THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DESIGN BEYOND INTERVENTIONS

Supporting Less Energy-reliant Activities in the Everyday

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ABSTRACT

This thesis addresses challenges and opportunities for product design to contribute to domestic energy conservation. The overall aim of the thesis is that of increasing the understanding of people's energy use and their use of energy-reliant artefacts in the everyday in order to propose ways of supporting energy conservation through design. Two main themes are explored within its scope: how people's doings in everyday life influence energy use and how energy-reliant artefacts designed to support energy conservation influence energy use.

Material from four empirical studies has been used to address the themes and discuss implications for design practice. Study A investigated how people's possession and use of appliances influenced energy use and Study B explored people's energy use and approach to energy conservation from the perspective of everyday activities. Studies C and D investigated how artefacts designed to support energy conservation may influence energy use through evaluations of an energy feedback system and kitchen appliances designed to mediate less energy-intensive use, respectively.

A cross-study analysis shows that people's energy use is embedded in the web of activities that make up everyday life and suggests that the design of energy-reliant artefacts mediates the actions and outcomes of those activities. Depending on their overall design, design characteristics, and their fit with the activity that is enabled, energy-reliant artefacts may either facilitate energy conservation or make less energy-intensive use challenging or undesirable. For instance, if artefacts are not easily understandable and easy to use, and if they do not provide suitable functions that enable people to use them effectively for a particular purpose, they risk being rejected or used in an energy-intensive way. The findings thus suggest that artefacts designed with one or more functions aimed to motivate or encourage people to reduce their energy use, commonly referred to as design interventions in literature, risk impeding energy conservation if they do not support energy conservation as a whole. To increase the potential for artefacts to support energy conservation, it is crucial to design suitable and relevant artefacts that provide for less energy-reliant everyday activities and that make it possible and desirable for people to meet their needs and attain their goals in less energy-intensive ways. If less energy-intensive use is only encouraged, but is not enabled and mediated, it will be difficult for people that do not have the preconditions to use less energy to actually reduce their energy use.

This thesis therefore argues for moving beyond design interventions and instead designing for less energy-reliant activities by holistically considering the preconditions and design characteristics that functions on all layers of design may give rise to. Such an approach has the potential to reduce mismatches between the design of an artefact and the activity enabled, which in turn may increase the potential for artefacts to be used in less-energy-intensive ways and be adopted long term. In conclusion, the thesis provides new insights into the way in which people's activities and use of artefacts influence energy use and highlights opportunities for design practitioners to create preconditions for less energy-reliant activities in the everyday.

Keywords: *Design for Sustainability, Energy use, Energy conservation, Everyday life, Activities, Enabling preconditions*

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I am also grateful for being part of a very inspiring research community in which sustainability, design and everyday life converge. To all my fellow researchers within the field, I look forward to being inspired by your continued work and future insights into the ways in which design can contribute to creating a better world.

Additionally, I have been fortunate to meet and collaborate with many people throughout the research presented in this thesis. Many thanks go to the teams at Exibea and the design bureau Boid for our fun and rewarding collaboration. Another thank you goes to Christian Marx and Jesper Knutsson at the department of Civil and Environmental Engineering at Chalmers for their dedicated contribution to this research. I would also like to express my deepest gratitude to all the people who have participated in the studies; thank you so very much for generously contributing your time and valuable reflections. Without you there would certainly be no thesis.

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Thank you.

APPENDED PUBLICATIONS

The studies and findings presented in this thesis are discussed in six appended publications:

PAPER A

Selvefors, A., Knutsson, J., Marx, C., Rahe, U. (2017, accepted) Designed to support or impede energy conservation? How design characteristics influence people's energy use. *Accepted for publication in Journal of Design Research.*

Contribution: Rahe, Marx, Knutsson and Selvefors planned the study. Selvefors carried out the interviews, analysed the data, and wrote the paper with feedback from Rahe and Marx.

PAPER B

Selvefors, A., Karlsson, I. C. M. & Rahe, U. (2015) Conflicts in Everyday Life: The Influence of Competing Goals on Domestic Energy Conservation, *Sustainability*, 7(5), 5963-5980.

Contribution: Selvefors planned the study, carried out the interviews, analysed the data, and wrote the paper with support from Karlsson.

PAPER C1

Selvefors, A., Karlsson, I. C. M. & Rahe, U. (2013) *What's in it for the user? Effects and perceived user benefits of online interactive energy feedback*. Paper presented at the 16th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP) & 7th Conference of the Environmental Management for Sustainable Universities (EMSU). Istanbul, Turkey.

Contribution: Selvefors planned the study, collected the data, analysed the data, and wrote the paper with feedback from Karlsson and Rahe.

PAPER C2

Selvefors, A., Karlsson, I. C. M. & Rahe, U. (2013) *Use and Adoption of Interactive Energy Feedback Systems*. In Proceedings of the 5th International Congress of International Association of Societies of Design Research: Consilience and Innovation in Design. Tokyo, Japan.

Contribution: Selvefors planned the study, collected the data, analysed the data, and wrote the paper with feedback from Karlsson and Rahe.

PAPER D

Selvefors, A., Marx, C., Karlsson, I. C. M. & Rahe, U. (2017, submitted) (How) can Appliances be Designed to Support less Energy-Intensive Use? Insights from a Field Study on Kitchen Appliances. *Under review for international scientific publication.*

Contribution: Selvefors planned the study and collected the data with support from Marx who prepared the measuring equipment. Selvefors analysed the data, and wrote the paper with feedback from Karlsson, Rahe and Marx.

PAPER E

Selvefors, A., Strömberg, H., & Renström, S. (2016) *What a designer can change: a proposal for a categorisation of artefact-related aspects*. In Proceedings of the Design Research Society 50th Anniversary Conference: Design + Research + Society, Future-Focused Thinking. Brighton, UK.

Contribution: Selvefors and Strömberg conceived the conceptual idea. Selvefors, Strömberg and Renström wrote the paper together.

ADDITIONAL PUBLICATIONS

Publications that are related to the topic of this thesis but not appended:

Strömberg, H., Selvefors, A., & Renström, S. (2015) Mapping out the design opportunities: pathways of sustainable behaviours. *International Journal of Sustainable Engineering* 8(3), 163-172.

Selvefors, A., Renström, S., & Strömberg, H. (2014) *Design for sustainable behaviour: a toolbox for targeting the use phase*. Paper presented at the Eco-design tool conference 2014, Swerea. Gothenburg, Sweden.

Renström, S., Strömberg, H., Selvefors, A., (2013) *Pathways of Sustainable Behaviours*. Paper presented at the 16th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP) & 7th Conference of the Environmental Management for Sustainable Universities (EMSU). Istanbul, Turkey.

Renström, S., Selvefors, A., Strömberg, H., Karlsson, I.C. M. & Rahe, U. (2013) *Target the Use Phase! Design for Sustainable Behaviour.* Paper presented at the 6th International Conference on Life Cycle Management. Gothenburg, Sweden.

Selvefors, A., Renström, S., Viggedal, A., Lannsjö, R. & Rahe, U. (2012) *Benefits and Difficulties for Industry when Designing for Sustainable Behaviour*. In Proceedings of the 17th International Conference on Sustainable Innovation: Towards Sustainable Product Design. Bonn, Germany.

Selvefors, A., Blindh Pedersen, K. & Rahe, U. (2011) *Design for Sustainable Consumption Behaviour - Systematising the use of Behavioural Intervention Strategies*. In Proceedings of the 5th International Conference on Designing Pleasurable Products and Interfaces. Milan, Italy.

Selvefors, A., Rahe, U., Karjalainen, T. (2011) *Using Product Innovation as Eco-Branding to Encourage Sustainable Lifestyles – An Exploratory Student Approach to Business Strategy*. In Proceedings of the 13th International Conference on Engineering and Product Design Education. London, UK.

TERMINOLOGY

The terminology used in research related to the topics of energy and design often differs between researchers and disciplines, which makes it essential to clarify the terms used. The choice of wording and the specific meaning of terms used in this thesis are described below and followed by the abbreviations used:

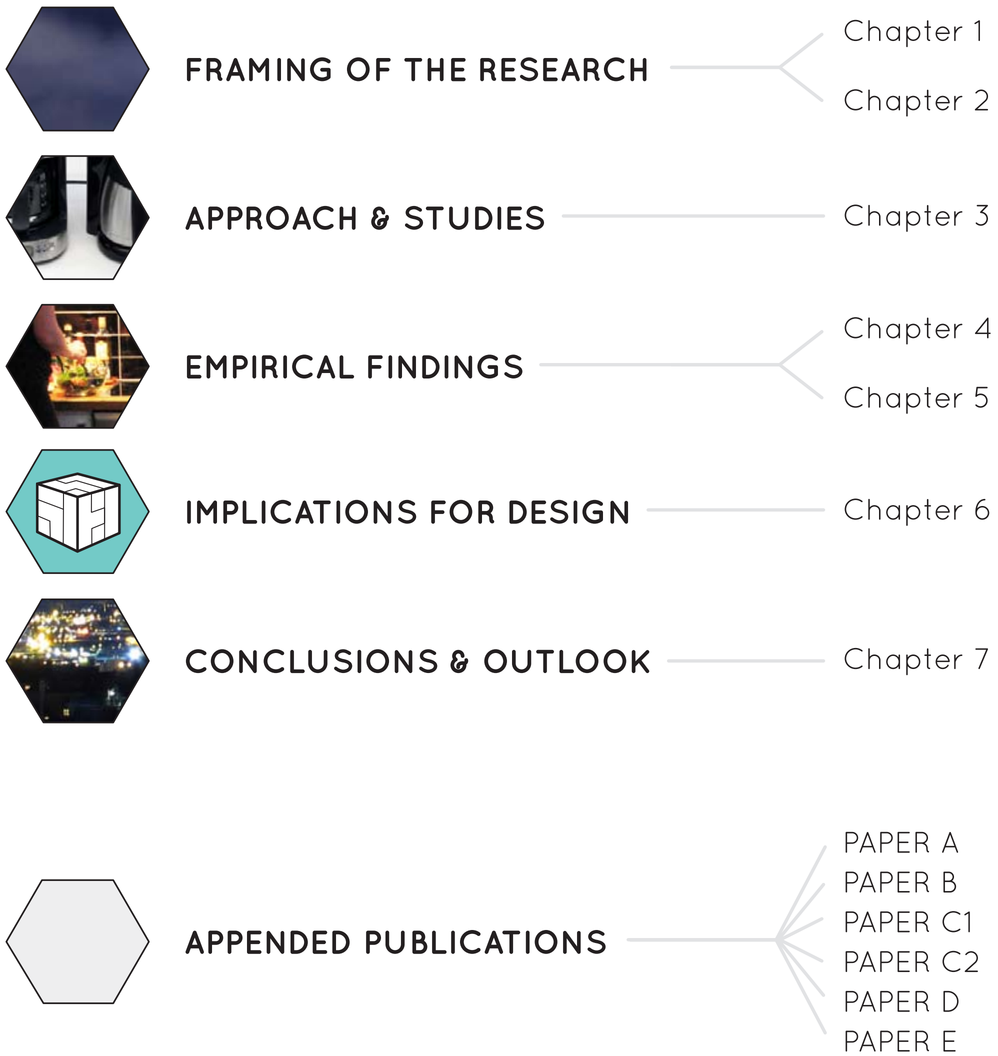
Activity	*A collection of actions and operations performed by one or more persons to achieve particular outcomes, commonly mediated by one or more artefacts*
Adoption	*A process whereby a person acquires a new artefact and continues to use it*
Artefact	*A manmade product, service or technical system*
Behaviour	*An action in response to stimuli related to internal and external determinants*
Doings	*An umbrella term for what people do in everyday life, used to jointly refer to behaviours, actions, activities and practices*
Enable	*To make something possible and feasible in particular situations*
Energy conservation	*An umbrella term used to refer to people's strategies and measures aimed at reducing the amount of energy used for different purposes*
Energy use	*An umbrella term used to refer to the energy use within a household or an activity, which may include both electricity use and use of energy in other forms such as district heating*
Energy-reliant activity	*An activity that is either partly or entirely dependent on the use of energy in order to enable people to achieve desired outcomes; An activity mediated by one or more energy-reliant artefacts*
Energy-reliant artefact	*An energy-using artefact that requires energy in order for people to be able to use its primary and/or supplementary functions*
Energy-intensive	*Using a large amount of energy*
Goal	*Operationalised motives that direct actions within an activity*
Interaction	*Reciprocal action(s) or influence between people, artefacts, and/or objects*
Intervention	*An artefact designed to change people's doings and the outcomes of those doings*
Motive	*A reason for engaging in an activity, which is not always conscious but emerges from a particular need*
Mediate	*To facilitate specific doings and shape doings in particular ways*
Need	*Used both to refer to a general necessity and to people's needs as a product of societal and social life, in the sense of what they need to survive as well as what they need to achieve goals and aspirations in life*

