) that could inform a more holistic policy and design approaches, going beyond the provision of smart consumption information (Foulds et al. 2014). In the following we discuss and exemplify the way social, material and sensory feedback changed practices-that-consume-energy in students’ households.

7.6.1. Social feedback on practices-that-consume-energy

Jake (House 3), provided me an example of the ways SEDMs may provide social feedback about energy consumption: *'... the benefit I got out of having the monitor and having that pence per minute, I can see what my kind of base usage is and if it's anything above that, then that gives me the indication to kind of think about oh have I changed something, have I turned something on and left it going?'.* Thus, Jake (House 3) in using the SEDMs established a 'base consumption', which he tried not to exceed: '*I mean I think my base consumption we were talking about earlier, think it went down by like three or four, or 0.3/0.4 pence an hour which isn't really very much; it adds up over time obviously.'*

On the other hand, in House 5, the girls were reluctant in using the SEDMs: '*We had a brief chat to begin with when you first put them in. I was like, this is what it looks like. But yes, I felt like we just sort of came into the kitchen, if it was on a higher number then we... There's obviously something in use in the house. But I don't feel like we properly spoke about it at any level'* (Melanie, House 5). This does not mean that feedback on energy consumption was not an essential aspect of practices-that-consume energy. For example, Emily (House 5) and Paula (House 5) reminded themselves to turn off unnecessarily lights or to keep heating low *'I think in this house like me and Rosie especially turn all the lights off, wherever. We don't leave the heating on for a long time. Whereas they'd like go out and leaving the heating on or whatever, which we don't do.'*

Similarly, in House 6 Paul advised (without using the SEDMs) her roommates on how to conserve energy: '*Let's turn off the boiler more and put it on only when we need it at night or something. But with electricity, we've never thought about it. I think we've just said, turn off the lights more often. That's what we've said. Because that's about it. Or, turn off your device when you're going to bed and you don't need it. Like, things like that'*. On the other hand, as Paul's roommates were reluctant to compromise on their comfort: '*I think it's part of my character really, but I wouldn't want to force someone to do something they didn't want to, especially if it's... Especially if it's something to do with their comfort, I guess. Like if I'm saying, look, stop using that, and it makes them feel uncomfortable, then I would rather not.'*

As the energy bill was included in students monthly rent the landlord also offered feedback on students' energy consumption: '*I don't feel like we used as much energy in the second semester. I think that's why we haven't been told about over-consumption by a landlord.'* (Paula, House 5) or '*Marc has never been like you've gone over your limit so I think we're pretty reasonable*.' (Melanie, House 5). Thus, feedback involves numerous actors (not only the imagined Resource Man) that operate on multiple temporalities (Foulds et al. 2014). In House 4 the involvement of the landlords in saving energy is judged differently by the students. For example, Emily (House 4) will complain about their landlord: '*No, because he's a bit useless about things. I mean we've got on-going problems with leaks, things in the house that he doesn't seem to... I think it's about money. So anything... Like when I wanted to put a hook on my door, I just did it myself because I thought he'd just... Like he gave us this really inefficient old fridge that has no space. It has a thing at the top, an ice box, and I said to him, for a house with three people this is... We're cramming it so the whole thing is having to work extra hard to keep things cool. And I was having to put my... Well, I decided to put my shopping outside in the outdoor area in the cupboards because I thought, well, it's cold enough. But now it's hotter, we've had to get another fridge, because that one was breaking down just because of the stress on it. So he's a bit rubbish at...'*

Arthur in House 2 tried to translate the information conveyed by the SEDM by impressing her girlfriend and friends with the wireless feature of SEDM 3: '*I showed her the lamp trick. I think I showed a couple people the lamp trick. Yes, because I was quite excited when I first got it. But again, you know, I wasn't going, oh, look how much energy I'm saving. I was going, how great is it that I can turn off this lamp from a distance? So yes, I don't know if that's good information or not.'*

The above examples suggested that just visualizing energy consumption data is not enough there is a need for a more flexible feedback that matters for practices-that-consume-energy (Strengers 2013). The success of the social feedback depends on the communicability of the information between household members as suggested by Chadni (House 7): '*In general, we were not communicating at all, really. I'm not sure why that is. But I guess we were all just busy. And I say that, but I feel like, I'm making excuse of it. But I think we were all quite busy, and I don't know, communication just didn't happen. We just weren't talking about things as much. So I'm not too sure.*'

7.6.2. Material feedback on practices-that-consume-energy

Other forms of feedback are explicitly material (Strengers 2013). In Chapter 5 we exemplified the way students are managing their home energy consumption by opening the doors and windows. Light timers and domestic technologies may also provide feedback on practices-that-consume-energy. For example in House 1 Steve was using light timers to reduce its standby power consumption:' *Yes, yes, sure. I'm using it on the tumble dryer. The catch that holds the door closed is powered so I didn't know how much electricity the tumble dryer was using once the dryer had finished. And so I was concerned that it might be using a bit more, you know, a bit more energy than I want it to use. And so… Come here, sit down. So yes, I used it, really, because I'd often put… If I'd done a wash on the night, I didn't want to leave the tumble dryer on overnight but I might want to put a tumble dryer load on in the morning before I go to university. So what I'll do is I'll set this so it literally comes on for, you know, an hour and a half, two hours at the most. And then set the tumble dryer to 60 minutes or something. But then I know once the tumble dryer's finished and the timer's finished, it's not then using more electricity to the actual machine with the door catch and things like that.'* While the 'timer plug' offered a flexible way for Steve (House 1) in scheduling (and switching off) his laundering practice it did not provided quantifiable data on energy consumption: '*It's a bit basic. It's a bit basic, it only works on a 24-hour timer. It doesn't work on a seven day timer. It doesn't, you know… None of the timers that I'm aware of adjust for changes in the daylight or anything like that. They don't have, like, a light sensor on them as well to override that for using it for lamps. So it's of limited use but it is useful.*' House 5 light-timer remained unplugged: '*never used it because our lamps didn't have working bulbs in them and so we... We didn't plug anything into it, we just sort of left it on the side of the room.* (Julie, House 5)'.

Some of the technologies in House 4 were designed to show standby power consumption: Emily's PC box had a 'vertical green light' that 'flashes when the computer goes into sleep'; Mark had a charging cable that had a 'ring that glowed' when it was plugged into a power source. Furthermore, in House 4 the electronic shower had an eco-setting that was trailed by Giulia: '*I start my shower at six. We've got an eco-setting... A cold setting, an eco, what's called an eco-setting which restricts the amount of water, I think that comes out and then we've got just two lines which is like the full power. I use the full power because I've found the eco-setting doesn't... Because I've got quite thick hair, it doesn't penetrate my* *hair enough to get the shampoo out. So... And I have it on six. I wash my hair, I rinse it, and then I put it on five. So it goes a lot cooler, and the stream is then more intense. And then I just...'*

In House 5 the washing machines had an eco-cycle that was used by Julie (House 5) regularly, without observing any difference in energy consumption '*I don't know. The other ones have temperatures next to them so I assume that the temperatures are lower on the eco cycle which I prefer.'* In general, in House 5 I observed that the use of the eco-efficient settings on the washing machine was defined by the amount of time the washing cycle it takes: '*I think the eco takes less time as well, and maybe a lower temperature.*'

In short, the above examples suggests that knowledge relevant to energy consumption is not only held by students but is also held by other agents within systems of provision/consumption (Foulds et al. 2014) such as materials. Thus, as suggested by Steve (House 1) a light timer can take control of doing the laundry scheduling it between other domestic activities. In House 5 the light timer was completely ignored, as it was considered to be uncontrollable.

7.6.3. Sensory feedback on practices-that-consume-energy

As we argued in Chapter 5 our bodies are important self-monitoring devices (Strengers 2013) providing feedback through our senses. For example, room temperatures were perceived differently by students: *'In the winter the house is far, far too hot for me. I mean you used to come around here, you've seen it. It was stifling. I'd open the front door and feel like I was walking into a sauna. And now I think that because of... I think the sunshine, whether it's hot temperature-wise or not actually changes people's behaviour in terms of heating. But I've only observed that, that's... If it was up to me it'd be off (Paul, House 6)'*. The influence of the weather on practices-that-consume energy was also observed by Julie (House 5) who remarks: '*In March I probably opened my window during the day, kept my radiator on two. Because it's not necessarily always set to the heating, we have a thermostat. But I would close it when I go to sleep. But now its warmer weather, and the radiator's off, I just think it's nice to get fresh air.'*

Perhaps, most importantly line drying was the most affected by the weather change: '*I think it's always going to be higher than I want it to be, living in a house that's poorly insulated. You know, I do try and watch how I use the electricity in the house. Plus, with the windy, coldish weather we've had, I haven't been able to… I've only been able to dry my clothes outside once so far. And then with the showers and things, I don't want to find my laundry blown all over the garden. So, this year's been a bit more difficult than most years. Normally I, once the weather warms up, I'll put the stuff outside. So, I've continued to use the tumble dryer.' (Steve, House 1).* Similarly, Melanie (House 5) will complain about the outside weather: '*In March the weather's still not great. We don't have a line outside either*.'

In House 6 Sandra was still heating with the radiator as she did not want to cut back on her comfort level: '*Yes, I learnt something from it, definitely. So, I would, kind of, cut back on my heating. But, like, I think when it's really cold, the first thing you think about is to keep warm. So, you find any way to keep warm rather than thinking about, okay, if I do this, the energy price is going to go up. You just think about keeping warm. So, I don't know if I would continue the trend next year and use it less. It depends on what the weather is like and how I feel.'*

7.7. Conclusions

The aim of this chapter was to identify the cause of change in practices-that-consume-energy with and without using SEDMs. In doing this first we looked after the cause of change in smart electricity display metering data. Only in one case the aggregated energy consumption data identified reduction in electricity consumption, while the disaggregated energy metering data suggested change in patterns of consumption. Students' video diaries provided an entry point in investigating students' motivation in living with SEDMs. While students who used the SEDMs suggested that smart metering data reduces consumption, the others were reluctant to compromise on their comfort. We also argued that students who used the SEDMs were already engaged in other monitoring or energy saving activities. For example, Jake (House 5) showed me his electricity provider mobile app telling me: '*I mean I have something on my phone, it's not electricity based but the data that you use on your mobile phone to check emails and things, I have a limit thing on there and then when I get close to it, it reminds me and it turns certain things off.'* Furthermore, I suggested flow management as an understanding the way practices are dispersed, interrelated and the ways they are enacted '*are contingent on the unique and shifting configurations of domestic environments'* (Pink et al. 2017, page 176).

In investigating the cause of change in households who did not used SEDMs we argued for other forms of feedback that looks beyond kWh (Strengers 2013, Foulds 2014). We exemplified the way social, material and sensory feedback transforms practices-that-consume energy even though SEDMs not. One plausible explanation of this is that the SEDMs feedback provide specific kinds of knowledge for a group of consumers to so called Resource-Man (Strengers 2013). On the other hand, social, material and embodied feedback play a critical role in the transformation of domestic practices-that-use-energy even if SEDMs feedback appears to play a limited role (Strengers 2013, page 92). Changing practices-that-consume-energy requires more than a narrow focus on designing feedback or SEDMs.

PART IV.
Conclusions

Chapter 8: Research conclusions on narrowing the gap between smart metering and everyday life

The overall aim of this thesis was to investigate the possibility of narrowing the gap between smart metering and everyday life by better understanding the energy management practices in newly established students' homes. This led to Chapter 2 introducing the smart residential demand response strategies that are characterized by the problematic divide between the spheres of supply and consumption. We presented the limitations of conceptualizing consumers as a motivated and knowledgeable micro-resource manager, who uses the data from the smart metering technologies to manage energy demand in a sustainable and affordable way. In challenging this individualistic, positivist and technology centred approach to understanding energy consumption we presented the way in which everyday practices are composed and changing. To challenge the technology centred approaches that seek to linearly change behaviour, we opted to explore how comfort and cleanliness practices are composed and changing in newly established students' households, and how smart metering strategies are reconfiguring the practices-that-consume energy.

This thesis adopted the following research question:

How can smart metering narrow the problematic divide between the policies and strategies of smart metering in undergraduate's day-to-day comfort and cleanliness practices?

Previous research investigating undergraduates' energy conservation behaviour in halls of residence identified real-time electricity feedback as the key motivator towards energy saving. Yet, there is limited evidence in the literature on the efficacy of real-time electricity feedback in managing everyday comfort and cleanliness practices.

In this final chapter we discuss the conceptual, methodological, and empirical contribution this research has made in answering the research question. We focus on key findings that could be adopted by institutional energy managers and other smart energy consumers.

8. 1. Summary of findings

In this section we explore the main findings and conclusions with regard to smart energy management practices, which were used to focus the discussion in Chapter 5-7.

8.1.1. The influence of moving home on practices-that-consume-energy

In Chapter 5, we investigated the effect of moving home on students' comfort and cleanliness practices-that-consume energy. In doing this we conceptualized students as managers of flows of air, light, and we highlighted how they make on-going interventions in the management of their homes as part of everyday life. For example, taking the example of the way students are lighting their rooms presented in Chapter 5 we could focus on the practice of lighting within which flow management is a skilled set of activities that are connected to the lighting practice and that are performed in normative ways (Pink et al. 2017). By giving analytical priority to the practice of lighting, we were are able to identify that when students are using for example their room lights, then the energy is consumed in a range of ways that are led by the practice of lighting, but that are not necessarily activities that are associated with lighting (such as listening to music or heating the room). This allowed us to question the 'neatness' of fit between (Pink et al. 2017), for instance, Emily (House 4) practice of lighting (Subsection 5.2.3., page 125) and the practices of, for instance reading a book, listening to music or more. As a conclusion, in attempting to capture and understand the connection between entities (such as heating and laundry) the flow management approach proved useful. The flow management approach reiterates that energy saving interventions need to look beyond consumers or technologies.

Furthermore we exemplified the way the in-between practices can be resurrected using the practice memory approach. This was exemplified with Emily's and Arthur's heating and ironing practice learnt in childhood and resurrected after moving home. For example Emily was using hand towels as a draft stopper to trap the hot air inside her room while heating and working on her PC. In this case we argued that the use of the draft stopper acted as an intervention in Emily's hot air flow management practices, suggesting a sustainable improvisation in flow management. On the other hand, in Arthur's case the use of the bathroom wall for steaming clothes suggested a resource-intensive intervention in-between practice of bathing and ironing. As a conclusion 'flow management' and 'practice memory' are useful concepts to demonstrate how change is everyday practices are happening in ways that are not commonly recognised by policy makers.