Object	*The "object of activity" that is formed by one or more motives in a particular situation and acted upon to achieve a particular outcome*
Practice(-as-entity)	*Routine and collectively shared doings considered as a coordinated entity that is carried out in different places, at different times and by different people*
Precondition	*A condition that either influences the outcomes of activities and actions or is a prerequisite for particular outcomes; Contextual conditions or artefacts used in everyday life*
Preference	*A person's liking for one thing rather than another*
Use	*A general term for making use of something such as an artefact or energy for a given purpose*

AT	*Activity Theory*
DfSB	*Design for Sustainable Behaviour*
POPD	*Practice-Oriented Product Design*
PT	*Practice theory*

THESIS STRUCTURE

The thesis is structured into six parts, where the first five parts of the thesis make up the cover essay and the six appended publications are provided in the final part of the thesis. The first part of the cover essay introduces the research, its aim and scope and positions it in relation to previous research addressing the topics of energy and design. The second part presents the research approach and studies conducted, while the third part provides an overview of the empirical findings. Implications of the empirical findings for design practice are discussed in the fourth part. The fifth part discusses the contribution of the findings and highlights the overall conclusions along with suggestions for future research.



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FRAMING OF THE RESEARCH

01 | INTRODUCTION

1.1. BACKGROUND AND AIM

A huge increase in domestic energy use took place in many western countries over the course of the 1970s and 1980s due to an increasing number of households and an increased use of domestic appliances (Swedish Energy Agency, 2015; European Union, 2015). Following the recommendations from the World Commission on Environment and Development (1987), a variety of initiatives were commenced that have proven successful in stabilising domestic energy use over the last decade, an outcome that is evident both in Sweden and the EU as a whole (Swedish Energy Agency, 2015; European Union, 2016). However, in order to combat climate change, a stable level is not sufficient. Since household energy use contributes to 21% of the resultant CO_2 emissions (United Nations, 2016b), there is an increasing consensus that domestic energy use needs to be reduced in order to mitigate climate change (United Nations, 2016a; 2016b).

Following policy recommendations (e.g. the Eco-Design Directive (European Union, 2012/27/EU)), increasing the efficiency of appliances has been a widely-used strategy when aiming to reduce domestic energy use from a product development and design point of view. This strategy has led to a greater number of energy-efficient appliances, which has reduced the energy use resulting from people's use of these particular appliances. However, this trend is countered by other societal developments, which outweigh the efficiency gains. For instance, the rising numbers of households, people's growing use of appliances as well as the growing number of functions integrated into new appliances contribute to increased energy use (Swedish Energy Agency, 2015). Merely considering the technical efficiency of appliances is thus not enough to reduce energy use; additional ways of contributing to energy conservation from a design perspective must be explored.

In order to identify new design opportunities with the potential to contribute to an overall reduction in domestic energy use, it is essential to acquire a richer understanding of people's energy use and its origins – people's use of energy-reliant artefacts (Elias et al., 2009; Jackson & Michaelis, 2003; Jones & Lomas, 2016). For such research ventures to be successful, it is argued that they should address people's energy use and use of artefacts in the context of everyday life (e.g. Gram-Hanssen, 2013a; Lutzenhiser, 1993; Wilhite, 2008). By doing so, an increased understanding can be gained regarding how people use energy-reliant artefacts and why people use them in particular ways. Addressing people's use of artefacts in relation to everyday life also provides possibilities for increasing the understanding of how the overall design of energy-reliant artefacts influence energy use in daily life, which is fundamental in order to identify relevant design opportunities with potential to contribute to energy conservation.

The overall aim of this thesis is therefore to increase the understanding of people's energy use and their use of energy-reliant artefacts in the everyday in order to propose ways of supporting energy conservation through design. The thesis thus not only sets out to provide new insights for the research community that address the topics of energy and design, but also to contribute new knowledge of value to design practitioners.

1.2 PREVIOUS RESEARCH AND RESEARCH QUESTIONS POSED

Different disciplines such as psychology, sociology, and design have over the years contributed to an increasing understanding of people's energy use. Even though the disciplines commonly approach energy use from different perspectives, which will be discussed in Chapter 2, they have contributed different pieces to the puzzle that together form the current knowledge base. This section will present a brief overview of previous research regarding domestic energy use and ways of supporting energy conservation in order to identify gaps in knowledge and present the two themes and research questions that are explored within the scope of this thesis.

1.2.1 DOMESTIC ENERGY USE

Researchers have adopted different approaches to increase the understanding of domestic energy use. One common approach has been to explore why the energy use of households differs based on aspects related to the households' socio-economic situation, such as the number of residents, the household's income, the size of the dwelling, and the residents' knowledge level. While these socio-economic aspects provide insight into preconditions influencing energy use, it is argued that they say little about people's actual energy use in everyday life (Jones et al., 2015; Lutzenhiser, 1993).

Another common approach has been to study how psychological aspects such as attitudes, beliefs, and norms influence energy use (e.g. Abrahamse & Steg, 2009; Gadenne et al., 2011; Kleinschafer & Morrison, 2014). Even though studies have found that these types of aspects influence energy use, it has also been argued that psychological aspects have low explanatory power and that they alone cannot fully explain people's energy use (Gatersleben et al., 2002).

To further increase the understanding of domestic energy use it has been suggested that yet another approach can be embraced. By addressing people's energy use in the context of everyday life, insight can be gained into the complexity and dynamics of everyday energy use (Gram-Hanssen, 2013a; Lutzenhiser, 1993; Wilhite, 2008). Research based on this approach has largely been directed at understanding the daily doings that generate energy use (e.g. Gram-Hanssen, 2013b; Pierce et al., 2010; Wallenborn & Wilhite, 2014) and what energy conservation measures people implement and find acceptable (e.g.

Crosbie & Baker, 2010; Niemeyer, 2010; Pelletier et al., 1999; Throne-Holst et al., 2008). As studies addressing people's doings in the context of everyday life increase in number, a new understanding is developing of people's energy use in everyday life. It is evident that energy plays a key role in daily life and that people use energy for varying purposes by engaging in a web of coexisting and interacting doings in which they make use of energy-reliant artefacts. This enriched understanding points to new knowledge gaps that can be addressed to further the understanding of people's energy use.

First, if people's energy use result from a web of doings, it becomes essential to acknowledge the interdependence between different doings and explore what implications the links between doings may have for people's use of energy and artefacts. However, studies within energy research commonly address people's doings one by one without discussing how different doings relate to one another (Abrahamse et al., 2005; Lopes et al., 2012). Addressing particular doings apart from other doings is insufficient as it provides little insight into people's prioritisations in everyday life, which have been found to be essential in order to understand people's energy use (Richetin et al., 2012). Exploring the interdependence between different doings and how people prioritise between them is thus important in order to contribute to a richer understanding of why people act the way they do and why they may find energy conservation undesirable to prioritise in daily life.

Additionally, how people's use of, and interaction with, energy-reliant artefacts influence their doings and energy use in everyday life has been given relatively little attention in energy research although it is highlighted in design literature. Even though design-related research has pointed to the importance of understanding more about how the design of artefacts influences energy use (e.g. Rodriguez & Boks, 2005; Thornander et al., 2011), the ways in which artefacts influence people's energy use has not been studied in depth.

To sum up, there is potential for increasing the understanding of people's energy use by exploring people's energy-reliant doings in the everyday, particularly by investigating how people's prioritisations in everyday life shape energy use and in what ways energy-reliant artefacts influence energy use during daily doings. Hence, *Energy use in everyday life* will be the first theme explored in this thesis with the overarching research question: *How do people's doings in everyday life influence their domestic energy use?* (RQ1). This research question is operationalised by two sub-questions that have been formulated to specifically address the knowledge gaps discussed above:

RQ1.1: *In what ways do people's everyday prioritisations shape their doings and energy use?*

RQ1.2: *In what ways do energy-reliant artefacts influence people's doings and energy use during everyday life?*

1.2.2 WAYS OF SUPPORTING ENERGY CONSERVATION

In addition to research efforts striving to increase the understanding of people's energy use, a major focus has been to study how energy conservation can be supported through different strategies. Researchers who have explored how people's energy use is influenced by socio-economic and psychological aspects have commonly focused on intervention strategies for influencing these types of aspects (Dwyer et al., 1993; Manning, 2009; Steg & Vlek, 2009). Numerous studies have addressed intervention strategies such as information strategies and incentives, and assessed their effectiveness in influencing, for instance, knowledge, attitudes, motivations and norms (for a review of studies see Abrahamse et al., 2005). It is generally concluded that these types of strategies vary in effectiveness depending on the situation addressed (Abrahamse et al., 2005; Ölander & Thøgersen, 1995; Steg & Vlek, 2009). For instance, information can contribute to energy conservation but only when it is relatively convenient for people to reduce energy use, when it is not very costly in terms of money, time, effort or social disapproval, and when people do not face severe constraints (Steg, 2008). Therefore, it is often argued that a combination of intervention strategies can increase the potential for supporting energy conservation long term (Abrahamse et al., 2007; Gardner & Stern, 2008; He & Greenberg, 2009; Steg & Vlek, 2009).

However, studies suggest that combining, for instance, incentives and information will not be enough when people are constrained or locked-in to unsustainable use patterns due to appliances, technical systems and the current infrastructure (Maréchal, 2010). For instance, the heating system in a house or the infrastructure providing electricity and heating in a building or a city can limit people's opportunities for reducing their energy use. Similarly, the appliances used in everyday life often require or lead to particular use patterns which can make energy reductions difficult to achieve.

Therefore, literature stresses the need for other strategies aimed at changing the infrastructures, technical systems, and appliances through which energy is used (Steg, 2008). Research within the field of design highlights opportunities for deliberately designing such artefacts so that they encourage and/or facilitate energy reductions (e.g. Kuijer & Jong, 2012; Lilley et al., 2005; Lockton et al., 2008; Rodriguez, 2004; Wever et al., 2008). Two principal approaches are often discussed: to design artefacts that aid energy conservation measures in everyday life and to design energy-reliant artefacts in such a way that they mediate less energy-intensive use.

The first approach, i.e. designing artefacts to aid energy conservation measures, addresses for instance artefacts that make measures easier such as on/off switches or timers, but is most frequently discussed with regard to energy feedback systems designed to encourage energy reductions and energy conservation activities. Numerous studies have been conducted to assess the effects of providing feedback on people's energy use through a variety of devices and displays (see reviews by Darby (2006), Fischer (2008), and Wilson et al. (2015)). Through energy feedback artefacts, energy can be made more visible in everyday life, which may increase not only their understanding of energy itself but also their perceived opportunities for taking measures and engaging in energy conservation activities. Feedback can be given in many different forms; it can be highly personalised or general, it can present real-time or historic data, and it can simply inform or also recommend action (Darby, 2001; Froehlich, 2009). Literature indicates that the potential for energy reductions increases if several types of feedback are provided and if it is given frequently, is presented in a clear and appealing way, and is provided through interactive artefacts (Abrahamse et al., 2005; Darby, 2001; Fischer, 2008). Even though studies show that the effects of feedback vary according to circumstances, the reported potential for decreased energy use usually ranges from 5-15% (Darby, 2006; Fischer, 2008). However, literature points to several issues that have not yet been adequately explored. As most studies have focused on quantifying the influence feedback artefacts have on energy use, measured savings are discussed to a greater extent than how, and to what extent, people use feedback artefacts as part of their everyday life. Without addressing the use of these types of artefacts it is not only impossible to determine whether changes in energy use can be attributed to people's use of the artefacts, but it is also difficult to gain an insight into what types of energy conservation measures they may aid. In order to explore the potential energy feedback artefacts have for supporting energy conservation, literature thus suggests that it is essential to explore how feedback artefacts intersect with everyday life (Steg, 2008; Strengers, 2011b). Such explorations not only entail studying how people use feedback artefacts, but also whether the artefacts may be adopted and why. Moreover, the potential for lasting effects is also unclear since few studies have addressed the duration of effects (Dwyer et al., 1993), and the few studies that have, did not find any sustained effects over time (Dwyer et al., 1993; van Dam et al., 2010; van Houwelingen & van Raaij, 1989). Hence, in addition to studying people's use and adoption of feedback artefacts in daily life, further study is required regarding the possibilities for lasting effects.

The second approach, i.e. designing energy-reliant artefacts in such a way that they mediate less energy-intensive use, has so far been given little attention in energy research but is highlighted in design literature. Design research argues that artefacts can be designed so that certain use patterns are made difficult while others are made easier, or even automatic (Lockton et al., 2008; Wever et al., 2008). It is often highlighted that constraints can place limitations on actions and that the affordances embedded in the design influence people's perception of possible actions and thus also the choices they make during interaction (Lilley et al., 2005; Lockton et al., 2008; Norman, 1999). Even though a variety of possibilities for design are suggested in literature, the evidence base is thin due to few case studies (Boks et al., 2015; Coskun et al., 2015). The studies that have been carried out have mostly focused on exploring the influence of different energy-reliant artefacts on people's energy use (e.g. Rodriguez & Boks, 2005; Thornander et al., 2011) but few studies have assessed artefacts specifically designed to mediate less energy-intensive use. Without addressing people's use of such artefacts, it is impossible to discuss what potential design may have for contributing to reducing energy use. In order to conclude whether artefacts can be designed to mediate less energy-intensive use, it is thus necessary to study how such particular artefacts and their functions actually influence energy use in everyday life and why. Additionally, to gain an insight into whether these types of artefacts are attractive to people, it is essential to also explore people's use of these types of artefacts in the context of everyday life as well as aspects influencing their use and adoption.

In sum, the two types of artefacts discussed above present ways for design to potentially contribute to energy conservation but additional research is required to better understand how artefacts designed to support energy conservation are used in everyday life and in what ways, and to what extent, they influence energy use. Hence, both types of artefacts will be considered within the second theme explored in this thesis: *Artefacts designed to support energy conservation*. This theme will address the overarching research question: *How do energy-reliant artefacts designed to support energy conservation influence domestic energy use in everyday life?* (RQ2). This research question is operationalised by three sub-questions that specifically address the knowledge gaps highlighted for the two types of artefacts:

RQ2.1: ***In what ways and to what extent do people use artefacts designed to support energy conservation?***

RQ2.2: ***What design-related aspects influence people's use and adoption of artefacts designed to support energy conservation?***

RQ2.3: ***To what extent, and why, do artefacts designed to support energy conservation influence people's energy use?***

1.3 SCOPE AND DELIMITATIONS

As described in the previous sections, this thesis addresses in part how people's doings influence domestic energy use in everyday life (*Theme 1*) and in part how energy-reliant artefacts designed to support energy conservation may influence people's doings and the resulting energy use (*Theme 2*). In addition, with the overall aim to increase the understanding of people's energy use and people's use of energy-reliant artefacts in order to propose ways of supporting energy conservation through design, the thesis also addresses what implications the insights acquired present for the development and design of new artefacts aimed at supporting energy conservation (*Implications for design practice*). In all, this thesis is thus concerned with exploring energy use and energy conservation from a product design perspective with a primary focus on everyday artefacts and their design.

As such, the thesis addresses only one of the many pieces of the puzzle needed to further an understanding of how domestic energy use can be reduced. It is beyond the scope of this thesis to address issues related to energy production and distribution infrastructures as well as societal change processes and transitions towards new socio-technical systems. Nor does the thesis contribute with design concepts or directly consider issues related to the design and development process, and the production and manufacture of artefacts.

Even though it is important to question society's consumption patterns in relation to the acquisition of energy-reliant artefacts in order to address the overall issue of energy demand, the thesis does not go deeper into these aspects. Rather, it focuses on people's interplay with the everyday artefacts that are commonly used in daily life and explores energy use and energy conservation from this perspective. What types of artefacts people use and how they use them are, however, discussed to a greater extent than, for instance, strategies for maintenance and repair.

The thesis builds upon empirical material collected in Sweden and the findings are thus limited to specific situations in Swedish households. However, the insights and discussions are considered relevant for other similar contexts.

02 | FRAME OF REFERENCE

The previous chapter highlighted the need to both increase the understanding of people's energy use in the everyday and the influence of energy-reliant artefacts designed to support energy conservation in order to explore how energy conservation can be supported through design. Within research that addresses the topics of energy and design, various theoretical frameworks and approaches are applied to study people's energy use and to utilise insights from a design point of view. This chapter provides an overview of common theoretical standpoints and approaches, and discusses their relevance and usefulness from a design perspective. The chapter concludes by providing a rationale for the perspectives that have been used for framing the work presented in the thesis.

2.1. PERSPECTIVES FOR UNDERSTANDING ENERGY USE

Over the years, different frameworks and models have been suggested to describe how various aspects influence peoples' doings in everyday life (comprehensive reviews are provided by Chatterton (2011), Darnton (2008), Jackson (2005), Kollmuss and Agyeman (2002), and Niedderer et al. (2014b)). This section provides a brief overview of a selection of prominent frameworks that can be used to understand people's doings and energy use in everyday life.

The frameworks are characterised by the various disciplines they originate from and differ in relation to a number of aspects. One fundamental difference is their approach to the locus of study; that is, what they aim to understand and therefore consider to be an appropriate unit of analysis for studying people's doings. A group of frameworks addresses doings from the perspective of the individual with a focus on the notion of behaviour, which is commonly considered to be a function or causal response to specific internal and/or external determinants. Another perspective addresses doings in terms of activities, which may involve several persons and consist of a collection of actions and operations carried out for a particular purpose. Yet another perspective addresses doings as social practices, which are collectively shared and carried out by a large group of people.

As the unit of analysis has fundamental implications for the way in which energy use should be explored, analysed, and understood, the overview is therefore structured according to the unit of analysis the different frameworks use to discuss people's doings in everyday life.

2.1.1 BEHAVIOUR AS A UNIT OF ANALYSIS

A multitude of frameworks addressing the behaviour of individuals have been brought forward by different disciplines, with the aim of understanding and predicting behaviour. While some frameworks address behaviour in general, others focus on pro-environmental behaviour in particular. Nevertheless, the frameworks all follow the key conceptual premise that antecedent variables, often referred to as determinants, moderate people's intentions and behaviours through a causal relationship. The frameworks commonly consider one behaviour at a time and focus on people's decision-making processes in specific situations at particular moments in time. Due to their distinct unit of analysis and defined determinants, a number of these frameworks have been used as a basis for studying and predicting people's energy use (Abrahamse et al., 2005).

Different assumptions regarding the nature of human behaviour are reflected in the models, depending on the field of study from which the models originate. Traditional economic models often describe people as rational decision-makers that weigh cost and benefits in order to choose a course of action that maximises the expected net benefit. Several key assumptions underlie this model, for instance, that choice is rational and deliberate and that choices are made in pursuit of individual self-interest (see Jackson, 2005 for an overview).

These assumptions are questioned in frameworks from other disciplines. For example, behavioural economics unifies theories looking at rational decision-making processes with theories that take into account individual preferences and mental shortcuts (Chatterton, 2011; Darnton, 2008). Others oppose the assumption of rational choice altogether, and argue that it is unrealistic to assume that people can make deliberate choices when facing complex decisions since they operate under time constraints and cognitive limitations (Jackson, 2005). Instead, some suggest that people often cope by following routines and habits guided by automated cognitive processes (Maréchal, 2010; Steg & Vlek, 2009; Verplanken, 2006).

One of the most commonly used social-psychology models for describing behaviour is the Theory of Planned Behaviour (Ajzen, 1991). According to the Theory of Planned Behaviour, a person's intention to carry out a particular behaviour is formed by attitudes, which are based on the person's beliefs about and evaluations of outcome, and subjective norms, which are based on perceptions regarding what other people think about the person's behaviour. Moreover, the person's perceived behavioural control influences the resulting behaviour and the intention both directly and indirectly through subjective norms, see figure 2.1. Applying such a model to predict people's energy use when they, for instance, cook dinner, entails studying particular behaviours, such as frying vegetables, boiling potatoes, and making a sauce. According to the theory, the behaviours must be studied separately as only behaviour-specific measurements can successfully predict behaviour. Hence, if aiming to predict whether a person will fry vegetables, the study

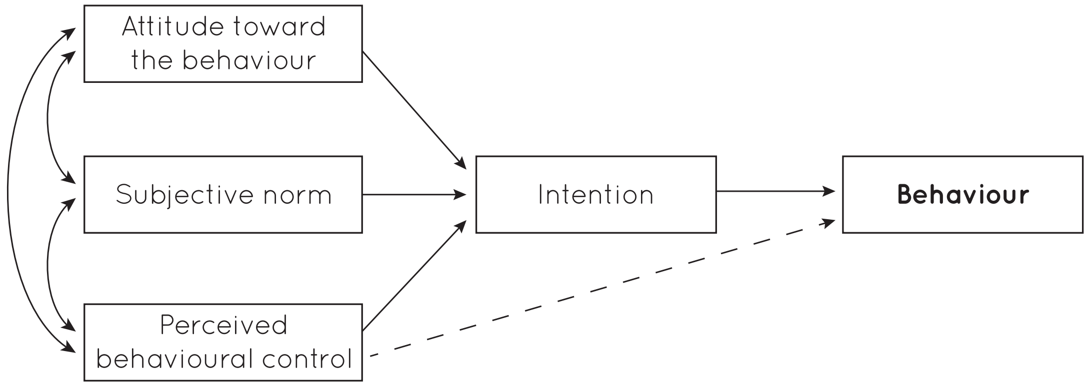

Figure 2.1 Theory of Planned Behaviour, adapted from Ajzen (1991)