8.1.2. Using smart metering data and house plan to explore the temporal organization of practices-that-consume-energy in everyday practices

The main contribution of Chapter 6 was its methodological approach in bringing together smart metering energy data with practice-based analysis of students' energy consumption. The mixing of two different types (qualitative and quantitative) of data and method was shown to be useful. The smart metering data provided a better understanding of the bundles of practices-that-consume energy in students' households and that would not have been possible if using a qualitative only approach.

The methodological approach suggested that students do pay attention in managing practices-that-consume energy. Perhaps most importantly the findings of this chapter suggested that a typical day was arranged with respect to fixed practices (such as showering, cooking, shopping etc.) (Southerton et al. 2006), around which malleable practices organised themselves (such as browsing the net, watching TV) and within which time fillers slotted in (such as reading, studying etc.). Another important theme of this chapter was investigating the way practices-that-consume- energy connect in time. We argued that the description of how practices-that-consume-energy connect in time is important because it shows us that certain features (such as engagement, know-how, institutional knowledge or technologies) of a practice matter for the ways in which it can link with others.

As a conclusion, the support from landlords and mentors were shown to play a limited role in transitioning the performance of practices-that-consume-energy, from their old to new homes. Furthermore, in some cases students were keen to buy new electric appliances to meet their aspirations of what constitutes a new home (such as electric radiators, bedside lamps or coffee makers).

8.1.3. The influence of SEDMs on students' practices-that-consume energy

Chapter 7 investigated the effect of the SEDMs on students' practices-that-consume energy. Even though three different types of SEDMs were provided to students, only in two cases did SEDMs influenced practise-that-consume-energy. While students who used the SEDMs suggested that smart metering data reduces consumption, the others were reluctant to compromise on their comfort. As we argued, one plausible explanation of this is that the SEDMs feedback provide specific kinds of knowledge for a group of consumers to so called Resource Man (Strengers 2013). However, the SEDMs revealed different forms of feedback that was already integrated in practices-that-consume energy. This would suggest that the view that the smart meter feedback can linearly reduce energy and emissions is unrealistic. One of the reason is that the smart meter feedback does not account for the dynamism of everyday life. Furthermore, the way technologies were used by students was not in line with their original purpose. For example, Steve (House 1) laundering practice using a light timer to control the dryer, resulted the dryer was being used in an unintended way.

We do not argue that the smart meters feedback will not save electricity, rather we emphasise that there are no guarantees. Examples of consequences coming from the provision of student households with SEDMs included: confusion and uncertainty regarding their practical use; other technologies (such as signal booster in House 1) brought into their home were influenced by the SEDMs; SEDMs changed how seemingly unrelated electricity consumption activities in the home were carried out (such as going to bed); to name only a few consequences.

In highlighting the consequences of rolling-out immediate, real-time electricity feedback, new questions are raised: how do we go about shifting the mindset of researchers and policy-makers that the interconnection between everyday activities influence electricity consumption and smart meters alone cannot guarantee particular patterns of usage? As a conclusion, changing practices-that-consume-energy requires more than a narrow focus on designing feedback or SEDMs.

8.2. Understanding the role of the SEDMs on practices-that-consume energy

The summaries of each of the subchapters suggests that domestic technologies actively shape students' everyday life and provide opportunities for students to improvise in making and managing their privately rented home to feel right. However, the SEDMs that provided data on everyday energy or carbon savings were used less by students in improvising practices-that-consume-energy. One reason for this is that it provides understandable data to a well-defined category of users. Thus, the view that the smart metering community holds that smart meters can linearly reduce energy as well carbon emissions is unrealistic. The main reasons are, that it ignores the dynamism of everyday life.

However, we hope that this new context (such as students moving house) and the methodological approach will help in better understanding the relationship between everyday life and domestic technologies. As we exemplified the way in which technologies shape everyday life can result in unintended consequences that could produce unexpected energy consumptions. This would suggest that SEDMs may work for a specific group of users and not for everybody (such as there is no such think that suggest one-meter fits all).

The thesis provided numerous illustrations of everyday improvisations in managing home environments. For instance, in House 1 laundering with timer plugs to control the electricity consumption of the dryer, making laundering practice more flexible. In addition, the ironing practise of Arthur (House 3) resulted in escalating energy consumption. Further, Chapter 7 identified how the effectiveness of the SEDMs changed some of the student's engagements with appliances, and thus how and why the appliances were used. As a general observation, the way a technology in student households came to be used was not in line with its purpose.

The improvisatory use of different technologies was not only relevant for the *in-situ* interpretation during operation, but also to understanding the way these technologies were designed and constructed. The design of smart meters to encourage consumers in conserving energy pose great challenges to industry. The SEDMs highlighted the way practices-that-consume energy depend on consumer's past experiences with technologies, access to information, personal trainings at many other context specific socio-technical influences. Put, differently, practise-that-consume energy could be resurrected or fossilized, they could be substituted with alternative practices, or they could have been adjusted in some way.

The time is important for the organization of practices-that-consume energy. This thesis exemplified the way timing of different parts of a practice influences the use of different appliances. However, this thesis found limited evidence in student houses on the common understanding that practices must complete for time. The way students were managing and coordinating their time was highly correlated with flexibility.

Landlords, mentors, or communities of practice could help in the co-management of practise-that-consume energy. This was suggested by the video diaries of two students studying environmental science: Marcus (House 7) and Paul (House 6). Co-management could help students: in making practices-that-consume-energy visible and understandable and most importantly could narrow the gap between supply and demand while highlighting the resource characteristics of materiality and scarcity. In this context, smart metering could take a whole new meaning. A good example of this is Michigan University (Petito et al. 2017) who developed a reflective teaching case based on smart meter roll out. For example, the smart meter case narrative would ask students to reflect on the infrastructural aspects of the roll-out of the smart meters. Doing this they are visually engaging with online narratives, video clips, interviews but also conduct quantitative analysis in reflecting toward a final decision. On the one hand, in this context smart metering could take on a whole new meaning. On the other hand, in this study students who studied environmental science did not engaged in energy managing practices with SEDMs. One of the main reason of this was lack of knowledge in translating and connecting SEDMs data to their consumption.

8.3. Key contributions to knowledge of this thesis

8.3.1. Empirical contributions

This thesis contributes to knowledge in a number of ways. Firstly, using everyday examples, this thesis discusses how smart metering technologies, which are designed to reduce energy use in the home, can influence everyday life in students' households. Secondly, for *designers for sustainability* this thesis provides useful information on how smart metering technologies are experienced in domestic environments. Finally, for *designers for sustainability* may provide vital information on designing more successful smart technologies for everyday life. In discussing the role of SEDMs numerous other everyday influences on energy consumption were also discussed, all of which can assists to save energy.

8.3.2. Methodological contributions

The main contribution of the thesis is in the way we used mixed methods and crossed disciplinary divides (by metering electricity) in understanding everyday practices. A relatively few practice studies have used SEDM data in co-investigating energy consumption, and none in investigating the temporalities of practices-that-consume-energy. Consequently, almost all the work in Chapter 6.2. is original. Furthermore, in writing up my thesis various attempts were made to draw together electricity consumption data, photography, video-recordings, observations into one place. We do feel that we have demonstrated the usefulness of using these methods in the future as well as the value of spanning disciplinary and methodological boundaries.

Finally, we recommend the use of self-tracking technologies (such as heart rate monitors or sleep monitors) in investigating everyday activities. The self-tracking technologies (such as Fitbit) produce data on activities performed in different environments, creating a digital evidence of their bodily activities. For instance, some of us use self-monitoring technologies to monitor daily routines such as getting up in the morning or arriving home after exercising. In this role the digital technologies and their built-in algorithms guide users through their everyday life in a highly individualised and personalised manner (Berg 2017). Thus, the self-tracking devices algorithms are built around models of behaviour that are used to make interventions toward ‘behaviour change’ such as through the delivery of a text message towards healthy living.

For everyday life researchers the self-tracking technologies produce data about how humans engage with technological, physical and human environments and become assemblages with these environments (Pink et al. 2017). Here the concern is how people use data to make themselves feel comfortable, for instance, through everyday routines or data practices and through the relationships they make between their bodies and their data. Pink et al. 2017 found that '*self-tracking can increase people's engagement with cycling because it relates to the way that people are able to accomplish routines, and self-tracking can be a central enabler of these routines*' as such, showing how self-tracking and personal data motivates individuals to cycle because it increases their sense of wellbeing in ways that are already suited to them. Furthermore, they demonstrate that the data produced through self-tracking intervenes as part of complex entanglements of digital materiality, involving '*people, things, affects, and temporalities*' as they move forward in the world. This approach contrasts starkly with behaviour change interventions that attempt to motivate people to live more healthily (Pink et al. 2017). They conclude that *'any interventions for change that involve data need to always account for (1) how data becomes part of the generative processes of everyday life, and (2) how data is engaged in any particular context as affective technologies*' (Pink et al. 2017).

Future research needs to investigate the role of self-tracking technologies in flow management and how self-tracking technologies can be used in processes of change-making through everyday life.

8.3.3. Theoretical contributions

In Chapter 5 we argued for a focus on the performances of practices rather than practice. We exemplified the usefulness of using practices for analysing and communicating findings; how energy management practices connect different aspects of everyday life; how practices-that-consume-energy change; how practices-that-consume-energy are positioned in time; to name a few contributions.

Flow management enabled a more relational understanding of everyday life, energy and technology use across a set of different buildings and environments. Therefore, we argued that taking the concept of flow as a key analytical unit we are able to explore what people do, how they move through, sense, make and direct the spatial and temporal environments they inhabit. As we exemplified in Chapter 5, flows of air and light were central concerns for students, since they were experienced through their own movement and 'practical activity'. Furthermore in Chapter 5, we demonstrated that these flows and their management are important to how energy is consumed since they are associated with the use of appliances (such as bedside lamps or electric heaters) and consume electricity (or other power sources).

At the same time by conceptualising students as managers of flows we suggested tricks and techniques used by students (such as draft stoppers or fairy lights) for managing flows of air or light that are designed to make the home feel right. This leads us to question how SEDMs that are designed to help consumers to reduce energy demand can became part of everyday life (rather than change it)?

To respond to this question, we conceptualized flows as constituting the in-between practices through which energy is consumed, connecting what might otherwise be distinguished as entities (such as heating and laundering). In Chapter 6 for example, we exemplified that practices of heating and doing the laundry are identifiable and they involve a series of activities. In zooming in on the connections between entities we argued that they have different temporal connections that makes SEDMs less efficient in managing energy consumption. For example, in House 5 the SEDMs temporary resurrected sustainable practices (such as powering down the microwave before leaving the kitchen), however with time these practices returned to a dormant state. This was not the case in House 1 were SEDMs were used in managing flows and became part of Steve everyday life. Thus, Steve example would suggest that SEDMs can be incorporated into comfort practices.

As a conclusion, as suggested by Pink et al. (2017) *'looking at the domestic environment through the prism of flows, considering it as made up of flows and in part determined by the actions of human subjects as directors and appropriators of flows, offers us one way in which to situate practices*'. Thus, this new approach to knowing about energy consumption allows us to identify '*the interrelated and contingent activities, based on embodied, partly habitual everyday creativity and to how these are implicated in determining how practices are performed and accomplished*' (Pink et al. 2017, page 169).

8.4. Social-material network for energy managing practice

Building on the thesis findings we provide ideas and recommendations on how to design a hypothetical social-material network (Figure 8.1.). This is another clear contribution of this thesis, since using practice theory in designing social-material network is a relatively new area of focus in social practice literature. The aim of my analysis is to make the social material network for energy managing practices, as well to map within this network, the particular territory for intervention in practise-that-consume energy (Vihalemm et al. 2017, page 51).

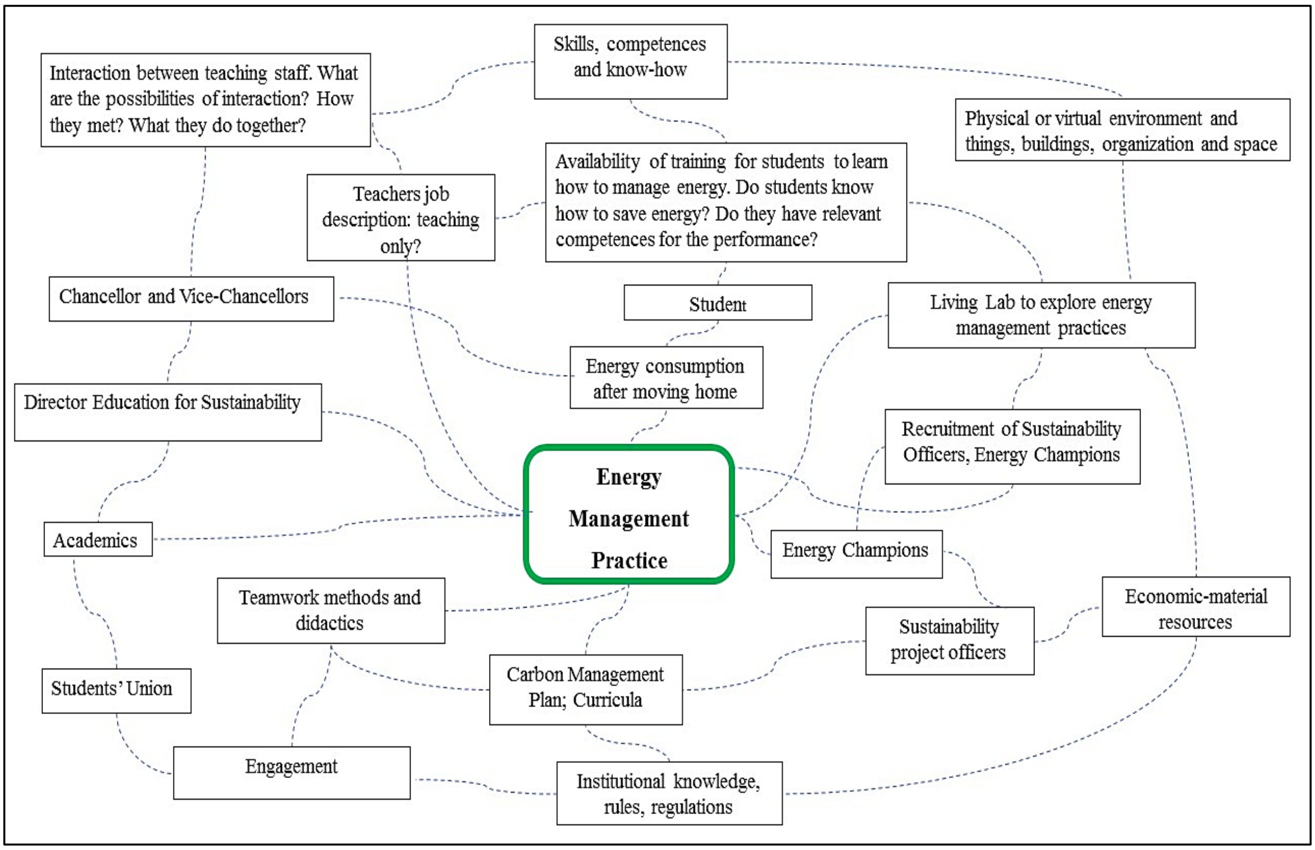


Figure 8.1. Visualisation of the socio-material network that enables energy management practice and the territory of a particular program to deal with it

We begin by mapping Gram-Hannsen (2010) elements of practice (technologies, engagements, know-how and embodied habits and institutional knowledge) that could be targeted in facilitating change, but also other types of factors affecting energy managing practices (such as home, landlord, etc). In the following we will briefly discuss (only) the elements of practice.