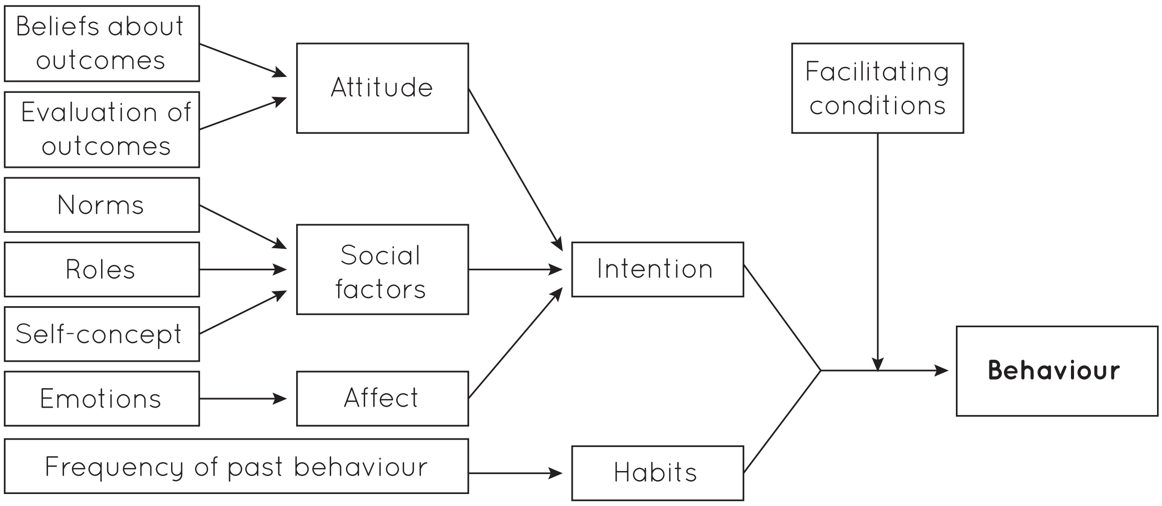

Figure 2.2 Theory of Interpersonal Behaviour, adapted from Triandis (1977)

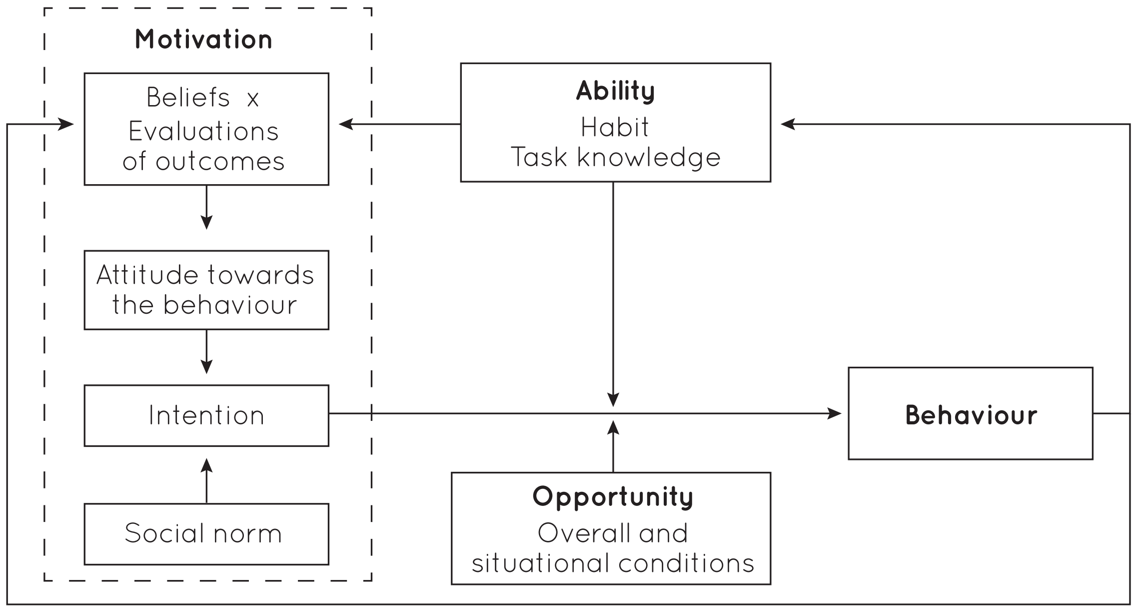

Figure 2.3 The Motivation-Ability-Opportunity Behaviour Model, adapted from Ölander and Thøgersen (1995)

should address the person's specific attitudes towards frying vegetables and subjective norms that concern frying and vegetables, as well as the person's perceived behavioural control, which can be measured by studying the person's perception of his or her ability to successfully fry vegetables based on the specific opportunities and resources available to the person at the time (e.g. time, money, skills). Ajzen (1991) argues that if a person has the required opportunities and resources, and intends to perform the behaviour, he or she should succeed in doing so.

The theory of Planned Behaviour focuses primarily on processes and determinants that can be conceived as internal to the individual but partly also includes external influences through the concept of perceived behavioural control. An additional framework that includes external determinants is the Theory of Interpersonal Behaviour (Triandis, 1977), which encompasses aspects such as attitudes, social aspects, affect, and habits as well as external determinants in the form of facilitating conditions, see figure 2.2.

Another example that includes external aspects is the Motivation-Ability-Opportunity Behaviour Model that highlights aspects such as motivation and ability, as well as opportunity as an important factor shaped by a person's overall and situational preconditions (Ölander & Thøgersen, 1995), see figure 2.3. The model illustrate that motivation may change over time as a person's beliefs about or evaluations of an activity are influenced by experience, both directly and indirectly through a learning process, which may increase task knowledge or lead to the development of habits.

Even though the frameworks provide different perspectives for understanding behaviour they are based on the idea of a causal relationship between determinants and behaviour. This implies that a change in determinants leads to a change in behaviour, which has made these types of frameworks popular for carrying out empirical energy research to assess to what degree different determinants influence energy use, and to understand the relationship between different aspects. Another common characteristic of these types of frameworks is that determinants are often discussed in terms of barriers or drivers that mediate the outcome of people's behaviours. As the determinants are considered to either provide for, or constrain, behaviour depending on the situation, energy research based on these types of models often suggests interventions aimed at removing barriers or facilitating or encouraging behaviour though triggering different drivers (Darnton, 2008; Steg & Vlek, 2009). Commonly discussed interventions include, for instance, providing information or feedback to increase a person's knowledge, providing rewards or penalties to increase motivation, and increasing normative concerns though competitions or by asking for commitments (Dwyer et al., 1993).

2.1.2 ACTIVITIES AS A UNIT OF ANALYSIS

Activity Theory (AT) provides another perspective for understanding people's doings in everyday life. According to AT, an activity is considered to be the smallest meaningful unit of analysis for studying people's doings, as the activity is what gives meaning to people's actions through an overall satisfaction of needs (Bødker & Klokmose, 2011; Kaptelinin & Nardi, 2006; Kuutti, 1996).

AT builds on the works of Vygotsky and Leontiev, which provided a cultural-historical perspective on psychology that was initially applied in studies on development and learning (see Kaptelinin and Nardi (2006) for an overview). This perspective has more recently been applied in fields such as organisational research (e.g. Engeström, 2000), human-computer interaction (e.g. Bannon & Bødker, 1991; Bødker, 1991; Nardi, 1996a),

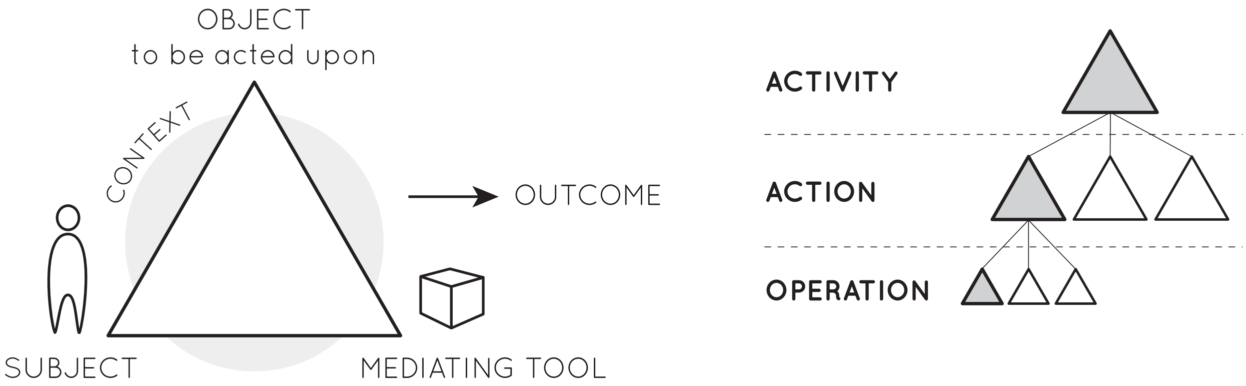

Figure 2.4 A simplified representation of an activity-system in which mediating tools enable a subject to act upon a particular object to achieve a desired outcome

and product design (e.g. Engelbrektsson, 2004; Hjort af Ornäs, 2010; Karlsson, 1996; Rexfelt, 2008).

As this thesis addresses people's energy use from a product design perspective, this section will provide an overview of the core concepts most relevant for design. The activity theoretical framework as applied in interaction design and product design, describes an activity as a subject acting upon an object to achieve a desired outcome through the use of one or more mediating tools, see figure 2.4. The activity can be described in a hierarchical structure and divided into one or more actions, which in turn can be divided into one or more operations. In everyday life, people engage in a web of activities, in which some activities are mediated by the same tools and require similar actions and operations. For instance, people may make use of a smartphone to call a friend, to find a restaurant, and to acquire travel information, all of which require actions such as activating the phone and starting an application, which in turn requires people to interact with the display.

It is argued that in order to understand an activity as a whole, it is important to consider its basic concepts in relation to the hierarchical structure of activities (Karlsson, 1996; Rexfelt, 2008). Figure 2.5 provides an overview of common conceptualisations of concepts on the three levels. At the activity level, the object of the activity is formed as the subject pursues one or more motives, which are not always conscious but emerge from one or more needs. The object is jointly defined by the particular motives the subject strives to attain through the activity in the particular context (Kaptelinin & Nardi, 2006). For example, members of a family may engage in cooking activities with the motive of satisfying their hunger, but also to gain a sense of belonging or to develop their cooking skills. The specific object formed in a particular activity thus differentiates it from other similar activities and sets the scene for the actions and operations carried out as part of the activity. At this level the subject can be either an individual or a collective, and the mediating tools include all tools that could be used for carrying out the activity (Karlsson, 1996).

One step down in the hierarchy, an individual carries out one or more actions that contribute to the overall activity. The actions are mediated by a specific tool and carried out in a tool-specific context (Rexfelt, 2008). The actions are directed towards conscious goals, also referred to as operationalised motives (Kaptelinin & Nardi, 2006), and the outcome of an action fulfils a particular goal, which together with the fulfilment of additional goals contributes to the overall satisfaction of needs. Depending on the motives that jointly form the object of the activity, different goals will come into play. For instance, if people

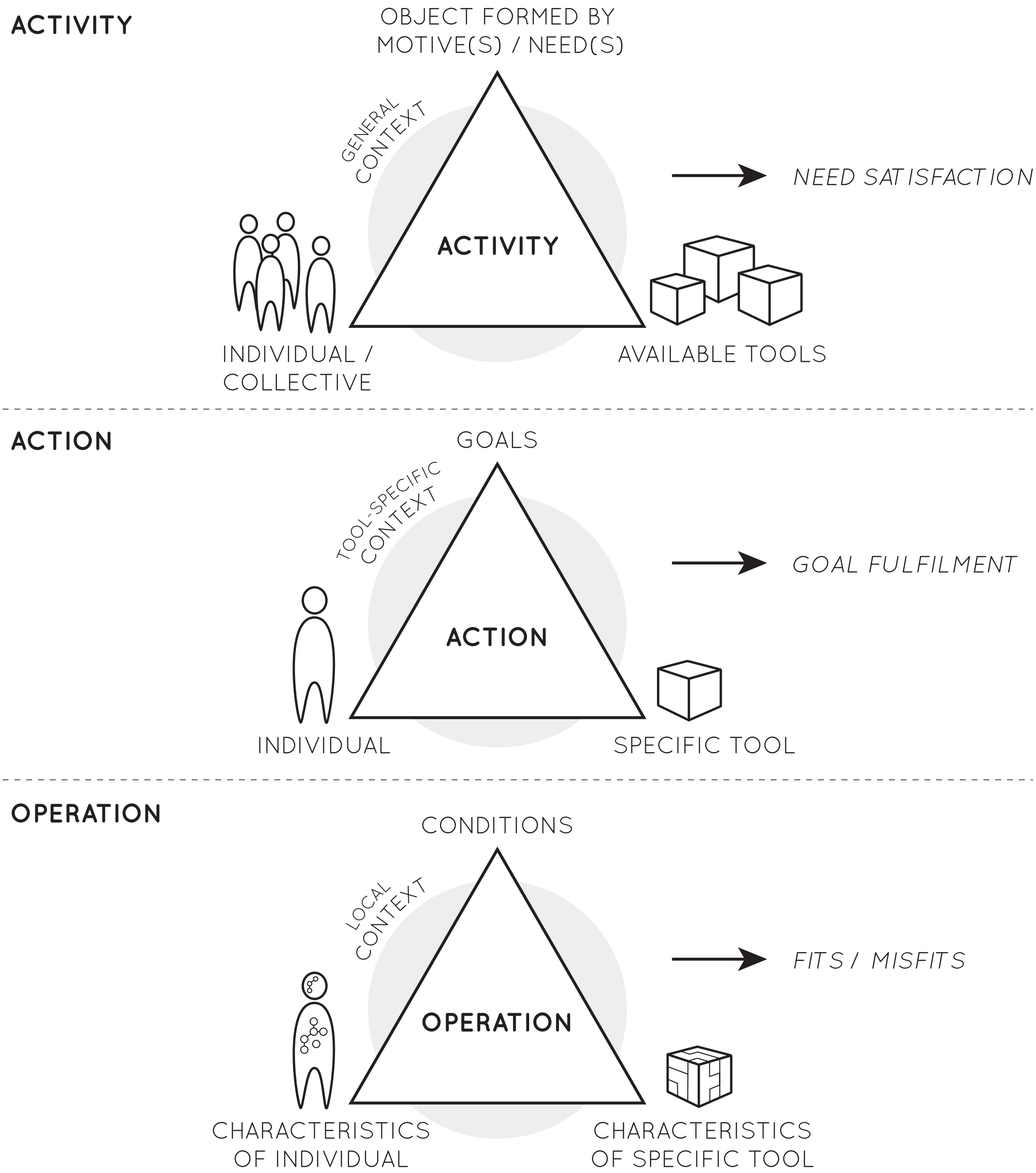

Figure 2.5 The hierarchy of activities, actions, and operations

cook dinner when they are really hungry, they may prioritise the need to save time over other goals. In contrast, if a family cooks dinner as a social activity, they may be more concerned with having a pleasant time together than reducing the time required.

At the bottom of the hierarchy, one or a series of unconscious operations are carried out for each action. The operations do not have goals of their own; instead they are well-defined routines used subconsciously and triggered by the characteristics of the tool and the specific contextual conditions present at the time (Kaptelinin & Nardi, 2006; Kuutti, 1996). The outcome of an operation depends on the fit between the characteristics of the individual, the specific tool, and the local context (cf. Rexfelt, 2008).

Even though the activity, actions and operations are often described on separate levels, they are not fixed; they change dynamically over time (Kuutti, 1996; Nardi, 1996b).

For instance, a set of actions can be transformed into a chain of operations if the actions are routinised through extensive practice. In contrast, if misfits or changed conditions are encountered on the level of operation, a breakdown can occur that will transform sets of operations back into conscious goal-directed actions (Bødker, 1995; Kaptelinin & Nardi, 2006; Koschmann et al., 1998). If other actions more successfully create desired outcomes under the new conditions, they may be transformed into a new set of operations that replace the old set in similar situations in the future.

Applying such as perspective for studying and understanding people's energy use, entails a different approach compared to the frameworks discussed in the previous section. For instance, when applying an activity theoretical perspective to understand people's energy use while cooking, it becomes essential to address the activity-system as a whole. Only when addressing aspects such as why people cook dinner, what actions they perform, what tools they use, how they carry out actions, and the outcomes that are generated, can an understanding of the activity as a whole be formed. By considering these types of aspects, an insight can, for instance, be gained into why people may fry vegetables using a stove instead of steaming vegetables using a microwave oven. Insight can also be gained into potential misfits that may make particular operations, such as turning a dial or pushing a button, difficult which may in turn make particular actions or the whole activity cumbersome.

As described above, the concept of mediation is central to AT. Tools enable purposeful activities through which people can achieve desired outcomes. The concept of a mediating tool can be understood widely as anything that may support a person to act upon an object in order to achieve a particular outcome (Hjort af Ornäs, 2010), such as symbols, language and technical artefacts (Bødker & Klokmose, 2011). Furthermore, mediating tools may in some situations be treated as goals for activities (e.g. to acquire a particular tool) or as objects to be acted upon (e.g. a broken tool that require repairing) (Hjort af Ornäs, 2010).

Another key concept in AT is development. It is argued that daily doings are continuously shaped and reformed in a cultural historic context and developed through a dialectical process in which contradictions within or between activities act as generative forces that transform both subjects and objects through the activity (Kaptelinin, 2014; Kaptelinin & Nardi, 2006). One contributing component of this transformative process is the development of new tools, which influence people's needs and ultimately change their motives and activities. As people's needs transform over time they acquire, use and appropriate new tools to better meet their needs, which will give rise to new needs and objects, which will subsequently lead to the acquisition and use of additional tools, and so on (Bødker & Klokmose, 2011). In order for the tools to be useful and enable people to meet their needs, they are re-created over time as the society transform. Their properties thus reflect the accumulated experiences of people carrying out similar activities in the past. Hence, tools provide a transmission of, for instance, knowledge and norms within a culture that allows people, and often makes people, to appropriate socially developed forms of acting in the world (Kaptelinin, 2014; Kaptelinin & Nardi, 2006; Kuutti, 1996).

2.1.3 PRACTICES AS A UNIT OF ANALYSIS

Another perspective for understanding people's doings that has gained many supporters in recent years is based on Practice theory (PT). A practice-oriented perspective acknowledges people as carriers of practices and considers practices as the appropriate unit of analysis though which people's doings should be understood. Such a perspective has been applied in several studies carried out to explore people's energy use, for instance in relation to people's use and adoption of new technologies (Spaargaren et al., 2006) and standby energy use (Gram-Hanssen, 2010).

Even though a diversity of different theories of practice is discussed in literature (see Gram-Hanssen (2007) and Warde (2005) for more detailed overviews), this section focuses on introducing basic principles and concepts related to Practice theory as commonly discussed in research that addresses the topics of energy and design.

Central to PT is the social nature of practices; practices are considered collectively shared coordinated entities that are carried out at different places, at different times, by different actors. A practice is sustained by repeated performances by the carriers of the practice, even though people's enactment of the practice may vary in different situations (Chatterton, 2011; Gram-Hanssen, 2008; Warde, 2005). A practice however exists beyond specific performances. According to PT, the practice-as-entity consists of interconnected sets of elements that interplay to shape performances and hold the practice together.

Different understandings of the elements of practice are discussed in literature (see Gram-Hanssen (2010) for an overview) and one understanding commonly applied refers to stuff, images, and skills (e.g. Kuijer, 2014; Pantzar & Shove, n.d.; Scott et al., 2012). Stuff includes all the technologies, spaces, bodies and structures in the practice. Images summarise the social and personal meaning achieved through the practice while skills represent the understanding and know-how associated with the practice and learned socially through the practice. Kuijer (2014) argues for considering the elements as groupings of elements and the links between them as a multitude of links, see figure 2.6. Such an understanding of the elements of practice is valuable as it distinguishes a single performance as one manifestation of the practice-as-entity. Kuijer also highlights that even though the practice-as-entity is made up of the sum of the elements and links that occur in its variety of performances, some elements and links are more essential for the practice than others.

Even though there is no consensus on what elements it is appropriate to consider in order to take the full complexity of practice into account, the evolving nature of the relationship between the elements is commonly emphasised (Gram-Hanssen, 2007; Shove & Walker, 2010). Practices may evolve due to several reasons. For instance, the

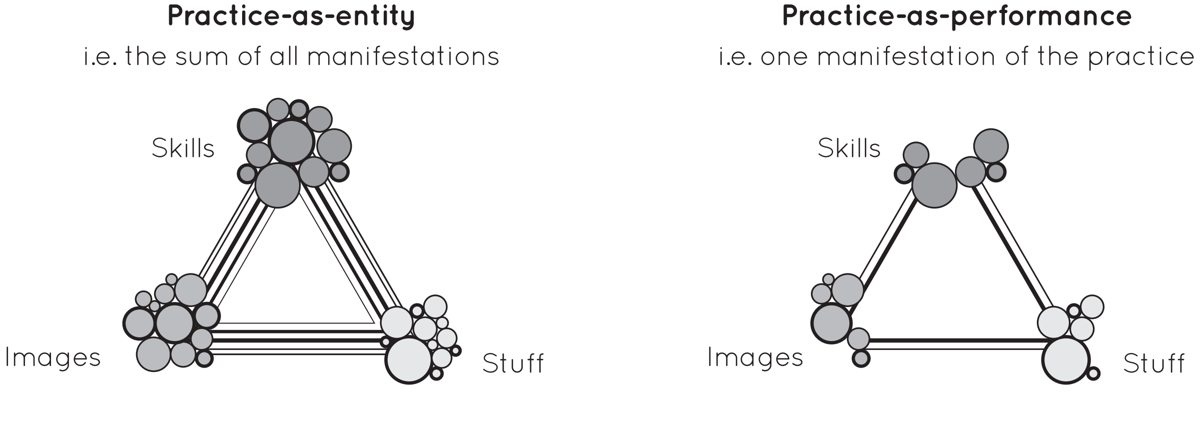

Figure 2.6. Key elements in the understanding of practice, adapted from Kuijer (2014), a) a practice-as-entity as a constellation of groupings of all elements and links, and b) a practice-as-performance as a constellation of particular groupings of elements and links

groupings of elements can shift over time either when elements are combined in new combinations or when unfamiliar elements and links are integrated in the practice through a reconfiguration process (Kuijer, 2014), see figure 2.7. Shifts in each performance change the conditions for the next, making new routines emerge and practices evolve over time. Shifting of elements and links may not only reconfigure practices, but can also disrupt practices or establish new ones. A practice-as-performance is thus both a consequence of the trajectory of the practice-as-entity and a catalyst for change (Shove et al., 2007). Change is considered to be continuous but not initiated by any actor in particular, neither is it directed in any particular direction (Kuijer, 2014). As a particular practice co-exists with other practices, changes in one practice may also lead to changes in other practices and influence other parts of everyday life (Pettersen, 2013).