Technologies: Connection is critical between different technologies of different scale. In Chapter 7 we exemplified the way SEDMs enable but also constrain the connection between different technologies (this was the case of Steve EEBooster). In Chapter 7 we also exemplified the way technologies could be scripted in a certain energy saving direction (such as eco-wash). As suggested by Jelsma et al. (2003, page 107) design should encourage *'As a result of earlier inscriptions, the scripted materiality of the* *landscape creates all kind of gradients for behaviour, encouraging and rewarding what is acceptable, desirable and comfortable while 15 counteracting what is strenuous, contemptible and forbidden.'* While, Steve (House 1) was using the light-timer that made her laundering more flexible, Jake complained about the difficulties (having fewer sockets) in performing energy managing practise: '*The plug is also used by my girlfriend so I think she would be frustrated if it was always turned off, she'd have to…yes.'* In general scripting in smart technologies could be useful if connected to practices-that consume energy.

In Chapter 7 we argued for in-between practices (such as switch off), suggesting that technologies need to be designed explicitly to link two practice (Pink et al. 2017). We also exemplified the way students prioritise their interactions with technologies on the basis of practices-that-consume-energy. The SEDMs revealed the importance of designing smart technologies considering the context and application in order to engage consumers. For example the improvements that Arthur (House 2) would make with the SEDM 3 display would be '*So immediately the thing that strikes me is if that was over there, and didn't have all these big, old telephone style buttons, and it was just all one screen'.*

Therefore, smart metering technologies need to be designed to be more similar to domestic energy technologies. For example, when asking Emily (House 4) what is the difference between SEDM 2 settings and their microwave she replies: '*I think the microwave is easier. Because there are less things to be considered, like just power and temperature. I can actually see how... I mean you can see... You can check your food and decide when to stop it. I mean, it's... You have more signals in how to use that thing instead of the meter*'. Thus a more user centred design would make residence existing knowledge transferable despite being based on a very different use of technology.

Engagements: In this thesis, we exemplified the way private economy, ownership and some cases environmental factors influence how practices-that-consume-energy are performed. For example, Jake (House 3) would tell me: '*You know, you can just use them for information to know more about yourself and your habits and on the impact that these habits have on your finances and on the environment. And they also have a function in managing your money because they actually tell you if you are spending too much money. So you can... I mean, there is a double effect on your behaviour if you look* *at them.'* Therefore, economic incentives (such as building retrofitting grants) could help in changing to less energy consuming practices.

The social expectation of energy feedback should be targeted by educating students on how to translate and communicate the SEDMs energy consumption data to their housemates. Thus energy saving (and environment saving) should be more widely promoted because it was less present in engagement throughout the thesis. Energy saving measures needs to be promoted by landlords who, during my fieldwork, suggested that they do not think about promoting energy saving.

Institutional knowledge and explicit rules: Institutions (such as Student Unions, Universities, Agencies) need to ensure a good communication between those who receiving and those providing advice, otherwise it may be ignored. As in the Eigg case it is critical that trust exists between and within different communities of practice. Paul (House 6) and Marcus (House 7) video diaries revealed that institutional knowledge is inherently a product of the practices that are performed on campus institutions (such as growing food, recycling). These practices are important in the social material-network and need explicit attention in understanding how they relate to energy managing practices. Instruction manuals should be given by landlords or by residential institutions. While the literature suggests that there is no difference between aggregated and disaggregated energy consumption data, a more detailed and more frequent information (not only on electricity, but also on water and gas) should be given to householders. As we exemplified in this thesis a more frequent information may be useful for students who are performing certain practices in a certain context.

Know-how and embodied habits: In Chapter 5 we showed the way students are learning through experience, but this kind of learning while experiencing could take different paths in everyday life. Therefore, we are arguing for the establishment of interactive and participatory learning environments (so called Living labs) where students could teach each other on how to perform different practices. For example, Emily is teaching the washing machine setting to Giulia who is '*I could see how it worked but I wanted to be sure because I am very bad with technology so I didn't want to ruin anything*'. Hence it is vital that students to be exposed to different learning environments. In this thesis, we also exemplified the way previous performances of practice may be resurrected from dormancy. These are only a few examples illustrating type of interventions that could be undertaken in encouraging smart metering uptake activities.

8.5. Methodological reflections

8.5.1. What worked well?

The four aspects of my methodology that worked well were (a) metering households' electricity consumption before and after receiving the SEDMs; (b) using smart metering data to identify temporalities; (3) using different methods that informed my research and (4) longitudinal case study design.

Household metering data guided my research, it helped to look behind the closed doors. Using it with qualitative data helped me in understanding the electricity consumption of students' households at different times of the day. It was useful in comparing electricity consumption before and after receiving the SEDMs but also in considering the electricity consumption of the house while students were away from their home. The visual representation of the data to students made the investigation more interesting. While some of the students did not enjoy staring in front of the camera others enjoyed sharing with me the different aspects of the mundane. The video diaries were extremely useful for preparing for the interview session as we could access quickly the data but also to have the interviewee in front of me. Furthermore, the videos were used in comparing different practices; for example, we video recorded Steve laundering before using the SEDMs and later we focused on understanding the role of switch off activity in his everyday life. Moreover, the video recording and the video diary was extremely useful and helpful in analysing the different temporalities of practices-that consume energy.

8.5.2. What could have been done better?

There is always space for improvements and we would outline three aspects that should be improved: a.) data analysis and understanding; (b) duration of the research and (c) monitoring technologies. Data analysis was difficult due to the complexity of the data. A better solution for this would be feeding back to students the findings that may engage better in energy saving measures. While all students enjoyed my study (some of them even mentioned in their reports), the physical time spent with students was limited. Students' houses are full of visitors; in my view is a continually changing environment. Even when students leave for term break the house, the landlord takes over the place rearranging the home (such as bleeding the radiators) preparing for the students. The landlord's involvement in this research was invisible, they were always hiding from the SEDMs owner. As landlords are the owners of the houses they need to get involved in any research that effects the home environment. They could help in understanding the history of the house, the way it was retrofitted or the way they are renting the home. Monitoring technologies was good in collecting useful data, however the accuracy and the reliability of the technology is debatable. While students more or less phone called me when in the house was a blackout it was difficult for me to restart the metering without losing any data. Sometimes it took me hours to reach the student flat, and reconnect the meter. Monitoring technology is expensive but investing in more reliable, user-friendly and accurate meters may yield longer-term savings. These are just assumptions as at this moment the literature suggests the disinterest of consumer in energy monitoring technologies.

8.6. Future research

This research provided an abundance of research ideas for future projects. From the perspective of the longitudinal study we would increase the time of the monitoring observation. Furthermore, we would suggest the monitoring to be more flexible to the researcher and participants. We would monitor the performances of practices not practice, in identifying change. In doing this we would focus not only on electricity consumption activities but also other domestic activates that are bundle together in everyday life. We would analyse the competition between the practices to identify the organization and structure of the bundles. This could be done using the video camera however this time the students need to move the lenses of the camera while moving along in their everyday environment. Body cameras, CCTV may record different aspects of the mundane, but may also hinder the understanding of a specific activity. Clustering practices and not practice may help in improving our understanding of the temporal structure of the bundles. Do bundles have the same temporal organisation across households? If yes, how they change are some of the questions that needs to be explored. At the end of the day we found looking across science enjoyable and fruitful for my fieldwork and wectices would advise scientist to join this fascinating area of research

Appendices

Appendix 1 -Video tour schedule: First round with households

- Present yourself, read together the information sheet, consent forms (ask for signature), look around the house while they are completing the '*Tell me about yourself'* survey.
- Ask to show you the electricity bill
- Show them the camera and what you want to do with it. If they want make a tour of the house – move with the camera as much as possible. Don't forget you have a zoom in and zoom out button on the camera.
- Interview them during home tour. Ask to show you the cold and the hot spots of the house.
- Why they oved in here? And when they moved in? How much they stay at home?
- Show me your electric appliances, do you have a heater fan? Why did you put it there?
- Is there any difference in temperature during the day? How do you set the heating?
- When do you turn on the lights? Where is your room? How do you find your tour? Can you show me?
- How many layers of clothing do you were? Do you think that you feel the temperature differently than your housemates?
- What do you like in this house?
- How do you save energy inside the house? Can you show me?
- Do you feel the breeze? Could you show me the direction of the breeze?
- Actually, after moving in what did you made to feel your room right?
- Did you move furniture? Did somebody help you?
- Do you use any energy saving gadgets? Could you show me please?
- Is there anything that you hate in this house? Could you shoe me?
- Is there anything special (reading to energy consumption) that you want to show me?
- Do you have any questions for me?
- Then I will install the meter and I will come back later to collect the data.

Appendix 2 -Focus group/Interview schedule: First round with households (examples of questions)

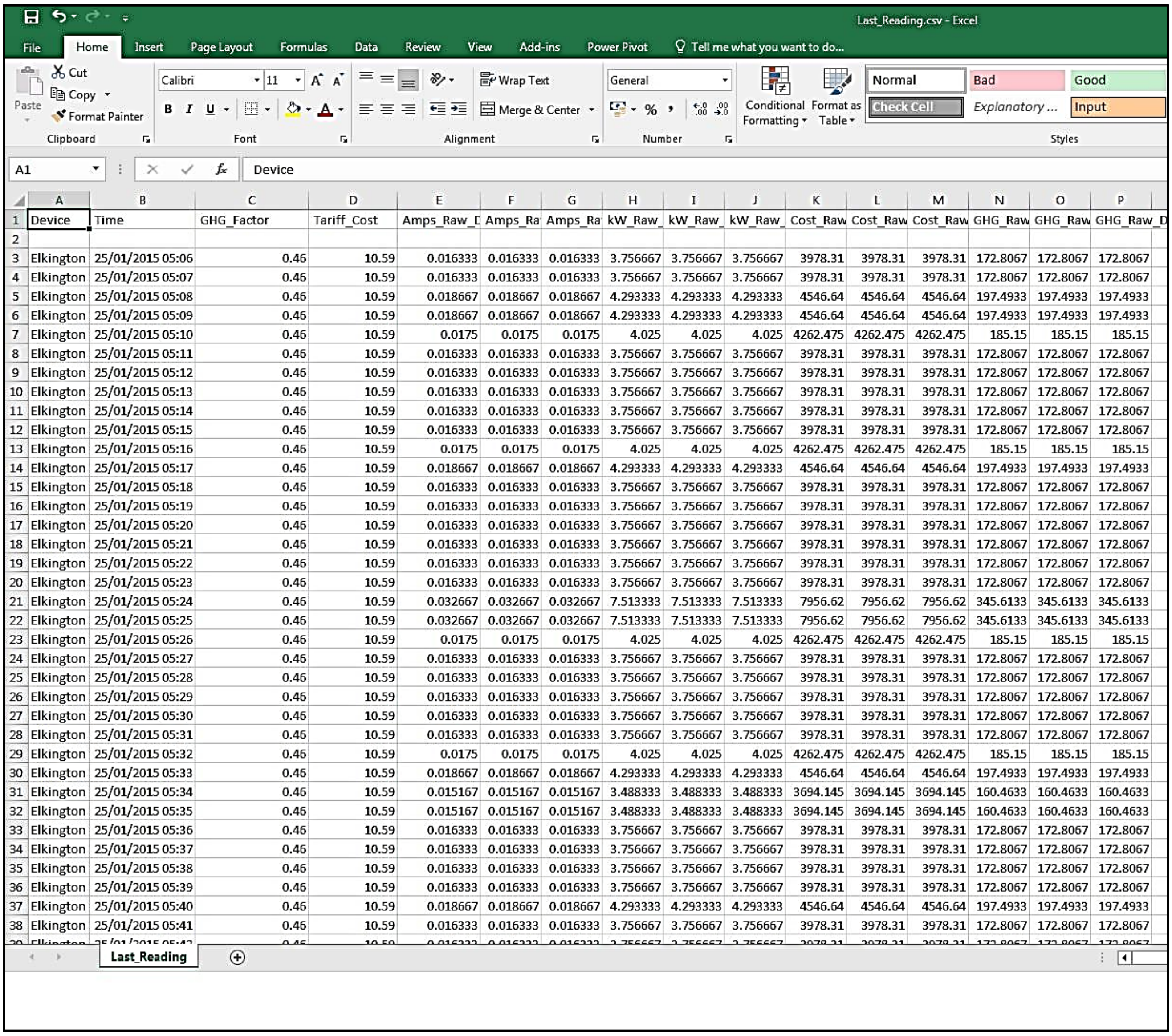
- Information sheet, read together and brief them about the evening session
- Ask if something happened while you were not here. Did you saw your landlord?
- Is the heating on?
- Explain to them the diagrams, ask to remember their yesterday.
- Help them, write on the graphs, make them to remember yesterday electricity consumption
- Ok, can you tell me who the first who wake up was? At what time? Did you wake up with your phone or with your alarm clock? Are you charging it during the night?
- How did you find the house in the morning? Are there any differences in the mornings?
- Which door are you using, the main door or you leave through the kitchen?
- At what time are you coming back? So this big peak is your afternoon shower?
- You are going straight to your room or are you preparing a snack.
- Ok, now I would like to interview individually, so who will be the first
- How often do you launder? Can you feel the smell of clothes? How does it smell?
- Can you show me the settings of the washing machine? Which one are you using?
- Why are using that one?
- Do you have eco-setting or eco-cycles?
- How much detergent are you using? Can you show me? How does it smell?
- Where do you dry your clothes? Is it healthy to dry your clothes on the radiator?
- What is the difference between the washing machine and microwave setting?
- Do you expects any visitors?
- Then please try to leave with these meters, and send the metering data. Don’t forget this because after 25 days the data gets overwritten, and we don’t want to lose it.
- If you have any concern regarding to the way the research is conducted please tell me
- Thank you and see you next time.