PT thus provides yet another lens through which people's energy use can be understood. When applying a practice-oriented perspective in considering the example of cooking, as also discussed in the previous sections, other aspects become important to address. Acquiring insight into, for instance, people's food preferences, food eating experiences, cooking skills, kitchen layout, kitchen appliances, and even spare time endeavours, and how these aspects have changed over time may be needed to gain insight into the elements and links that shape people's particular performances of the practice. To gain insight into the cooking practice (as entity) also requires studies that address a large number of carriers of the practice so that an understanding of all elements and links that make up the practice can be formed.

Material artefacts and the dynamic interplay between people and artefacts are especially emphasised in PT as they contribute to reproducing practices. Artefacts are seen as bearing with them the potential for change as they make particular practices possible and influence people's perception of normal or appropriate conduct (Ingram et al., 2007; Shove et al., 2007). Since daily routines involve the practical handling of artefacts, a change in technologies most often requires a change in routines (Gram-Hanssen, 2008). Material artefacts are not only considered to play an important role in the transformative process of practices; they co-evolve with the practices of everyday life (Ingram et al., 2007; Shove & Pantzar, 2005).

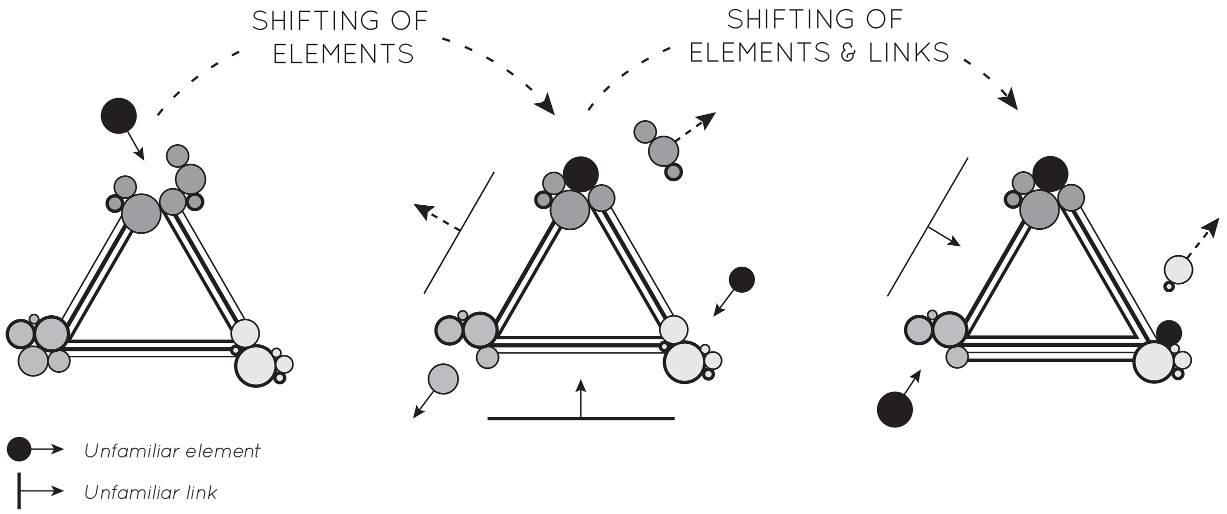

Figure 2.7. Reconfiguration of practices through integration of unfamiliar elements and links, adapted from Kuijer (2014)

As PT is concerned with routinised and socially shared practices, research with a practice stance typically entails empirical explorations that focus on understanding people's routines as well as the elements and links that hold the practice together. Studying how technological structures contribute to the emergence and development of practices is another common theme.

2.2 PERSPECTIVES ON DESIGNING FOR CHANGE

The notion of design is multifaceted and its meaning differs between disciplines. Within product design, design can be considered both an activity in which something is designed, and the output of a design activity such as an idea, a concept, a drawing or a created artefact. Heskett (2005, p. 5) argues "*design, stripped to its essence, can be defined as the human capacity to shape and make our environment in ways without precedent in nature, to serve our needs and give meaning to our lives*". This central underpinning of design brings forth the idea that artefacts can be designed to contribute to change, which has been a key element of the research presented in this thesis.

As artefacts influence the possibilities people have for achieving particular purposes, the introduction of new artefacts and technologies may consequently change the way people live their lives. In shaping the development of products, services, and technical systems, designers thus bear a direct impact on the transformation of society and the environment (Midden et al., 2007; Niedderer et al., 2014b; Papanek, 1985). How change will manifest itself in everyday life, and how artefacts may influence, for instance, people's use of energy, is less certain. Designers can nonetheless strive for preferred trajectories in which less energy-intensive ways of life can potentially emerge, by embedding their visions of the world in the artefacts they design (cf. Fry, 1999). If artefacts are designed without intent, there is a risk of supporting change in the direction of more, rather than less, energy-intensive ways of life.

Emerging design perspectives highlight how design and designers can drive the sustainability agenda by designing for change in different ways (see overview by e.g. Ceschin and Gaziulusoy (2016)). Joore and Brezet (2015) propose a multi-level design model in which they classify four distinct levels on which design can contribute to societal changes. They define the highest level as the *Societal System* and changes at this level are often referred to as transitions, i.e. gradual, continuous processes of societal change in which the character of society undergoes structural change. At the next level, the *Socio-Technical System*, changes are defined as large-scale transformations in the way societal functions are fulfilled. *Product-Service Systems* form the next level at which changes can be made in regard to the available mix of tangible products and intangible services designed to satisfy people's needs. Physical artefacts or *Product-Technology Systems*, form the basic level of the model at which changes are related to clearly distinguishable functions. Different levels can thus be relevant to consider when designing for change. However, as the research presented in this thesis does not address the societal system or socio-technical systems, the potential for design to contribute to change on these levels will not be addressed. Two main stances for addressing people's use of resources in everyday life related to the two lower levels have emerged during the last decade: *Design for Sustainable Behaviour* and *Practice-Oriented Product Design*. They represent different theoretical viewpoints but both provide insight into how people's use of resources can be addressed from a design perspective. This section briefly reviews these two design directions.

2.2.1 DESIGN FOR SUSTAINABLE BEHAVIOUR

Design for Sustainable Behaviour (DfSB) addresses how artefacts can be designed to encourage and facilitate sustainable behaviour (Bhamra & Lilley, 2015; Coskun et al., 2015). DfSB researchers primarily draw on theoretical perspectives that take behaviour as the unit of analysis in order to explore opportunities for designing interventions with the aim of changing people's doings and outcomes of those doings.

Based on various theoretical frameworks for describing behaviour, a large number of models encompassing different design strategies and toolkits for idea generation have been proposed to aid designers in designing for sustainable behaviour (e.g. Bhamra et al., 2008; Daae & Boks, 2014; Lidman & Renström, 2011; Lockton et al., 2010; Wever et al., 2008). Even though no consensus on suitable terminology for categorising the design strategies has been reached, similar types of strategies are emphasised by different groups of researchers. The categorisations also usually indicate the varying level of control that the strategies place on the user or the artefact. Commonly, literature suggests that people can be enlightened, spurred on, steered, and/or forced to behave in a certain way. Additionally, it is proposed that an artefact's functions can be matched to a user's current behaviour or intended behaviour to, for instance, make the behaviour less resource-intensive. For a comprehensive review of design strategies please refer to the work by Lidman and Renström (2011).

In addition to suggesting design strategies and toolkits, DfSB research has been concerned with exploring people's use of artefacts to identify opportunities for intervention and with exploring the choice and effectiveness of the design strategies by assessing design interventions (Coskun et al., 2015). Studies exploring opportunities for intervention and the effectiveness of different strategies in relation to energy conservation are particularly plentiful (e.g. Hanratty, 2015; Oliveira et al., 2012; Rodriguez & Boks, 2005; Tang & Bhamra, 2012; Wilson, 2013).

2.2.2 PRACTICE-ORIENTED PRODUCT DESIGN

In contrast to DfSB, Practice-Oriented Product Design (POPD) does not centre on the behaviour of individuals, but on the dynamics and elements of practice (Niedderer et al., 2014b; Shove et al., 2007). POPD is concerned with reconfigurations of elements of practice through designed interventions so that new ways of living may come to pass (Kuijer & Jong, 2012; Lopes & Gill, 2015; Pettersen, 2013; Scott et al., 2012). Novel elements can be integrated into novel configurations and contribute to the on-going reproduction of practices, which have the potential to influence the trajectory of current practices in a more sustainable direction or allow completely new practices to emerge (Kuijer & Jong, 2012; Scott et al., 2012; Shove et al., 2008).

It is suggested that by taking practices as a unit of analysis when studying people's resource use, designers may gain an understanding of available opportunities for intervention. When analysing a particular practice-as-entity, Kuijer (2014) suggests that, in addition to addressing the targeted practice itself, the historic evolution of the practice should be charted as well as similar but less resource-intensive practices. Moreover, multiple performances of the practice and their constellation of elements and links must be studied in detail since they form the practice-as-entity as a whole. Kuijer (2014) also argues that practices can be taken as a unit of design with the aim of identifying element configurations that work. For instance, through an iterative process of suggesting new artefacts and evaluating how they may trigger novel ways of acting in the context of everyday life, designers can help people prototype new and desirable practices. Similarly, Scott et al. (2012) suggest a participatory design approach through which people can reflect on current practices to deconstruct them and integrate new ideas for practice through stages of experimentation.

As the study of a practice-as-entity requires both a broad and detailed analysis, most POPD studies have studied manifestations in performances. While some studies have aimed to identify opportunities for design intervention, others have evaluated what reconfigurations of performances various design concepts may give rise to through participatory processes in which people improvise, experiment and try out new practices (Kuijer, 2014; Kuijer & Jong, 2012).

2.3 POSITIONING OF THE RESEARCH

As discussed in the previous sections, many models and theoretical frameworks can be used to understand people's energy use and to design for energy conservation. The multitude of perspectives has sparked an ongoing debate in the research community as to which theoretical perspective is most relevant and useful for design (Boks et al., 2015; Niedderer et al., 2014b). The choice of perspective(s) has implications that influence not only how energy use is generally conceptualised, as discussed in 2.1, but also how energy use is studied and what possibilities researchers refer to regarding the ways in which design can support energy conservation.

Identifying suitable perspectives for understanding people's energy use is not about picking the most accurate model to describe people's doings, it is about finding useful perspectives that can contribute to a deeper understanding that is meaningful for design. From this point of view, the different perspectives discussed in previous sections for understanding people's doings can be considered to be complementary from a design perspective as they all aim to increase our understanding of people's doings in everyday life, but suggest different ways of doing so (cf. Chatterton, 2011).

This section will discuss the usefulness of the aforementioned perspectives for understanding people's energy use and for identifying design opportunities in relation to the aim of the research and clarify which perspectives have been most influential. Suitable studies and methods for research that addresses the topics of energy and design will also be discussed to present a rationale for the choice of studies and methods that have been conducted within the scope of the research presented in this thesis.

2.3.1 USEFUL PERSPECTIVES

As the relevance and usefulness of different perspectives can only be discussed in relation to the aims of the research, the discussion will be structured in relation to the perspectives' usefulness for exploring: how people's doings in everyday life influence energy use (*Theme 1*); how energy-reliant artefacts designed to support energy conservation influence energy use (*Theme 2*); and in what ways energy conservation can be supported through design (*Implications for design practice*).

The perspectives' usefulness for addressing the first theme

Perspectives that can be used to address the first theme should situate people's doings in everyday life and also take people's use of artefacts into consideration. Even though none of the perspectives for understanding energy use discussed in section 2.1 can fully describe the complexities of people's doings in everyday life, all present different viewpoints.