Appendix 3 -Focus group/Interview schedule: Second round with households (examples of questions)

- Information sheet, read together and brief them about the evening session. Ask if they have any concern question regarding to the research
- Thank them for submitting the video diaries and tell them that this is our lost meeting.
- So did you take the challenge and lived after the SEDMs?
- Which meter did you preferred? Why?
- Where is that meter now? Why did you placed there? Is visible form there?
- What is the meter telling you know? Why are the number changing?
- Is it the same when all day?
- Oh this you consumption diagram before and after having the meters. Do you observe change on the diagram?
- Could you show me? What caused the change?
- Were you inside the house or on work placement?
- Do you thing that you save energy? Why do you think that? Can you show to me?
- How do you feel the room know? Can you tell me the temperature of the room?
- What is the difference between SEDM 1 and SEDM 3, please show me.
- What was your first impression when using these meters?
- Why do you say that you changed your behaviour?
- What are you doing now with the meter that you did not before? Does it make sense?
- Would you buy tis meter?
- Do you want to have the meter for longer period of time?
- Would you like to join another project?
- If you have any remark how the research went please tell me, or email me.
- Thank you for your time.

Appendix 4 - Building monitoring data record extract

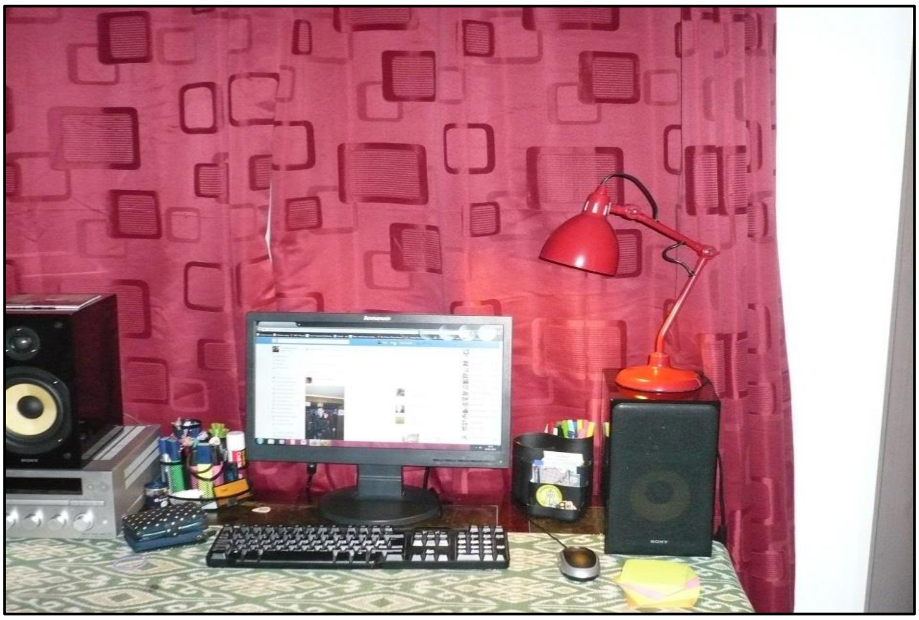
This appendix summarises the parameters of the building monitoring data: GHG Factor, Tariff Cost, and Amps_Raw . It also serves to demonstrate the size of the dataset used in this research,as the electricity was metered per minute.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Device	Time	GHG_Factor	Tariff_Cost	Amps_Raw_D	Amps_Ra	Amps_Ra	kW_Raw_	kW_Raw_	kW_Raw_	Cost_Raw	Cost_Raw	Cost_Raw	GHG_Raw	GHG_Raw	GHG_Raw_D
2																
3	Elkington	25/01/2015 05:06	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
4	Elkington	25/01/2015 05:07	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
5	Elkington	25/01/2015 05:08	0.46	10.59	0.018667	0.018667	0.018667	4.293333	4.293333	4.293333	4546.64	4546.64	4546.64	197.4933	197.4933	197.4933
6	Elkington	25/01/2015 05:09	0.46	10.59	0.018667	0.018667	0.018667	4.293333	4.293333	4.293333	4546.64	4546.64	4546.64	197.4933	197.4933	197.4933
7	Elkington	25/01/2015 05:10	0.46	10.59	0.0175	0.0175	0.0175	4.025	4.025	4.025	4262.475	4262.475	4262.475	185.15	185.15	185.15
8	Elkington	25/01/2015 05:11	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
9	Elkington	25/01/2015 05:12	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
10	Elkington	25/01/2015 05:13	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
11	Elkington	25/01/2015 05:14	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
12	Elkington	25/01/2015 05:15	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
13	Elkington	25/01/2015 05:16	0.46	10.59	0.0175	0.0175	0.0175	4.025	4.025	4.025	4262.475	4262.475	4262.475	185.15	185.15	185.15
14	Elkington	25/01/2015 05:17	0.46	10.59	0.018667	0.018667	0.018667	4.293333	4.293333	4.293333	4546.64	4546.64	4546.64	197.4933	197.4933	197.4933
15	Elkington	25/01/2015 05:18	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
16	Elkington	25/01/2015 05:19	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
17	Elkington	25/01/2015 05:20	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
18	Elkington	25/01/2015 05:21	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
19	Elkington	25/01/2015 05:22	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
20	Elkington	25/01/2015 05:23	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
21	Elkington	25/01/2015 05:24	0.46	10.59	0.032667	0.032667	0.032667	7.513333	7.513333	7.513333	7956.62	7956.62	7956.62	345.6133	345.6133	345.6133
22	Elkington	25/01/2015 05:25	0.46	10.59	0.032667	0.032667	0.032667	7.513333	7.513333	7.513333	7956.62	7956.62	7956.62	345.6133	345.6133	345.6133
23	Elkington	25/01/2015 05:26	0.46	10.59	0.0175	0.0175	0.0175	4.025	4.025	4.025	4262.475	4262.475	4262.475	185.15	185.15	185.15
24	Elkington	25/01/2015 05:27	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
25	Elkington	25/01/2015 05:28	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
26	Elkington	25/01/2015 05:29	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
27	Elkington	25/01/2015 05:30	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
28	Elkington	25/01/2015 05:31	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
29	Elkington	25/01/2015 05:32	0.46	10.59	0.0175	0.0175	0.0175	4.025	4.025	4.025	4262.475	4262.475	4262.475	185.15	185.15	185.15
30	Elkington	25/01/2015 05:33	0.46	10.59	0.018667	0.018667	0.018667	4.293333	4.293333	4.293333	4546.64	4546.64	4546.64	197.4933	197.4933	197.4933
31	Elkington	25/01/2015 05:34	0.46	10.59	0.015167	0.015167	0.015167	3.488333	3.488333	3.488333	3694.145	3694.145	3694.145	160.4633	160.4633	160.4633
32	Elkington	25/01/2015 05:35	0.46	10.59	0.015167	0.015167	0.015167	3.488333	3.488333	3.488333	3694.145	3694.145	3694.145	160.4633	160.4633	160.4633
33	Elkington	25/01/2015 05:36	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
34	Elkington	25/01/2015 05:37	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
35	Elkington	25/01/2015 05:38	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
36	Elkington	25/01/2015 05:39	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067
37	Elkington	25/01/2015 05:40	0.46	10.59	0.018667	0.018667	0.018667	4.293333	4.293333	4.293333	4546.64	4546.64	4546.64	197.4933	197.4933	197.4933
38	Elkington	25/01/2015 05:41	0.46	10.59	0.016333	0.016333	0.016333	3.756667	3.756667	3.756667	3978.31	3978.31	3978.31	172.8067	172.8067	172.8067

Appendix 5 – Examples of appliance photographs

Photographs were taken to record the positioning of appliances in the room:



In some case photos with energy performance certificates were taken:

Appendix 6 – Sample consent form

Title of Project: Investigating the effect of visible energy-metering, as form of immediate feedback, on undergraduates' energy consumption practices

Name and contact details of Principal Investigator: Máté János Lőrincz PhD Researcher, Keele University Sustainability Hub, Home Farm, ST5 5AA, telephone: 01782 733555, m.j.lorincz@keele.ac.uk

Please tick box if you agree with the statement:

1	I have been informed of and understand the purpose and procedures of this study and I have had the opportunity to ask questions.	□
2	I understand that my participation is voluntary and that I am free to withdraw at any time.	□
3	I agree to take part in this study.	□
4	I understand that data collected about me during this study will be anonymised before it is submitted for publication.	□
5	I agree to the focus group session being audio/ recorded	□
6	I agree to photos being used for research purposes (e.g. written reports) and understand that no personally identifiable features (ex. anything with your name or address on it) will be included in these images.	□
7	I agree to allow the dataset collected to be used for future research projects	□
8	I agree to be contacted about possible participation in future research projects.	□

______________________	______________________	______________________
Name of participant	Date	Signature
______________________	______________________	______________________
Researcher	Date	Signature

Appendix 7 – Project information sheet

Title of Project: Investigating the effect of visible energy-metering, as form of immediate feedback, on undergraduates' energy consumption practices

Thank you for your interest in this project. My name is Máté János Lőrincz from the Research Institute for the Environment, Physical Sciences and Applied Mathematics at Keele University and I am seeking research participants for my research project.

Please read this information sheet carefully before deciding whether or not to participate. Please take time to read this information carefully and discuss it with friends and relatives if you wish. Ask us if there is anything that is unclear or if you would like more information. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind.

What is the aim of the project?

I aim to understand how technological feedback mechanism can be applied towards the reduction of domestic electricity consumption within students' housing. More broadly, my research is investigating how students' expectations of comfort (heating and cooling) and cleanliness (bathing and laundering) are influenced by electricity-display monitors.

This research is important for several reasons. If comfort and cleanliness expectations increase or decrease as a result of smart energy monitors or in-home displays that provides real-time feedback to households about their energy consumption patterns, so too will greenhouse gas emissions, water consumption and cost of electricity for consumers. These impacts will be magnified with the roll-out of smart meters, which is expected to encourage householders to monitor and manage their energy use to save money or reduce their carbon emissions.

Do I have to take part?

No special knowledge, experience or preparation is required to participate in this research. The participants for this project are students who are studying at Keele University. You are free to decide whether you wish to take part or not. If you decide to take part you will be asked to sign two consent forms, one is for you to keep and the other is for our records. You are free to withdraw from this study at any time and without giving reasons. This will result in the whole house being withdrawn from the study as all four housemates must be involved to be included.

What are participants asked to do?

If you agree to partake in the project, your house will be invited to take part in the following activities:

- First, guided video tour, during which I will record the changes you made inside your room after moving to a new house.
- Second, one-hour focus group session in at your residence where I will ask you questions about your household practices which rely on electricity, water and domestic technologies. After this session you will receive smart electricity display meters (SEDM) and I will ask you to monitor your electricity consumption.
- Third one hour focus group session in at your residence were I will ask you questions how you felt having SEDMs inside your home and whether and how the SEDMs changed your household practices.
- Approximately 20 minutes to complete some simple video recording activities which can be undertaken at your leisure.

The focus group sessions will be tape recorded. The audio and video recordings, as well as transcripts will be kept on a password-protected office computer accessed by Máté János Lőrincz PhD Researcher. These files will be backed up on a USB memory stick kept in Máté János Lőrincz PhD Researcher office at Keele University Sustainability Hub.

Please be aware that you may withdraw from participation in the project at any time and without any disadvantage.

What data or information will be collected and what use will be made of it?

If you agree to partake in the project, your house will be invited to take part in three focus group sessions. I will ask your questions about your heating and cooling practices and how they have changed (or not changed) after receiving an SEDM. I will also ask some questions about your cleanliness practices.

In the event that the line of questioning does develop in such a way that you feel hesitant or uncomfortable you are reminded of your right to decline to answer any particular question(s) and also that you may withdraw from the project at any stage without any disadvantage to yourself of any kind.

With your permission, we will record and transcribe the session and summarise the information. The personal data will remain confidential to the research team (Dr Sharon George, Dr Zoe Robinson, Dr Lydia Martens and Máté János Lőrincz PhD Researcher). Only these individuals will have access to data.

Who is funding and organising the research?

My project has received ethics approval from Keele University and is being supervised by senior academic staff. The research is funded by EPSAM/ACORN.

How can I win the £15 iTunes/book voucher?

Houses that complete all stages of the study, i.e., complete all metering and attend a focus group are eligible to be entered to a £15 iTunes/book voucher.

What if I have questions or concerns?

If you have a concern about any aspect of this study, you may wish to speak to the researcher(s) who will do their best to answer your questions. You should contact Máté János Lőrincz PhD Researcher on m.j.lorincz@keele.ac.uk. Alternatively, if you do not wish to contact the researcher(s) you may contact Dr Sharon George on s.m.george@keele.ac.uk.

If you remain unhappy about the research and/or wish to raise complaint about any aspect of the way that you have been approached or treated during the course of the study please write to Nicola Leighton who is the University's contact for complaints regarding research at the following address:

E-mail: n.leighton@uso.ac.uk
Tel: 01782 733306

Appendix 8 – Description of Households Before and After receiving SEDMs

Household One

Two bedroom privately rented semi-detached house in a quiet area of an English town. Steve, who is a 35+ Pharmacy Student, have heard of this research from myself during the 'Society Sign Up' event and volunteered to try to live with smart electricity display meters. Gas cooker and the heating was managed with electric heater fans. Kettle hardly used. Electricity bill was paid by direct debit.

Electricity consumption before receiving the SEDMs: Steve was using timer plugs (set-and-forget devices) in his home. During the home visit he told me that the responsibility of the timer plugs was to control his tumble dryer electricity consumption. Thus, according to Steve '*I did not know how much electricity the tumble dryer was using once the dryer had finished…so I was concerned it might be using a bit more…you know…more than I wanted to use*'. Steve spends most of his time around his

PC; he had a thermometer in front of his PC monitor which was normal and necessary; his work flexibility meant reliance on different appliances connected to his PC but also, he had three different lamps in front of his PC that were used in lighting his living room.

Electricity consumption after receiving the SEDMs: For Steve, the SEDMs *'make you more aware'* of your electricity consumption because it happened with Steve to be 's*o tired I got into the bed...end I looked on the next morning, I did not shut..I did not shut it off...so it makes you more aware that things are plugged in end using power even if they are switched off...it is still using a residual amount of power... [...]... What I mean you can observe what's' plugged in. I mean if I had all the items around the house plugged in, and all set up on this things you could observe, you could see very quickly what things are currently plugged in, what's' currently using power and that sort of thing*'.

Steve would never buy one of these because *'they are very expensive for what they are really...you know almost £80£ for one of those with 2 or 3 plugs or something...I was thinking it is lot of money trying to save money...how long you have to use it for...to save any typical amount...other than saving money by switching the plugs off...at the mains...really*'.

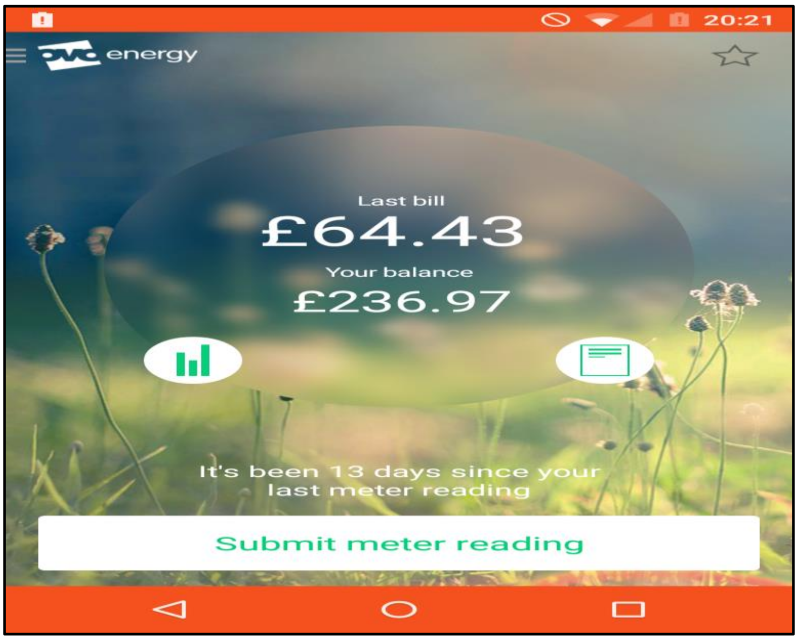
Household Two

One bedroom mid-floor flat with an open lounge and kitchen and a bathroom without shower. The heating is managed with storage heater. The flat was rented by Arthur, a 23 year old Pharmacy student who did a master degree on student perception of their greenhouse gas emissions. He joined my project to monitor his carbon footprint. Electricity bill was paid by direct debit.

Electricity consumption before receiving the SEDMs: Arthur was spending most of his time working from his living room. His desk was close to his large window and he was using desktop lamps. During afternoon he tended to have his desktop lamp on: '*The moment you get this on and you got these side lightings, it's a bit nicer. That tends to be now the one that I keep on the most. And often I just have that one on. If I'm watching a film or watching videos on my laptop and not drawing, it's that one now, because it feels nice...[...]... It's not about those kind of lights. It's probably just it feels homely and things like that. That's what I mean by cosy.'* Arthur was taking baths and was using the Campus launderette to wash his clothes. For Arthur long, steamy baths are part of his everyday activities: *'In the morning. Very, very occasionally I won't have time in the morning, because I might wake up, forget to put the hot water on before I go back to bed. Like if I'm really tired, I'll just wake up and go back* *and get back into bed. And then I'll wake up and be like, no, and I'll have to have one in the evening. Sometimes I'll have two a day. If I'm not well, it's really nice to get in the bath, or if I'm going out at night, like some people might have a shower, I just have a quick bath or something. Just to get nice and fresh and something. I really enjoy it as well. It's just really relaxing.'*

Electricity consumption after receiving the SEDMs: Arthur tried to translate the information conveyed by the SEDM by impressing her girlfriend and friends with the wireless feature of the SEDMs: '*I showed her the lamp trick. I think I showed a couple people the lamp trick. Yes, because I was quite excited when I first got it. But again, you know, I wasn't going, oh, look how much energy I'm saving. I was going, how great is it that I can turn off this lamp from a distance? So yes, I don't know if that's good information or not.'*

Household Three



Three bedroom semi-detached property, but just one room was rented by Jake, a 24 year old Music student and her girlfriend. One TV, gas cooker, washing machine, tumble drier, electric shower, TV, Xbox, kettle and gas central heating. He joined my project to monitor their flat electricity consumption. Electricity bill was paid by direct debit.

Electricity consumption before receiving the SEDMs: Jake is submitting regular meter readings and he is using energy management applications: *'I mean I have something on my phone, it's not electricity based but the data that you use on your mobile phone to check emails and things, I have a limit thing on there and then when I get close to it, it reminds me and it turns certain things off.'* He electricity saving behaviour is driven by personal finances: '*when I look at my electricity consumption…I look to lower it mainly because of the financial…kind of incentive rather trying to be green or trying to help the environment…that kind of things.'* He likes to play on his Xbox while waiting on her girlfriend to get ready: '*After that usually when I have breakfast I come in here and maybe I play some Xbox. Because I don't take very long to get ready. My girlfriend does; so I will have time to play, maybe 20 minutes.*'

Electricity consumption after receiving the SEDMs: Jake (House 3) used the SEDM as an energy-management tool, in monitoring his household standby power consumption. He was interested to find out how much energy should be used on a specific time of the day. For example while playing on his Xbox he observed: '*As you can see it's 21 degrees now but back in April time because we only really have the heating on in the evenings so in the daytime when I'm not usually here, sometimes when I am here I look at it and it's like 13 degrees and I think oh, it's actually quite cold in here. It made me more aware how cold it was, I hadn't really noticed before.'* Furthermore, Jake defined a 'baseline consumption', which he tried not to exceed: '*I mean I think my base consumption we were talking about earlier, think it went down by like three or four, or 0.3/0.4 pence an hour which isn't really very much; it adds up over time obviously.'*

Household four

Emily (31 year, Environmental Sustainability & Green Technology student) and her two housemates Mark (21 year, Biochemistry and Neuroscience student) and Steven (22 year, Law student) were renting a two bedroom mid-terrace flat-with the living room converted into a third bedroom. The layout of the house was quite unusual: with long and dark corridors, with a tiny kitchen located at the back of a sitting room and an upstairs bathroom located above the ground floor kitchen. This layout had implications on energy use, for example in reaching the kitchen from the first floor you had to switch on the corridor and stairway lights, the sitting room lights as well the kitchen lights. Fairly standard fittings with gas central heating and gas cooker. No TV, no tumble drier, everyone has a laptop, they have a record player and one fan heater in one bedroom. Unfortunately, before the first group session Mark left the house and on the day of the focus group session a new student - Giulia moved in. Electricity bill included in the rent.

Electricity consumption before receiving the SEDMs: Emily was complaining about the big gap under her door, and she showed me what she is doing to keep out the cold air and corridor lights. Emily was using a bedside the lamp more than the room main lights stating that is easier because when you do the University work '*you can move it (the light) where do you need it*'. Emily's PC box had a vertical green light that flashes when the computer goes into sleep; Mark had a charging cable that had a ring that glowed when it was plugged into a power source. Steven in his room was hiding a small office portable fan heater, which was designed to be easy for manoeuvring around the home, so to be used where it is needed the most. When it comes to the use of the washing machine Emily was considered to be the expert in the house as she was previously working in a BEKO call center and was advising customers on the use of the washing machine. Giulia was using bedside lamps to light her room; she was considering that the general lamp is too strong and she was using a softer light that is strong enough to light the space.

Electricity consumption after receiving the SEDMs: Asking about disruptions in everyday caused by the SEDMs they will say *'if any change came would it be 'unconsciously because of the meters. Maybe the meters had some conscious level...we realized that they were there ...but not knowingly...' and they did not consciously modified behaviour.*'Their 'impression' on standby power consumption is: *'overtime is obviously quite significant because it is continuously using energy and now that I have seen this on this graph, I think I would just flick the plug at the plug...so my AMP is not at standby at night, because what's' the point...I didn't realized that standby...and if everybody ...we switch things off we would save like...so much carbon...emissions...because of the power needed for the standby..[...]' and if technologies 'would get rid off standby it would be quite cool actually.'*Reducing standby power is not just one's responsibility and '*switching all the things in the kitchen in everyday might be problematic, because we don't want to do that because it is a communal kitchen for different people and we have so different lives'.* For example *'when Mark was turning the oven off... every single time these mains they break a switch...I would come in and without a fail I would put the oven on waiting the oven to heat up...and then come back [go back to her room]...because it was off...at the switch...but is that a standby?...so, I was moaning at him about him switching it off, I used to say please leave it on because I forget you switched off...and I would spend another half of an hour waiting for the oven the heat up.* '

When questioning students on '*how electricity consumption should be represented*' they will start to contradict each other. For example for Giulia the diagrams '*are easier to read instead of the meter...and if there would be a 'quotion' with money, I would be really interested to read this graphs*' but this not the case for Emily who thinks that 'i*f people would understand the significance of the amount of the carbon in atmosphere ...properly...like you know ...'Keeling Curve' and the parts per million and how* *if reach a certain amount of increase in temperature that will affect the whole Planet and if people could commit these things together they would see much more value in reducing carbon emissions than in money...*'

House five

Melanie (23 year old, Environment and Sustainability), Julie (23 year old, Physiotherapy) and Paula (23 year old, History and Politics) were renting from their last year landlord a three bedroom semi-detached house close to their last year or previously rented home. The house had two entrance: one leading to the kitchen and one leading to hallway. For security reasons the landlord installed spot lights above the entrance and these were controlled with motion detector sensors. The house had a nice layout with one bedroom and the kitchen on the ground floor and a bathroom, a 'meeting room' and 2 more bedrooms on the first floor. The main entrance had a thick curtain that was used by the students to keep the heat in. Furthermore a draft stopper was used to stop the cold air coming into the home. One TV, three laptops, washing machine, tumble drier, fridge, microwave that doesn't work correctly. Otherwise fairly standard fittings. GCH and gas cooker. The bill was included in the rent.

Electricity consumption before receiving the SEDMs: The girls would spend their time in the TV room chatting and watching the Simpsons. In doing this they usually keep the TV room curtains closed, and sometimes they would have a bedside lamp turned on. When watching TV they will have their room lights on (beside lamps and 'fairy lights'), the first floor corridor lights (landing lights) and the TV room little lamp on also.

Sunday, the girls would spend less time inside the house, for example Melanie has trainings and she would leave the house in the morning and she would come back late afternoon. Paula is rarely here in the weekends, she left the house Saturday morning and she come back Sunday afternoon 7pm. Before leaving she would take a shower, have a breakfast and inside her room she would unplug her devices for safety reason. The householders do not have a 'set day' for cleaning the house; this happens *'when it strikes one of us*' and they would tell me that they '*hoovered last week*'. When asking about the social time or the time that they spend together they would tell me that usually they meet after 5pm inside the TV room when watching TV series.

Electricity consumption after receiving the SEDMs: To a certain extent the information made available by SEDMs influenced students electricity consumption. They had a brief chat about the SEDMS, '*but probably that it...this is what it looks like..but we did not spoke about them at any point...what we spoke about was when the numbers went high...what's' that?...'*

In this case the meters were not used they *were just noticed* they were left in the corner. The SEDMs according to the girls have *'their intention to reduce electricity consumption and they are positive in some way when you turn off appliances,..but we still need to take shower, use the fridge...we can change that.*' But SEDMs made visible standby power because they always turned off '*appliances in the corner..from standby...and also from the TV room*', mainly because the smart plugs are recognisable things in the corner. On the other they never talked about standby power or electricity consumption.' The SEDMs reminded them that something is plugged in inside the house.

Household six

Paul (20+ year, Environment and Sustainability student), Alison (22 year, History and Politics) and Sandra (21 year, Social Work) were renting a 4-bed semi-detached house close to the University Campus. The house was refurbished and it was advertised as a shared house with four bedrooms (one with a shower), a WC which was shared between 3 rooms, a lounge with TV, utility room, a large bathroom and a fully equipped kitchen. The central heating and the cooker was powered by gas. What was quite strange (or 'awkward') with the house was the 'entrance'. Shortly, the house had 2 entrances: one from the front of the terrace and one at the back of the house. Basically, in order to reach the first floor rooms from the terrace entrance you had to go through the utility room, kitchen, lounge and stairs. Students were using the terrace entrance and when they came home they had to turn on almost all the lights inside the house. The door at the back of the house was leading straight to the stairs and to the lounge but due to missing pavement it was difficult to access, and was not used by the students only by the landlord. One TV, three laptops, two electric fans, two washing machines, tumble drier, rice cooker, two fridges, freezer, electric shower, microwave, and a kettle. The bill was debited by the residents.

Electricity consumption before receiving the SEDMs: Sandra's' room was on the ground floor, between the lounge and the kitchen. She was using different technologies, for example during our meeting she was playing music; she will tell me that the ' *I love music, and if I don't have my music on I feel empty, so [music] feel like home, play it makes me to feel good...comfortable*.' Sandra considers that her rooms is *'the hottest in the house, so that heater [pointing to the radiator] works very well' but because she works 'I do night shifts, I come back in the early morning..obviously the heaters [pointing to the radiator] is off...and I put that one [pointing to the electric heater] on*'. She doesn't know how her radiator valve is set, and later she would tell me that this not really important to her. Her room ceiling light is a really bright light, a fancy light, but she also uses a bedside lamp '*when I want light but not to much light, so when I do my work or something, I turn that off [pointing to the ceiling lights] and put that on*'. When she moved in she did made any changes inside her room (for example moving furniture) and she would say to me that she spends most of her time inside her room. She will leave her room just when he needs '*to go to Uni or cooking...and even when my friends are around I am bringing them to my room*'. The only thing that she bought after moving in was an air freshener that '*makes my room nice, I like when I have a guess over, it just give a nice smell* '. What she doesn't likes is her room the floor. she would like to have a 'carpet' on the laminate floor; and she has an issue with her door or '*I am anxious when I see bugs and staff...when I first moved in there was a spider which entered in my room...but I don't have that problem all the time.'*

Alison's' room was the smallest in the house. She was using her room just for sleeping, she would tell me that she is working from the campus and is very busy with her upcoming exams. When she moved in she 'pushed' her bed to the radiator because she was cold. So, she turned up the radiator valve and moved the bed close to the radiator. However because her bed is close to the window her room still doesn't get the right temperature; therefore she is also using an electric radiator fan.