Models and frameworks that address behaviour can be useful for studying how people act in particular situations under specific conditions and to explain why people act the way they do based on different determinants. However, even though some take both internal and external determinants into consideration, the web of doings and everyday life dynamics influencing people's energy use are seldom discussed (cf. Kuijer, 2014). In line with other researchers who argue for a transition in perspectives, from behaviour and causal factors to frameworks that address the dynamic and interconnected nature of people's doings (Aune, 2007; Chatterton, 2011; Gram-Hanssen et al., 2004; Lutzenhiser, 1992), a perspective focused on behaviour is considered too narrow for the research presented in this thesis, as it does not allow for exploring prioritisations between different doings.

Proponents of PT argue that change-oriented perspectives are more useful for understanding the complexities and dynamics that influence people's use of resources in everyday life (Pettersen, 2013; Scott et al., 2012). PT takes into account the evolution and reconfiguration of practices over time and can thus be used for exploring how people's use of energy related to a particular practice are influenced by other practices and societal changes. However, this perspective may make it difficult to discern what should be considered when studying a particular practice or a web of practices (Pettersen, 2013), which has practical implications for research. As there are no distinct boundaries for what should be considered, the research focus may quickly expand to include more and more aspects related to the past and the present. Many detailed accounts of a variety of performances as well as the range of rationales that justify them must be studied in order to gain insight into a practice-as-entity. Obtaining an overview of a practice and how it is situated in, and influenced by, a web of practices is thus challenging.

In contrast, AT provides a framework that is also change-oriented but advocates a more distinct unit of analysis. As an activity consists of a collection of actions and operations carried out by one or more persons to achieve a particular outcome, an activity can be studied and understood more comprehensively than the multitude of performances that constitute a practice. AT also clearly emphasises the importance of understanding why people carry out different activities in everyday life and how multiples motives and goals influence how people act within those activities (Kaptelinin & Nardi, 2006), which are relevant when aiming to understand more about people's prioritisations in everyday life. Even though some practice theorists (e.g. Gram-Hanssen, 2013b) argue that there are intentions and goals guiding practices, general PT literature seldom discusses the motives and goals of individuals (Shove & Walker, 2014; Warde, 2005), which makes PT less useful for exploring the first theme addressed in this thesis.

The central role artefacts play in people's doings in everyday life is highlighted by both AT and PT but in slightly different ways. Both emphasise how artefacts contribute to the emergence of new needs (Kaptelinin & Nardi, 2006; Shove et al., 2007), but while PT literature focuses more on how artefacts contribute to the on-going reproduction of practices and less on micro-level dynamics (Pettersen, 2013), AT literature commonly highlights the mediating role of artefacts and how artefacts influence people's actions during particular activities (Kaptelinin & Nardi, 2006).

As the research in this thesis is less concerned with studying how people's energy use changes over time and more directly concerned with how people's doings, everyday prioritisations, and use of artefacts in everyday life influence energy use, an activity-oriented perspective can be considered more meaningful and useful than a practice-oriented one. As an activity theoretical perspective brings attention to the multiple motives and goals that directs people's activities as well as the interplay between people and artefacts, it presents a relevant lens for the research presented in this thesis as it has the potential to contribute new insights into the way in which people's energy use can be explored and understood.

The activity theoretical framework as commonly applied in interaction design and product design will thus be applied in framing the research presented in this thesis (Karlsson, 1996; Rexfelt, 2008). More specifically, the concepts of motives, goals and mediating tools will be addressed to understand why people engage in energy-reliant activities, what they do, how they do it, and the outcomes of the activities. Even though the concept of a mediating tool can be understood widely from an activity theoretical perspective, the tools specifically addressed in this thesis are energy-reliant artefacts. Additionally, the hierarchical structure of activities, actions, and operations will be used as a foundation for understanding people's use of energy-reliant artefacts on different levels.

The perspectives' usefulness for addressing the second theme

Turning to the second theme, useful perspectives must address people's use of artefacts and be suitable for evaluating how artefacts influence energy use. Traditionally, energy researchers advocating a social-psychological perspective with behaviour as the locus of study have assessed people's use of artefacts through intervention studies evaluating potential changes in energy use and determinants. In such studies, specified metrics are often used for quantifying outcomes, which make evaluations of interventions straightforward, but they provide little understanding of people's actual use of the artefacts.

Researchers within the DfSB domain have started to study people's interaction with artefacts to a greater extent, based on user-centred design approaches (e.g. Daae, 2014; Oliveira, 2013; Wilson, 2013). As behaviour models and frameworks addressing people's abilities to perceive and process information is often used as a basis for analysis, it is argued that a DfSB approach is useful for studying and evaluating people's use of and interaction with artefacts (Pettersen, 2013). Nevertheless, this perspective has been criticised by PT proponents as it often results in researchers pointing out right and wrong behaviours, in order to identify opportunities for interventions, instead of increasing the understanding of why people use artefacts the way they do in everyday life (Brynjarsdottir et al., 2012; Kuijer, 2014; Kuijer & Bakker, 2015).

While a practice-oriented perspective may prove useful for understanding people's use of artefacts as it takes place in everyday life, it may be considered less useful in evaluating how particular artefacts influence practices and energy use. As the reconfiguration of practices is a slow process that requires a majority of the carriers of the practice to reconfigure their performances, evaluating changes in practices-as-entities entails studying the doings of a large number of people over time. Due to limited resources, studies often end up analysing a small group of people and subtle shifts in performances. Additionally, while the intervention and its links to other elements are commonly discussed in relation to their contribution to the observed shifts in performances (e.g. Hargreaves, 2011), few discuss aspects related to the use and design of the designed intervention in detail.

An activity theoretical perspective provides a somewhat different stance on how people's use of artefacts can be explored in the context of everyday life. Kaptelinin (2014) argues the value of studying the role that artefacts play within the hierarchical structure of activities. By studying how artefacts mediate not only the activity itself, but also actions and operations carried out within the activity, insight can be gained into how artefacts influence people's doings at different levels. However, Karlsson (1999) stresses that even though there is value in studying specific actions and operations, explorations must aspire to gain an understanding of people's use of artefacts in relation to the activity as a whole. Otherwise, studies will be limited to assessing fits/misfits between the properties of the artefact and the properties of the user in interaction (Karlsson, 1999), which provides only a limited understanding of how and why the artefact is used. As an activity theoretical perspective is concerned with people's goals and motives for carrying out an activity, it seems suitable for exploring why people use certain artefacts in particular ways, which in turn may provide valuable insights into how to develop useful and meaningful artefacts (Bødker & Klokmose, 2011; Flach & Dominguez, 1995; Karlsson, 1996). For the research carried out within the scope of this thesis, an activity theoretical perspective thus seems promising for evaluating how artefacts influence energy use, especially if combined with an approach for quantifying potential changes in energy use.

The activity theoretical framework adapted to interaction design and product design chosen as the foundation for discussing the first theme will thus also be applied in exploring the second theme. In order to further the understanding of how artefacts designed to support energy conservation influence energy use, the relationship between subject and tool will be explored in relation to the hierarchical structure of activity as recommended by Engelbrektsson (2004), Karlsson (1996) and Rexfelt (2008). Activities as a whole as well as their actions and operations will thus be considered jointly to gain an understanding for how particular artefacts may contribute to mediating purposeful activities, and to provide insight into relevant design opportunities.

The perspectives' usefulness for exploring how design can contribute to energy conservation

A perspective suitable for exploring a variety of design opportunities would be valuable in order to identify ways through which energy conservation can be supported through design. The two main design approaches discussed in literature, DfSB and POPD, present different perspectives on how design can contribute to change. DfSB is commonly referred to as an interaction-oriented approach that often addresses changes related to the redesign of particular artefacts (Pettersen, 2013). As DfSB on the whole is founded on taking behaviour as the unit of analysis, the recommended design process and strategies discussed often entail targeting particular behaviours by targeting the determinants or barriers related to those behaviours. Even though this approach is often straightforward to implement, and design concepts may have a relatively short time to market, several issues can be considered problematic with this perspective. First, the opportunities for design to contribute to change are often referred to from a designer's point of view with the aim of changing people's behaviour through design interventions. For instance, design is considered to be able to "*motivate people to change their behaviours*" (Oliveira et al., 2012), "*influence behaviour*" (Wood & Newborough, 2007b), or "*regulate consumer behaviour*" (Tang & Bhamra, 2012). Such a design stance is problematical from an ethical perspective, which is evident from the ongoing discussion in the research community regarding ethical considerations (e.g. Lilley & Wilson, 2013; Pettersen & Boks, 2008). Second, as the DfSB design process often entails selecting and analysing a particular artefact or situation, identified design opportunities are often based on existing artefacts instead of other opportunities for change. As Kuijer and Bakker (2015) point out, this may risk resulting at most in incremental savings that may also be reduced or nullified by trends in product development and design. In addition, by focusing too narrowly on incremental changes, the need for change at other scales beyond particular behaviours on an individual scale may be neglected (Brynjarsdottir et al., 2012). If aiming for radical design capable of creating new patterns of behaviour and demand, one must instead question the artefact and its essential functions in order to identify other alternatives (Cross, 2008; Jones, 1992).

In contrast to DfSB, POPD aims to identify opportunities for creating new artefacts that may disrupt current practices and lead to reconfigurations (Kuijer, 2014). POPD literature seldom discusses ways of addressing people's interaction with artefacts; instead interventions for change are often discussed in terms of what opportunities new types of artefacts may provide for sustainable living. POPD thus shifts attention to a larger scale of change that may open up the way to new innovations with potential for achieving more radical change and greater reductions in resource use (Pettersen, 2013). Experimenting with new artefacts could transform current practices in a more sustainable direction or contribute to establishing novel practices (Scott et al., 2012; Shove et al., 2008). However, this perspective is also associated with a number of disadvantages. As the recommended participatory design process entails the involvement of people in prototyping new practices over time, it may be too resource intensive for design practice (Pettersen, 2013; Scott et al., 2012). Moreover, as PT suggests that no set of agents has control over the transformation of a practice (Shove, 2010), it is generally impossible to plan transition processes from the perspective of a single organisation (Spaargaren et al., 2006). In addition, literature on POPD gives little to no guidance regarding the embodiment of artefacts even though some (e.g. Kuijer, 2014), suggest ways of identifying suitable types of artefacts and new configurations of the elements of practice that work.

To sum up, both perspectives have potential for identifying design opportunities that can contribute to energy conservation, but both are limited and neither address the full scope of design opportunities spanning the range from efficiency to sufficiency strategies. Furthermore, both focus primarily on how design can contribute to changing people's doings, and less on how to design artefacts. Even though DfSB and POPD researchers and designers also base their work on design theory, common design considerations, such as the usability of interactive features or communicative qualities, are often not directly discussed when exploring the scope of design opportunities. As neither DfSB nor POPD presents a perspective that addresses the full scope of design opportunities (at least not in the way they are commonly discussed in literature), they are not of direct use for exploring the variety of ways through which artefacts can be designed to support energy conservation. Hence, instead of grounding the exploration of design opportunities on one of these perspectives, this thesis will explore what insights an activity theoretical perspective and the empirical findings combined with design theory may present for identifying ways of supporting energy conservation through design. Exploring design opportunities from the perspective of activity has also previously been argued for in design literature as an alternative to user-centred design (Flach & Dominguez, 1995; Norman, 2006).