Rosie, who just moved spends most of her time at the Uni and she is using her room just afternoons '*I will come back for dinner and I will spend my afternoon...*'.She likes her room because 'is a good size, I like the layout'. What made Rosie to choose this room was the storage space '*I had place where to put my clothes and a few outlets to plug in my lamp, my laptop and sort of things to charge...*' When inside the room she will 'usually' have her TV and laptop on, even if she leaves her room for chatting with my housemates downstairs. The TV in not '*important but is nice to be there, I did not had a TV in my last 2 apartments, so is not necessary is just nice luxury*'. She would use her room electric shower '*each day, when I am here, I am here only a half week because I go home to work..but yeah I use to shower each day, but I don't use a hairdryer though…*' She will tell me that she adjusted her radiator valve setting when she moved in '*because the setting was on low, so I turned quite high*' but '*it wasn't working initially and my landlord came and fix it, but now is still on high because we don't have the heating on*.' She considers the printer to be the most important device in her room because: 't*he nature of my course, I print quite lot of lecture slides and like sort of things..yeah'*. Her room ceiling room light is sufficient, '*I think is an energy saving bulb which is nice..so it doesn't ….that of shower has a light as well and I got the lamp for my desk...I got two lamps…[...]….but not even used the one on the desk yet...I hadn't needed to...so*'. She 'bought the one on the desk' because '*at home my desk doesn't get very good light so I thought I will needed it here studying...but I didn't*'. The '*other lamp is a dinner lamp so when I am reading at night*', but also '*my Kindle light is on, so I have a light when reading in the dark*'. Rosie's' air freshener is on just 'half of the week', she will turn it off when going home, 'my mom bought it for me ', but 'is not important to have it in my room because it is another added extra, not necessary, I don't think so,...but it is just nice smell.'

Paul is using his room when he needs to do a work and when he goes to bed. When inside his room he will have his main lights one, because is a dark room, he will shut his curtains and maybe he will open the window. He never adjusted the radiator, when he feels cold he takes up a jumper and when he is to warm open he will open the window. He considers his room fit for his needs. During nights he is using a sleeping bag that keeps him warm.

Electricity consumption after receiving the SEDMs: At the beginning of our focus group session I asked the students if they took the challenge of living with SEDMs. Interestingly there answer was positive: '*we used some of them, there were quite a lot...' Thus 'smart-metering devices' were used and they are 'quite clear, they show level and stuff, but they are quite bulky...'because '...we got quite a lot of kitchen tops and that..*'

When questioning about '*what did you metered first?'* Paul would tell me: *'when charging my laptop I was looking a little bit...using my laptop charger...so it's seemed that the actual greenhouse gas emissions...to see that in a figure….uhhhh….it kind make you to feel guilty .*' But they never discussed between them the data they just looked at it because '*you never thought how much electricity that you use everyday*'. In other words it was expected from the SEDMs to meter individual everyday electricity consumption and as this was not possible 'it *was quite interesting to see how much electricity is building up as we went along*'.

At the end of the day, for this household the SEDMs were designed for people 'w*ho kind of bit more energy savvy...and kind a really concentrating on...reducing bills and stuff…' and not for them who are 'busy doing other stuff…[...] the meters are in the background all the time*'. They also consider '*if they would talk more about the meters,...or if we would be more energy savvy...probably we would look at them more...and kind of concentrating on….maybe we can cut a little bit here….more or something.*' The biggest barrier in discussing electricity consumption is:' *we never at home...and to be honest forgetting...is easy to forget….[...] so I think if we would more in the house then maybe...*'

Household seven

Sustainable Student Bungalow (SSB) is based in Barnes Halls of residence at Keele University. SSB is a project that was initially started by four BSc Environment and Sustainability students in 2011 and since then students with different backgrounds practiced sustainable living. Basically, the project aims to underline the benefits of living a more sustainable lifestyle. Students who live in SSB are working together in managing their resources, such as metering electricity consumption with SEDM or growing their own food in the garden. Not anybody can live in SSB, Markus (22 year, Politics student), Ayesha (21 year, Environment and Sustainability student), and Kerry (21 year, Applied Environmental Science and International Relations) and Chandni (21 year, Environment and Sustainability student) were selected based on their academic results but also on their willingness to live a sustainable lifestyle.

During my PhD years I observed that students' who apply for a place in SSB already volunteered for 'green activities' (such as gardening or leafleting Green:Week), and after moving in they share their knowledge of 'sustainable living' (such cooking and serving meals to other students) and share (such as during gardening) with other students. In my view, some of the students before moving to SSB have their annual sustainable living plan in place also some students know each other before moving to SSB, they already visited the SSB before moving in or some students were living together before the SSB tenancy. At the end of the day, all of these (and many others) factors influence students sustainable consumption and sustainable use of resources. Students also know that they need to report to future tenants the advantages and disadvantages faced in living a sustainable lifestyle on campus.

Metering the electricity consumption of SSB was always an ‘issue’ for the tenants, for example the 2013/2014 Annual Report will mention: ‘*...the energy data collection this year has been poor at best. This is due to a combination of hardware problems and the residents’ inadequacies, including times where the problems appear to have been fixed, only to find out a week or so later that the data was still not recording or it was recording intermittently, as happened in February. A new energy monitor has been acquired which is yet to be installed, so hopefully these mistakes will be avoided in future.* ’

Electricity consumption before receiving the SEDMs: The kitchen cooker is old, probably from the 1960, without any eco-friendly certification on it and the microwave is ‘probably standard or similar with the other microwaves across the halls of residences.

Inside the kitchen I observed so called energy saving messages or tailored energy saving advices left by previous tenants. Basically, these were guiding messages on how to save water and electricity, but also information on future planned activities. The living room had its own entrance and it was the room were friends would stay or ‘would stay overnight. The room was heated by three radiators. Marcus told me that his bedroom number four is not used therefore ‘is not relevant to the research, and Marcus was sleeping in this room as his room was not ‘warm enough’. Ayesha's’ room had two windows with curtains that were positioned differently during the day. Basically, during night all the curtains were shut and during the day the back window curtain remained open, to get some sunshine.

Chandni after moving in started to rearrange her room. She moved her bed from the radiator -thinking ‘*it will be really warm*’ but ‘*it was warmer on the other side of the room then next to the radiator...I don’t know how that works*’. She mostly keeps her windows door closed, because outside is quite cold, she would just open her curtains to get some light. She would wear jumpers when inside the SSB and she would tell me that she is quite used with the heating system of the halls of accommodation as previously she was leaving on Campus. When inside her room she would practice on her guitar or work on her essays. At the back of her radiator she has a radiator reflector panel that is used to reflect the heat in the room but they are '*working quite well, I don't think...especially when the radiator is right near my window*'.

Electricity consumption after receiving the SEDMs: The SSB with one of the lowest energy footprints and possibly the most energy conscious practices also has the highest peaks.

Even students from the SSB which could be described as an environment where institutional regulations have more authority over heating, lighting or laundering admitted that they have raed the university accommodation regulations but admitted at least partly ignoring them. For example Kerry was telling me: *'During the winter I did have an electric blanket thing that I put under my bed because it was really, really cold. That was my sister's, that she gave to me, so I put that on like, two or three hours before I went to sleep and then I'd switch it off when I go to sleep, yes.'* Marcus considered using the SEDMs in the future, in real time context '*…I do have a solution…get some solar panels on what was once a garden shed and see what's happens from there…and this is largely due to the energy monitor and obviously being in the Bungalow having this kind of deep awareness.*'

At the end of their tenancy students in their report mentions electricity monitoring just once: 't*aking part in a PhD Research Project which involved the occupants using energy monitors to observe our energy consumption inside the bungalow.*' Later, the end of the document gives an explanation of the 'poor data collection process': '*One of the main challenges that we faced throughout the year was communication with each other and finding time to work on the SSB project together as a group. Some of us lacked motivation towards the project which was a huge challenge in trying to achieve our goals. We believe that communication was a challenge, because we didn't take the time to build a relationship between the four of us at the start of the year. Therefore, we didn't fully understand each other leading to some misunderstandings, negatively affecting the project. On the whole, the experience taught us all a lot about time management, group work and what it means to live communally. We learnt that proper communications plays a huge role in group projects. It takes time understanding each other and our differences and it takes effort to make it work.* '

Appendix 9 – Example of recruiting material used

I published a short article in Keele Concourse student newspaper with the title: 'How one gadget inspired us to go green'

Are your house bills leaving you with a sour taste in your mouth every quarter? Máté Lőrincz's were, so he did something about it - he went green.

Like many Keele students, my parents always told me to turn off the lights when leaving an empty room. As I grew up in an Eastern European country, I often didn't bother, because power cuts were a daily routine. Besides, as an adult, I had no idea of the monetary repercussions. If my memory is correct, the 'switch-off' rule was never strictly enforced by my parents. As I am the lead tenant of our flat I would have a short constructive discussion whenever I found all the lights or electrical equipment left on, but all that has changed now. I turned from a Keele student who cared little about our flat electricity usage to 'switch-off'-dictator, and I demand my room-mates to switch-off lights and electrical appliances. So, why I have made this switch?

The (energy efficient) bulb turned on when I received a fancy gadget, an electricity-display monitor (EDM) that helped me to calculate how much energy we were using to run our flat appliances (such as the fridge and microwave) and how much we were paying to run them. What I found was horrifying; our flat of four students was consuming around 10,000 kilowatt-hour per year, and for that we were paying £171 a month – more than £2000 a year. This was madness. Although we were using our washing machine, dryers, kettles, microwave, etc. daily, I could see no reason why we were using so much power. It was clearly my flatmates' fault. Maybe mine, but just a little. Immediately I set up a flat meeting to discuss the flat electricity bill, and we agreed that something needed to be done. More importantly, we agreed that just promising each other to turn off the lights was nonsense because we are lazy and forgetful (and maybe a little bit busy too).

So I googled the cheapest electricity supplier, and switched to a cheaper tariff. This meant that immediately the rate we were paying per kilowatt was reduced from 19p to just 12p. If my maths is correct we would save about £600 a year, but this was not enough. I was determined to cut our annual electricity bill down to £1000. Therefore I convinced my flatmates (with packs of oatcakes, of course) to buy the EDM that today monitors and controls our appliances in our flat. The installation of the EcoManager was a breeze. I simply had to clip a sensor onto the main electricity feed cable that in turn connects wirelessly to a meter that shows you how many watts your flat is consuming, and also how much you are paying for it. The result was terrifying. Before having the EDM I had to argue with Steve to put a lid on the pot when cooking or to turn off lights after leaving the kitchen, but with EcoManager, everything changed. I no longer had to argue with him, now that we could see how much electricity we were wasting when cooking. Steve made some calculations and worked out that when cooking a soup, we were using some 3 kilowatts – or almost 40p – per hour. Just for boiling soup!

But why were we using so much power to boil a soup? Our kitchen bulbs were halogens and consumed 50 watts each. With 10 constantly on, it meant that they were consuming about £300 of electricity per year. So we decided to swap them, and bought “expensive” LED bulbs that consume only 3 watts per bulb. And today we are spending around £20 per year for lighting the kitchen and not £300. EcoManager also made us realise that our tumble dryer was made only for millionaires: it uses 3.7 kilowatt-hour, which is more than a kettle! Furthermore, it helped us calculate how much we pay out on standby lights.

And it is massive. Now, each of us, before going to bed, unplugs laptops, mobile-phone charges, iPod speakers, everything. After all, why should we pay for the electricity that we do not consume? In the morning, I like to upload the previous electricity usage into my laptop and make a note of what we have used. On a good day we use 20 kilowatt-hour, on bad days (which generally involve friends staying overnight) our electricity consumption almost doubles. But the best of all is when my flatmates go away for a weekend and our usage goes down to just 9 kilowatt-hour. When they return, the number keeps rising, and thanks to EcoManager we never stop discussing our electricity consumption. Thank you, EcoManager. You made us Think and Go Green.

References

Abrahamse, W. (2005), A review of intervention studies aimed at household energy conservation. Journal of Environmental Psychology, 25(3): 273-291.

Ajzen, I. (1991), The Theory of Planned Behavior. Organizational Behavior and Human. Decision Processes, 50(2): 179-211.

Alberts, G., Gurguc, Z., Koutroumpis, P., Martin, R., Muûls, M., Napp, T. (2016), Competition and norms: A self-defeating combination? Energy Policy, 96:504-523.

Asimakopoulos, S., Asimakopoulos, G., Spillers, F. (2017), Motivation and user engagement in fitness tracking: Heuristics for mobile healthcare wearables. Informatics - Multidisciplinary Digital Publishing Institute.

Barlett, P.F., Chase, G.W. (2004), Sustainability on Campus: Stories and Strategies for Change; MIT Press: Cambridge, MA, USA.

Bates, O., Clear, A., Friday,A., Hazas,M., Morley J. (2012), Accounting for Energy-Reliant Services within Everyday Life at Home. Pervasive Computing. J. Kay, P. Lukowicz, H. Tokuda, P. Olivier and A. Krüger, Springer Berlin Heidelberg.

Bekker, M.J., Cumming, T.N., Osborne, K.P., Bruining, A.M., Mclean, J.I., Leland L.J. (2010), Encouraging electricity savings in a university. Journal Applied Behaviour Analysis, 1 (43):327–331.

Bell, G., Blythe, M., Sengers, P. (2005), Making by making strange: defamiliarization and the design of domestic technologies, ACM Transactions on Computer-Human Interaction, 12 (2):149-73.

Benders, R.M.J., Kok, R., Moll, H.C., Wiersma, G. and Noorman, K.J. (2006), New approaches for household energy conservation - In search of personal household energy budgets and energy reduction options. Energy Policy, 34(18):3612–22.

Berker, T. (2013), In the Morning I Just Need a Long, Hot Shower. A Sociological Exploration of Energy Sensibilities in Norwegian Bathrooms. Sustainability: Science. Practice and Policy, 9 (1): 57–63.

Blue., S., Spurling., N. (2017), Qualities of connective tissue in hospital life: how complexes of practices change in The Nexus of Practices: connections, constellations, practitioners in 2017, available online: https://www.routledge.com/The-Nexus-of-PracticeConnections-constellations-and-practitioners/Hui-Schatzki-Shove/p/book/9781138675155

Brewer, R. (2010), Fostering sustained energy behaviour change and increasing energy literacy in a student housing energy competition. Ph.D. Dissertation, University of Hawai'i at Manoa.

Bryman, A. Social Research Methods. Oxford University Press, 2012. 4th edition.

Buchanan, K., Russo, R., and Anderson, B. (2014), Feeding back about ecofeedback: how do consumers use and respond to energy monitors? Energy Policy, 73:138–146.

Bulkeley, H., Broto, VC., Maassen, A. (2014), Low-carbon Transitions the Reconfiguration of Urban Infrastructure. Urban Studies, 51 (7):1471-1486.

Burchell, K., Rettie,R., Roberts, T. (2014), Working together to save energy? report of the smart communities project. Technical report, Behaviour and Practice Research Group, Kingston University.

Catney, P., Macgregor, S., Dobson, A., Royston, Hall, S., Robinson, Z., Ormerod, M., Ross, S. (2014), Big society, little justice? Community renewable energy and the politics of localism, Local Environment, (19):715–730.

CEC (2009), Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC. Available

from: http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:211:0055:0093:EN:PDF〉.

Chappells, H., Van Vliet, B., Southerton, D. (2004), Conclusions, in Southerton,D., Van Vliet, B., Chappells, H., Sustainable Consumption: the Implications of Changing Infrastructures of Provision, Edward Elgar, Cheltenham, UK.

Churchwell, C., Sullivan, M., Thompson, D., Oh, J. (2014), HAN phase 3 impact and process evaluation report, Nexant, Tech. Rep.

Cole, R.J., Robinson, J., Brown, Z., O'Shea, M. (2008), Re-contextualizing the notion of comfort. Building Research and Information, 36(4):323-336.

Cuijpers, C., Koops, B.-J. (2013), Smart Metering and Privacy in Europe: Lessons from the Dutch Case. In S. Gutwirth, R. Leenes, P. de Hert, & Y. Poullet (Eds.), European Data Protection: Coming of Age (pp. 269 – 293). Dordrecht: Springer Netherlands.

D'Oca S. (2016), A multidisciplinary research approach to energy-related behavior in buildings. PhD thesis.

Darby, S. (2010), Smart Metering: What Potential for Householder Engagement? Building Research and Information 38 (5): 442–457.

Darby, S. (2006), The effectiveness of feedback on energy consumption: A review for DEFRA of the literature on metering, billing and direct displays. Oxford: Environmental Change Institute.

Darnton A, Verplanken B, White P, Whitmarsh L. (2011), Habits, Routines and Sustainable Lifestyles: a Summary Report to the Department for DEFRA.

De Dear, R., Brager, R. (1998), Developing an Adaptive Model of Thermal Comfort and Preference. Center for the Built Environment.

DECC (2014), Smart meter roll-out for the domestic and small and medium non-domestic sectors (GB). Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/276656/smart_meter_roll_out_for_the_domestic_and_small_and_medium_and_non_domestic_sectors.pdf

DECC (2015), Smart Metering Early Learning Project: Consumer survey and qualitative research. Retrieved 28/05/15 from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/407543/3_Smart_Metering_Early_Learning_Project_-_Consumer_survey_and_qual_research_-_Main_report_FINAL_CORRECTED.pdf〉.

Denzin, N. K., Lincoln, Y. S. (1998), Collecting and interpreting qualitative material. Thousand Oaks, CA: Sage.

Denzin, N.K., Lincoln, Y.S. (2012), Introduction: the discipline and practice of qualitative research, The Sage Handbook of Qualitative Research, 3rd Edn, SAGE Publications, London.

Devine-Wright, P., Wrapson, W., Henshaw, V., Guy, S. (2014), Low Carbon Heating and Older Adults: Comfort, Cosiness and Glow. Building Research and Information 42 (3): 288–299.

DeWaters, J.E., Powers., S.E. (2011), Energy Literacy of Secondary Students in New York State (USA): A Measure of Knowledge, Affect, and Behavior. Energy Policy 39 (3): 1699–1710.

DG Energy (2011). A New Directive on Energy Efficiency: Challenges Addressed & Solutions Proposed. June 22. http://ec.europa.eu/energy/efficiency/eed/doc/2011_directive/20110622_energy_efficiency_directive_slides_presen tation_en.pdf

Donaldson, S.I., Grant-Vallone, E. J. (2002), Understanding self-report bias in organizational behavior research. Journal of Business and Psychology, 17(2): 245–260.

EDRP UK smart meter programme: preparing for evaluation http://webarchive.nationalarchives.gov.uk/20121217150421/http:/www.decc.gov.uk/assets/decc/11/tackling-climate-change/smart-meters/5699-aecom-uk-smart-meter-programme-research-preparing.pdf

Ehrhardt-Martinez, K., Donnelly, K.A., Laitner, J.A. (2010), Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity-Saving Opportunities. In American Council for an Energy-Efficient Economy.

Energy Efficiency Directive (2009), https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive

Energy Saving Trust (2011), Trigger Points – A Convenient Truth: Promoting Energy Efficiency in the Home. London.

EPRS (2015), European Commission's 2015 Work Programme, http://www.europarl.europa.eu/EPRS/EPRS-Briefing-545732-Commissions-2015-work-programme-FINAL.pdf

ESMA (2010), European Smart metering alliance annual report on the progress in Smart metering. Version 2.0.

Emeakaroha A.,Ang C.S., Yan Y., Hopthrow T. (2014), Integrating persuasive technology with energy delegates for energy conservation and carbon emission reduction in a university campus. Energy, 76:357–74.

Emeakaroha A, Ang C.S., Yan Y. (2012), Challenges in improving energy efficiency in a university campus through the application of persuasive technology and smart sensors. Challenges, 3(2):290–318.

Faruqui, A., Sergici, S., Sharif, A. (2010), The impact of informational feedback on energy consumption—a survey of the experimental evidence. Energy, 35 (4): 1598–1608.

Fine., G. (1990), Organizational time: Temporal demand and the experience of work in restaurant kitchens. Social Forces, 69(1): 95–114.

Fischer, C. (2008), Feedback on household electricity consumption: a tool for saving energy? Energy Efficiency, 1(1):79–104.

Fishbein, M., Ajzen, I. (1975), Belief, attitude, intention, and behavior: An introduction to theory and research.

Foulds, C., Powell, J., Seyfang, G. (2013), Investigating the performance of everyday domestic practices using building monitoring.

Foulds, C., Powell, J., Seyfang, G. (2015), How moving home influences appliance ownership: a Passivhaus case study. Energy Efficiency.

Foulds, C., Royston, S., Buchanan, K., Hargreaves, T. (2014), The Many Faces of Feedback: Beyond the kWh. In Practices, the Built Environment and Sustainability – A Thinking Note Collection, edited by C. Foulds and C. L. Jensen, 19–21. Cambridge.

Gajowniczek K, Ząbkowski T. (2017), Electricity forecasting on the individual household level enhanced based on activity patterns. PLoS ONE 12(4).

Goulden, M., Bedwell, B., Rennick-Egglestone, S., Rodden, T., Spence, A. (2014), Smart grids, smart users? The role of the user in demand side management. Energy Research and Social Science, (2): 21–19.

Gnoth, D. (2013), Moving Home and Changing Behaviour – Implications for Increasing Household Energy Efficiency. ECEEE Summer Study Proceedings: Rethink, Renew, Restart . Belambra Presqu'île de Giens, France.

Gram-Hanssen, K. (2010), Standby consumption in households analyzed with a practice theory approach. Journal of Industrial Ecology, 14(1): 150–165.

IPCC, 2014. Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs−Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York.

Hacking ,I. (1990), The Taming of Chance. Cambridge University Press.

Halkier, B. (2001), Routinisation or reflexivity? Consumers and normative claims for environmental consideration, in J Gronow & A Warde (eds). Ordinary Consumption, Routledge, London.

Halkier, B., Jensen, I. (2011), Methodological challenges in using practice theory in consumption research. Examples from a study on handling nutritional contestations of food consumption. Journal of Consumer Culture, 11:101-123.

Hand, M., Shove, E., Southerton, D. (2005), Explaining Showering: a Discussion of the Material, Conventional, and Temporal Dimensions of Practice. Sociological Research Online.

Hand, M., Shove, E. (2007), Condensing practices: ways of living with a freezer. Journal of Consumer Culture, 7(1):79-104.

Hargreaves, T., Nye, M., Burgess, J. (2010). Making Energy Visible: A Qualitative Field Study. Energy Policy, 38 (10): 6111-6119.

Hargreaves, T., Nye, M., Burgess, J. (2013), Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. Energy Policy, (52):126–134.

Harries, T., Rettie, R., Studley, M., Burchell, K., Chambers S. (2013), Is social norms marketing effective? A case study in domestic electricity consumption. European Journal of Marketing, 47 (9):1458–1475.

Higginson, S., Hargreaves, T., McKenna, E., Chilvers, J. and Thomson, M. (2016), Diagramming Commuting Practices: The connections within and between practices and their relevance for the shifting of energy demand in time. DEMAND Centre Conference, Lancaster, 13-15 April 2016.

Hinton, E. (2010), Review of the literature relating to comfort practices and socio-technical systems. Paper 35, Environment, Politics and Development Working Paper Series, London: Department of Geography, King's College London.

Holliday, R. (2000), We've been framed: visualising methodology. Sociological Review, 48(4): 503-521.

Ingold, T. (2011), Being Alive: Essays on Movement, Knowledge and Description. London and New York: Routledge.

Fontana, A., Frey, J. (2005), The interview: from neutral stance to political involvement, in NK Denzin & YS Lincoln (eds), The Sage Handbook of Qualitative Research, 3rd edn, SAGE Publications, London.

Jalas, M., Rinkinen, J. (2013), Stacking wood and staying warm. Time, temporality and housework around domestic heating systems. Journal of Consumer Culture, 11(1): 61–78.

Janda, K.B. (2011), Buildings Don't Use Energy: People Do. Architectural Science Review, 54(1): 15–22.

Jelly, R. (2008), Phase 2: Qualitative Assessment of Consumer Responses to the National Electricity Smart Meter Rollout Program, Red Jelly, prepared for NERA Economic Consulting on behalf of the Department of Industry, Science and Tourism, Sydney, NSW.

Jensen, J. (2012), Framing of regimes and transition strategies: An application to housing construction in Denmark. Environmental Innovation and Societal Transitions, 4:51-62.

Johnson, P.M., Brewer, R.M., (2010), The kukui cup: proposal for a UH residence hall energy competition. University Hawai'i, 1 (1): 1–16.

Keller, M., Halkier, B., Wilska, T.A. (2016 forthcoming), Policy and Governance for Sustainable Consumption at the Crossroads of Theories and Concepts, Environmental Policy and Governance.

Kelly J., Knottenbelt W. (2016), Does disaggregated electricity feedback reduce domestic electricity consumption? A systematic review of the literature, Proc. NILM2016 3rd International Workshop on Non-Intrusive Load Monitoring, 5-7.

Kidd, A., Williams, P. (2008), Retreat from http://www.fozienergy.com/Talybont_Trial_UK_Efergy_2008.pdf

Krishnamurti, T., Alexander, D. L., Wong-Parodi, G., Casey, J. C. (2013), Creating an in-home display: Experimental evidence and guidelines for design'. In: Applied Energy, 108: 448–458.

Kuijer, L., de Jong, A. (2009), A Practice Oriented Approach to User Centered Sustainable Design. Delft: Department of Industrial Design, Delft University of Technology.

LaMarche, J., Cheney, K., Christian, S., Roth, K. (2011), Home energy management products & trends. Cambridge: Fraunhofer Center for Sustainable Energy Systems.

Langenheld, A. (2010), Advanced metering and consumer feedback to deliver energy savings – Potentials, Member States experience and recommendations Report prepared by the Joint Research Centre of the European Commission: Ispra.

Lefebvre, H. (2004), Rhythmanalysis: Space, Time and Everyday life. A&C Black.

Ligtvoet, A., van de Kaa, G., Fens, T., van Beers, C., Herder, P., & van den Hoven, J. (2015), Value Sensitive Design of Complex Product Systems. Policy Practice and Digital Science, 157–176.

Lutzenhiser, L. (1992), A question of control: alternative patterns of room air-conditioner use. Energy and Buildings, (18):193-200.

Macrorie, R. (2012), The dynamics and governance of thermal comfort practices in low carbon housing: A comparative analysis of domestication theory and theories of social practice. Norwich: Science, Society and Sustainability Research Group. 3S Working Paper 2012-16.

Maller, C., Strengers, Y. (2013), The global migration of everyday life: investigating the practice memories of Australian migrants'. Geoforum, (44):243–52.

Marres N. (2011), The costs of public involvement: everyday devices of carbon accounting and the materialization of participation. Economy and Society, 40 (4):10–533.

Martens, L. (2007), The visible and the invisible: (de)regulation in contemporary cleaning practices', in B Campkin & R Cox (eds), Dirt: New Geographies of Cleanliness and Contamination, I.B. Tauris & Co Ltd, London, UK.

Martens, L. (2012), Practice 'in talk' and talk 'as practice': Dish washing and the reach of language. Sociological Research Online, 17(3):22.

Martens L., Scott S. (2017), Understanding Everyday Kitchen Life: Looking at Performance, into Performances and For Practices in Methodological Reflections on Practice Oriented Theories, 177-191.

Martiskainen, M. (2007), Affecting consumer behaviour on energy demand: Final report to EdF Energy. Brighton: Sussex Energy Group, SPRU. Available at: References 307 www.sussex.ac.uk/webteam/gateway/file.php?name=seg-consumer-behaviourfinal-report.pdf&site=264.

Mateas, M. S., Scholtz, T., Sorensen, D. (1996), Engineering Ethnography in the Home. Conf. Companion on Human Factors in Computing Systems, 283–284. ACM.

McCalley, L., Midden, C.J.H. (2002), Energy conservation through product-integrated feedback: The roles of goal-setting and social orientation. Journal of Economic Psychology, 23(5):589–603.

Melville, E., Christie, I., Burningham, K. A, Way, C., Hampshire, P. (2017), The electric commons: a qualitative study of community accountability. Energy Policy, 106: 12-21.

Miller, N. H., Hill, M., Kottke, T., Ockene I.S. (1997), The multilevel compliance challenge: recommendations for a call to action. A statement for healthcare professionals. Circulation, 95: 1085-90.

Mitchell, V., Mackley, K. L., Pink, S., Escobar-Tello, C., Wilson, G.T., Bhamra, T. (2015), Situating digital interventions: mixed methods for HCI research in the home. Interact. Comput.er.

Morley, J., Hazas, M. (2011), The significance of difference: Understanding variation in household energy consumption. In: Energy efficiency first: The foundation of a low carbon society. Proceedings of the ECEEE summer study 2011. 6 – 11 June 2011, Toulon, France.

Moholy-Nagy, L. (1947), Vision in Motion. In Paul Theobald, 1965.

Murtagh, N., Gatersleben, B., Uzzell, D. (2014), 20:60:20 - differences in energy behaviour and conservation between and within households with electricity monitors, PLoS ONE, 9 (3).

Naus, J., van Vliet, B., Hendriksen, A. (2015), Households as change agents in a Dutchsmart energy transition: on power, privacy and participation. Energy Research and Social Science, (9): 125–136.

Nicolini, D. (2012), Practice Theory, Work, and Organization – an introduction. Oxford University Press.

NUS (2013), report on students https://www.nus.org.uk/Global/Campaigns/Accommodation%20Costs%20Survey%20V6%20WEB.pdf

Nyborg, S., Røpke, I. (2013), Constructing users in the smart grid - insights from the Danish eFlex project. Energy Efficiency, (6):655–670.

Odom, W., Pierce, J., Roedl, D. (2008), Social incentive & eco-visualization displays: toward persuading greater change in dormitory communities. In Workshop Proc. of OZCHI '08. ACM Press.

Peschiera, G., Taylor, J.E.,Siegel J.A. (2010), Response-relapse patterns of building occupant electricity consumption following exposure to personal, contextualized and occupant peer network utilization data. Energy Build, 42 (8) :1329–1336.

Petersen, J., Shunturov, V., Janda, K., Platt, G., Weinberger, K. (2007), Dormitory residents reduce electricity consumption when exposed to real-time visual feedback and incentives. International Journal of Sustainability in Higher Education, 8 (1):16–33.

Petito, G., Burmeister, G., Moore, M., Golrokhian, A., Waisanen E. (2017), Michigan Sustainability Case: Smarting over Smart Meters: Does Smart Grid Technology Have a Home in Maryland? Sustainability: The Journal of Record. February 10(1): 14-23.

Pierce, J., Paulos, P. (2010), Materializing Energy. Proceedings of DIS Conference on Designing Interactive Systems. Aarhus: ACM Press.

Pierson, P. (1993), When Effect Becomes Cause: Policy Feedback and Political Change. World Politics 45 (4): 595–628.

Pink, S., Fors, V. (2017), Being in a mediated world: self-tracking and the mind–body– environment. Cultural Geographies.

Pink, S., Sumartojo, S., Lupton, D. (2017), Mundane data: the routines, contingencies and accomplishments of digital living. Big Data & Society. Available at http://dx.doi.org/10.1177/2053951717700924

Pink, S., Leder Mackley, K. (2015), Moving, Making and Atmosphere: routines of home as sites for mundane improvisation. Mobilities.

Pink, S. (2001), More visualising, more methodologies: on video, reflexivity and qualitative research. Sociological Review, 49(4):586-599.

Pink, S. (2005), Dirty laundry. Everyday practice, sensory engagement and the constitution of identity. Social Anthropology, 13(3):275-290.

Pink, S. Tutt, D., Dainty, A., Gibb, A. (2010), Ethnographic methodologies for construction research: knowing, practice and interventions. Building Research & Information, 38(6): 647-659.

Pink, S., Leder Mackley, K. (2015), Flow in Everyday Life: Situating Practices in C. Maller and Y. Strengers (eds) Beyond Behaviour Change: Intervening in social practices for sustainability, Routledge.

Pink, S., Leder Mackley, K., Mitchell, V., Escobar-Tello,C., Hanratty,M., Bhamra, T., Morosanu, R. (2013), Applying the lens of sensory ethnography to sustainable HCI, ACM Transactions on Computer-Human Interaction, 20(4):22-40.

Pink, S. (2012). Situating Everyday Life: Practices and Places. London.

Poortinga, W., Steg, L.,Vlek, C. (2004), Values, Environmental Concern, and Environmental Behavior: A Study into Household Energy Use. Environment and Behavior, 36(1): 70–93.

Powells, G., Bulkeley, H. A., Judson, E. P. and Bell, S. (2014) Peak electricity demand and the flexibility of everyday life. Geoforum, 55:43–52.

Pullinger, M., Heather L., Webb J. (2014), Influencing household energy practices: a critical review of UK smart metering standards and commercial feedback devices. Technical. Analysis and Strategic. Management, 26: 1144-1162.

Raimi,K. T., Carrico, A. R. (2016), Understanding and beliefs about smart energy technology. Energy Research and Social Science, (12):68–74.

Reckwitz, A. (2002), Toward a Theory of Social Practices: A Development in Culturalist Theorizing. European Journal of Social Theory, 5(2): 243–263.

Richards, J.G.J. (2013), Shared accommodations: experiences of houses of multiple occupation in south Manchester. Phd Thesis.

Richardson, I. (2010), Integrated high-resolution modelling of domestic electricity demand and low voltage electricity distribution networks, Engineering PhD edn, Centre for Renewable Energy Systems Technology (CREST), Department of Electronic and Electrical Engineering, Loughborough University, UK.

Rinkinen, J. (2013), Electricity Blackouts and Hybrid Systems of Provision: Users and the ‘reflective Practice. Energy Sustainability and Society 3 (1): 1–10.

Rinkinen, J., Jalas, M., Shove, E. (2015), Object-relations in accounts of everyday life. Sociology, 49(5): 870-885.

Røpke, I. (2009), Theories of practice - New inspiration for ecological economic studies on consumption. Ecological Economics, 68(10): 2490–2497.

Royston, S. (2014), Dragon-Breath and Snow-Melt: Know-How, Experience and Heat Flows in the Home. Energy Research & Social Science 2:148–158.

Schatzki, T. (1996), Social Practices: A Wittgensteinian Approach to Human Activity and the Social, New York and Cambridge: Cambridge University Press.

Schatzki, T. (2002), The Site of the Social: A Philosophical Account of the Constitution of Social Life and Change. University Park, PA: Penn State University Press.

Schatzki, T. (2010), Materiality and social life. Nature and Culture, 5(2): 123–149.

Schatzki, T. (2012), A primer on practices. In J. Higgs (ed.) Practice-based education. Rotterdam: Sense Publishers.

Shirani, F., Butler,C., Henwood, K., Parkhill, K., Pidgeon.N. (2013), Disconnected Futures: Exploring Notions of Ethical Responsibility in Energy Practices. Local Environment, 18 (4): 455–468.

Shove, E. (2003), Comfort, cleanliness and convenience. Oxford, UK: Berg.

Shove, E., Pantzar, M., Watson, M. (2012), The Dynamics of Social Practice: Everyday Life and How it Changes. London: Sage Publications.

Shove, E., Walker, G., Brown, S. (2014), Material Culture, Room Temperature and the Social Organisation of Thermal Energy. Journal of Material Culture, 19 (2): 113–124.

Shove, E., Watson, M., Hand, M., Ingram, J. (2007), The Design of Everyday Life. London: Bloomsbury Academic. Smart Energy GB.

Shwartz, B. (2017), The Paradox of Choice: why more is less. Harper Collins. USA.

Simcock, N., MacGregor, S., Catney, P., Dobson, A., Ormerod, M., Robinson, Z., Hall, S. M. (2014), Factors influencing perceptions of domestic energy information: content, source and process. Energy Policy (65):455–464.

Sintov, N.D., Dux, E., Tran, A. Orosz, M. (2016), What goes on behind closed doors? How college dormitory residents change to save energy during a competition-based energy reduction intervention, International Journal of Sustainability in Higher Education, 17(4):451-470.

Soares, N., L. D. Pereira, J. Ferreira, P. Conceição, P. Pereira da Silva. (2015), Energy Efficiency of Higher Education Buildings: A Case Study. International Journal of Sustainability in Higher Education 16 (5): 669–91.

Sofoulis, Z. (2005), Big water, everyday water: a sociotechnical perspective, Continuum: Journal of Media nad Cultural Studies, 19(4):445-63.

Sokoloski, R. (2015), Disaggregated electricity consumption: Using appliance-specific feedback to promote energy conservation, M.A. California State University San Marcos.

Sorrell, S. (2007), The Rebound Effect: An Assessment of the Evidence for Economy-wide Energy Savings from Improved Energy Efficiency. UK Energy Research Center Report.

Southerton, D. (2001), Consuming Kitchens: Taste, context and identity formation. Journal of Consumer Culture, 1(2),179–203.

Southerton D. (2003), Squeezing Time: Allocating Practices, Coordinating Networks and Scheduling Society, Time and Society 12: 5-25.

Southerton D. (2006), Analysing the Temporal Organization of Daily Life: Social Constraints, Practices and their Allocation. Sociology 40(3): 435-454.

Southerton D. (2009), Re-ordering Temporal Rhythms: Coordinating Daily Practices in the UK in 1937 and 2000. In: Shove E, Trentmann F and Wilk R (eds) Time, Consumption and Everyday Life : Practice, Materiality and Culture.

Southerton D. (2013), Habits, Routines and Temporalities of Consumption: From Individual Behaviours to the Reproduction of Everyday Practices. Time and Society 22: 335-355.

Southerton, D., Warde, A., Hand, M. (2004), The limited autonomy of the consumer: implications for sustainable consumption. In: D. Southerton, H. Chappells and B. van Vliet, eds., Sustainable Consumption: the implications of changing infrastructures of provision. Cheltenham: Edward Elgar, 32–48.

Southerton, D., Olsen, W., Warde, A., Cheng, S.L. (2012), Practices and trajectories: A comparative analysis of reading in France, Norway, the Netherlands, the UK and the USA. Journal of Consumer Culture, 12(3):237–262.

Spurling, N. (2015), Differential experiences of time in academic work: How qualities of time are made in practice. Time and Society.

Spurling, N., McMeekin, A., Shove, S., Southerton, D., Welch, D. (2013), Interventions in Practice: Re-framing Policy Approaches to Consumer Behaviour. University of Manchester, Sustainable Practices Research Group, Manchester.

Stake, R. E. (1995), The art of case study research. Thousand Oaks, CA: Sage.

Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., Thorsnes, P. (2010), Energy cultures: A framework for understanding energy behaviours. Energy Policy, 38(10): 6120-6129.

Strengers, Y. (2011), Negotiating everyday life: The role of energy and water consumption feedback. Journal of Consumer Culture, 11(3): 319–338.

Strengers, Y. (2013), Smart Energy Technologies in Everyday Life: Smart Utopia? Palgrave Macmillan, London.

Strengers, Y., Maller. C. (2012), Materialising Energy and Water Resources in Everyday Practices: Insights for Securing Supply Systems. Global Environmental Change 22 (3): 754–763.

Strengers, Y., Nicholls,L., Maller, C. (2014), Curious Energy Consumers: Humans and Nonhumans in Assemblages of Household Practice. Journal of Consumer Culture.

Tsuda, K., Hara K., Uwasu, M. (2013), Prospects and Challenges for Disseminating Life Cycle Thinking towards Environmental Conscious Behaviors in Daily Lives, Sustainability, MDPI, Open Access Journal, 5(1): 1-13.

Van Dam, S., S., Bakker, C., A., van Hal, J., D., M. (2010), Home Energy Monitors: Impact over the. Medium-Term, Building Research and Information, 458–469.

Van Elburg, H. (2008), Effective Customer Feedback Mechanisms: Deliverable 6, workpackage 2, tasks 2 and 3. Description ESMA Deliverable 6 according to EU Grant Agreement EIE/06/031/S12.448010. Project partners European Smart metering Alliajnce Report. SenterNove.

van Vliet, B., J., M. (2006), Citizen-consumer roles in environment management of large technological systems', in P-P Verbeek & A Slob (eds). User Behavior and Technology Development: Shaping Sustainable Relations.

van Vliet, B., J., M. (2012), Sustainable innovation in network-bound systems: implications for the consumption of water, waste water and electricity services. Journal of Environmental Policy Plan, 14 (3):263–278.

Vassileva, J. (2012), Motivating participation in social computing applications: a user modeling perspective. User Modeling and User-Adapted Interaction, 22 (1):177-201.

Vihalemm,T., Keller, M., Kiisel, M. (2015), From Intervention to Social Change. A Guide to Reshaping Everyday Practices. London: Ashgate.

Wallenborn, G., Orsini, M., Vanhaverbeke, J. (2011), Household appropriation of electricity monitor. International. Journal.of Consumption. Studies, 35 (2):146–152.
Wallenborn, G., Wilhite., H. (2014), Rethinking Embodied Knowledge and Household Consumption. Energy Research and Social Science 1 (3): 56–64.

Warde, A. (2005), Consumption and Theories of Practice. Journal of Consumer Culture, 5(2):131–153.

Warde, A., Southerton, D. (2012), The habits of consumption. COLLeGIUM of Studies Across Disciplines in the Humanities and Social Sciences. Vol. 12. Retrieved from http://www.helsinki.fi/collegium/e-series/volumes/volume_12/index.htm]

Warde, A. (2013), What sort of a practice is eating? In: E. Shove and N. Spurling, eds., Sustainable Practices: Social theory and climate change. Abingdon, UK and New York, USA.

Watson, M. (2012), How theories of practice can inform transition to a decarbonised transport system. Journal of Transport Geography, (24):488-496.

Watson, M., Shove, E. (2008), Product, competence, project and practice: DIY and the dynamics of craft consumption. Journal of Consumer Culture, 8(1): 69-89.

Weitzman, E., Miles, A., Matthew, B. (1995), Computer programs for qualitative data analysis. A software sourcebook, London.

Wilhite, H. (2008), New thinking on the agentive relationship between end-use technologies and energy-use practices. Energy Efficiency, (1):121-130.

Wilhite, H. (2012), Towards a Better Accounting of the Roles of Body, Things and Habits in Consumption. In: A. Warde and D. Southerton, eds., The Habits of Consumption. Helsinki: COLLeGIUM of Studies Across Disciplines in the Humanities and Social Sciences, pp.87–99.

Wilhite, H. Shove, E., Lutzenheiser L, Kempton, W. (2000), The Legacy of Twenty Years of Energy Demand Management: we know more about individual behavior but next to nothing about demand. In: Jochem, E. Sathaye, J. Bouille, D. (eds), Society, Behaviour and Climate Change Mitigation. Dordrecht: Kluwer Academic Publishers.

Wilhite, H. (2001), What can energy efficiency policy learn from thinking about sex. In: Proceedings of European Council for an Energy Efficient Economy ECEEE 2001.

Wilk, R., R., Wilhite, H. (1985), Why don't people weatherize their homes? An ethnographic solution. Energy, 10(5):621-9.

Wilson, G.T. (2013), Design for Sustainable Behaviour: Feedback Interventions to Reduce Domestic Energy Consumption. 1-393. Doctoral thesis at Loughborough University.

Wood, G., Newborough, M. (2003), Dynamic energy-consumption indicators for domestic appliances: environment, behaviour and design. Energy and Buildings (35):821–841.

Yadoo, A., A. Gormally, H. Cruickshank. (2011), Low-carbon off-grid electrification for rural areas in the United Kingdom: Lessons from the developing world. Energy Policy (39): 6400–6407.

Yin, R. K. (2009), Case Study Research. Design and Methods. SAGE Publications.

Zografakis, N., A. Menegaki,N., Tsagarakis K. P. (2008), Effective Education for Energy Efficiency. Energy Policy 36 (8): 3226–3232.

Zwick D., Knott J. D. (2009), Manufacturing customers: The database as new means of production. Journal of Consumer Culture, (9): 221-247.