2.3.2 RELEVANT TYPES OF STUDIES AND METHODS

Different types of studies are represented in literature that addresses the topics of energy and design. The studies usually vary in terms of the type of approach and data considered relevant and useful; a divide is evident between the quantitative and statistically focused approaches and the qualitative and meaning-making approaches. The majority of studies in the energy research domain are focused on collecting quantitative data on energy use and determinants from large sample sizes, which are useful for assessing effects, identifying changes, and making generalisations (Abrahamse et al., 2005). This type of data is however less useful for providing insight into why the changes came about and how the participant's everyday life was influenced. Therefore, qualitative research techniques are needed that do not aim to collect data about people who are generalised into a stereotypical user. Small-scale in-depth investigations can be carried out to address "*particular, if not unusual situations, that are glossed over and consciously excluded from sampling in surveys but that can yield important insights into specific design-related needs of particular kinds of users in particular settings*" (Franck, 1987, p. 66).

Recent studies follow the qualitative approach and are focused on collecting rich data on people's energy use in everyday life. Some focus on acquiring user insight in order to design concepts aimed to enable or encourage energy conservation. These types of studies often generate knowledge related to the generation of concepts and design strategies but provide little insight into which types of concepts can contribute to energy conservation. Other studies focus more specifically on assessing different concepts or prototypes to test what effects different design strategies or interventions may have on people's energy use. They often follow the common recommendation of assessing one strategy at a time (Abrahamse et al., 2005; Dwyer et al., 1993) in order to establish what potential effects each separate strategy may give rise to. These studies often aim to understand people's behaviour in particular situations and to identify effective ways of changing it. Even though these types of studies can increase general understanding of the effectiveness of different interventions, they do not contribute notably to the knowledge on the variety of ways in which energy use can be supported through design.

AT literature does not prescribe particular types of studies or methods but suggests that suitable studies and methods should be chosen based on the objectives of the research (Kaptelinin & Nardi, 2006). Nevertheless, as discussed in the previous sections, understanding people's doings in the real world is essential from an activity theoretical perspective as artefacts, people and their objects cannot be studied independently of their context (Kaptelinin & Nardi, 2006). Karlsson (1996) similarly argues that the hierarchical levels of activity must be addressed through contextual methods in order to form an understanding of the complexity of mediated activity. Field research is thus endorsed when relevant to enable analysis of the way in which artefacts are used and mediate activities over time in particular settings (Kaptelinin, 2014; Nardi, 1996b). In contrast to laboratory studies, field studies allow for the studying of people's energy use and the use of artefacts as parts of dynamic activities in everyday life. During evaluative field studies, it is essential to collect data on people's actual use of artefacts and energy so that potential changes in energy use can be attributed to the artefacts assessed. Additionally, in order to elicit opportunities for design, Engelbrektsson (2004) argues the importance of studying use situations in which practical experience makes people aware of potential misfits so that they can verbalise their experiences. It is also important that the research studies allow an open and attentive dialogue to be cultivated between the researcher and the participants engaged in the studies.

As AT addresses the transformative nature of activities, it is also argued that research cannot be limited to isolated variables at particular moments in time (Kaptelinin & Nardi, 2006). From an activity theoretical perspective, it is thus crucial to study energy-reliant activities over time to gain an understanding of activities as a whole and how energy-reliant artefacts mediate the outcome of those activities over time. Additionally, literature generally recommends a varied set of data collection techniques to avoid undue reliance on any one method (Nardi, 1996b) and a mix of both quantitative and qualitative approaches whenever relevant (Abrahamse et al., 2005; Lopes et al., 2015; Sovacool et al., 2015).

APPROACH & STUDIES

03 | RESEARCH APPROACH AND METHODOLOGY

This chapter provides an overview of the overall research approach taken for the work presented in this thesis. Following the recommendation of Creswell (2014), a short description of the author's personal background and research interest is initially provided to give insight into the values and prior understanding that have directed the choice of research focus and the research approach. A brief clarification of theoretical assumptions is also given to provide more insight into the foundations of the approach and choice of methods.

The next section provides an overview of the empirical studies and the cross-study analysis that this thesis is based on as well as the research process. It clarifies the relationship between the studies, appended papers, and the research questions addressed, and it also describes the studies and overall analysis in more detail. Reflections on the research approach and methodology are provided in the remaining section.

3.1 PERSONAL BACKGROUND AND RESEARCH INTEREST

The author's undergraduate education – studying Industrial Design Engineering at Chalmers University of Technology, Sweden, and Industrial Design at the University of New South Wales, Australia – introduced a number of approaches related to design and product development. The people-centred design process, which points to the value of understanding the interplay between people and artefacts, was especially emphasised and has thus to a great extent influenced the author's view on design. Through practical experiences of exploring and choosing between multiple approaches for addressing design challenges or developing knowledge (not only throughout education but also during research projects and involvements in teaching), the author has developed a pragmatic view of the design process and design work. From such a perspective, it is key to find and use suitable approaches to gain new knowledge and address the challenges at hand, which has also been essential for the research presented in this thesis as discussed in section 2.3.

By learning about sustainability challenges in relation to the design discipline, the author's interest in issues of sustainable development has also grown over the years. A strong belief that the world can be, and is, affected by human influence and that humans are also influenced by the world, fostered an aspiration to learn more about how to contribute to creating a more prosperous world. Not only as a basis for future personal work, but also to identify possible ways for design practice to move forward. The personal desire to learn more about design for sustainability, and the research ambition to aid design practice, promoted an overall prescriptive research focus that sought to increase the common understanding of how designers can contribute to sustainable development.

Gaining practical and applicable knowledge of what works and what does not was thus considered desirable, as it may present insights into how changes can be made and how change may come about (cf. the pragmatic worldview (Johnson & Onwuegbuzie, 2004)). To manage this, knowledge is not only needed about what is, but also about possible alternatives and how those may be achieved. As knowledge of the world is not objectively true and also forever changing with society, the common understanding of the world and the meaning we make of it can be considered socially constructed within specific contexts (cf. the constructivist worldview (Creswell, 2014; Crotty, 1998; Grix, 2010; Guba & Lincoln, 1994)). Thus, there is not one all-encompassing truth about how design influences the dynamics of everyday life nor how to design for sustainability, but rather multiple perspectives that can be considered to contribute different pieces to the puzzle.

Some pieces could be acquired and added to the puzzle by studying people's activities in the light of the real world conditions of everyday life, as argued in the previous chapter. From a pragmatic point of view, using a variety of ways to collect data and interpreting research results can prove meaningful for such a research venture as it provides multiple ways of understanding the phenomena under study.

3.2 RESEARCH DESIGN AND STUDIES

The research presented in this thesis is concerned with generating new knowledge for design that is valuable both for the research community and for design practice. As highlighted by the aim in the introduction, the research is focused not only on contributing knowledge in the form of insights into people's energy use and use of energy-reliant artefacts, but is also intended to provide knowledge on how artefacts can be designed to support energy conservation, which is valuable for addressing particular design challenges in practice. The overall research approach builds on the type of research that is often referred to as *Research for Design*, in which theoretical outcomes such as guiding philosophies and design implications arise through investigations of people, contexts, and the use of artefacts (see Forlizzi et al. (2009) for an overview of different types of design research). As discussed in the previous sections, the overall research approach is also characterised by pragmatic thinking, i.e. seeking useful ways of addressing the themes explored (Creswell, 2014; Johnson & Onwuegbuzie, 2004). Based on the overall research approach, studies suitable for addressing the themes were chosen and designed to both generate valuable insights and be feasible to carry out. As indicated in figure 3.1, the four empirical studies conducted and the cross-study analysis were designed to explore people's energy use and use of artefacts in everyday life in different ways.

Study A focused on investigating and mapping people's possession and use of energy-reliant appliances through semi-structured interviews to describe and discuss

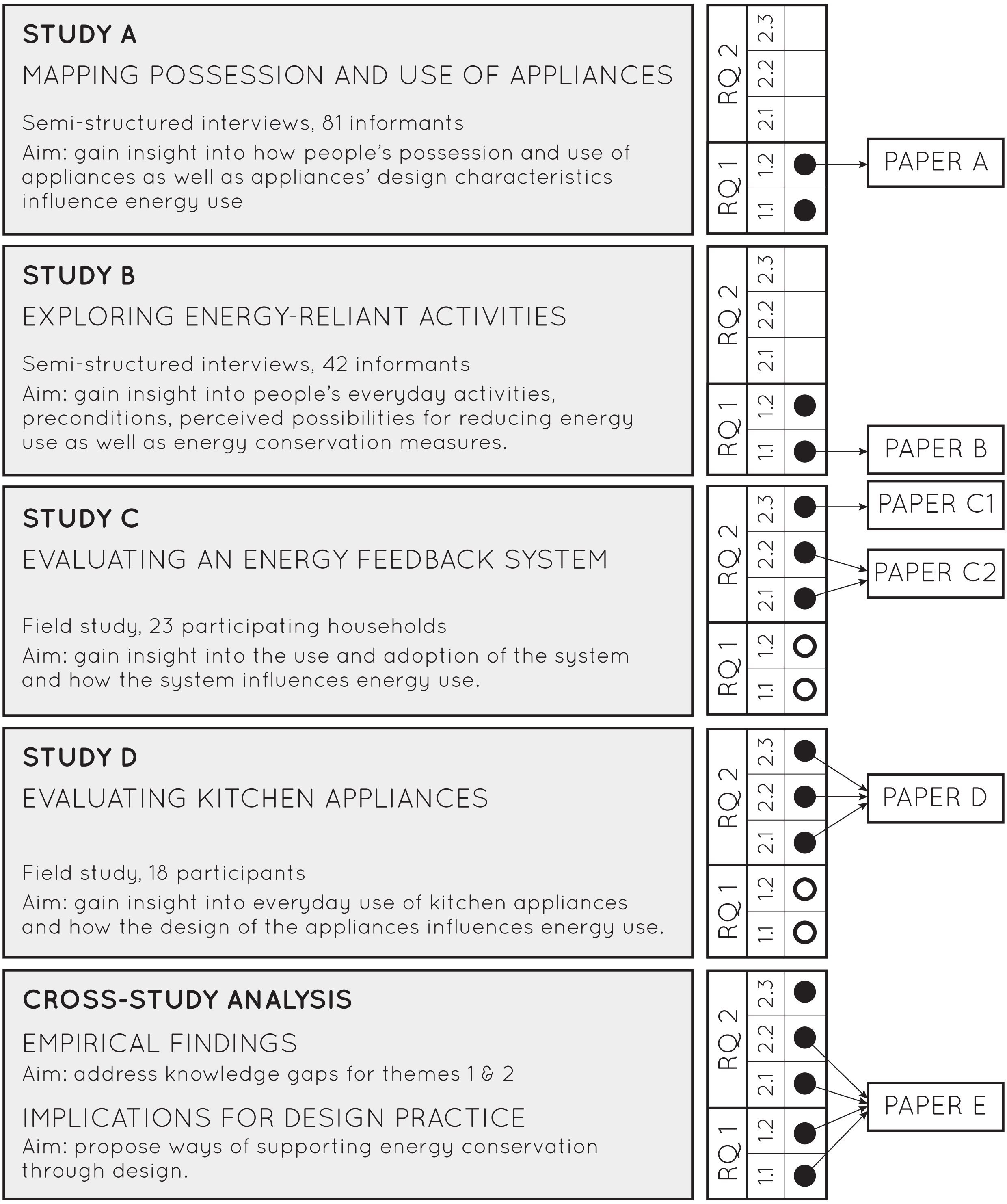

Figure 3.1. Overview of studies, cross-study analysis, research questions addressed, and appended papers

the relationship between their appliances and energy use. Study B also involved semi-structured interviews but took a more exploratory approach with the aim of shedding more light on people's energy use from the perspective of everyday activities. The two remaining studies were evaluative in nature and designed as field studies to address how particular artefacts were used in everyday life and how they influenced the participants' energy use and activities. The cross-study analysis combined material from all four studies

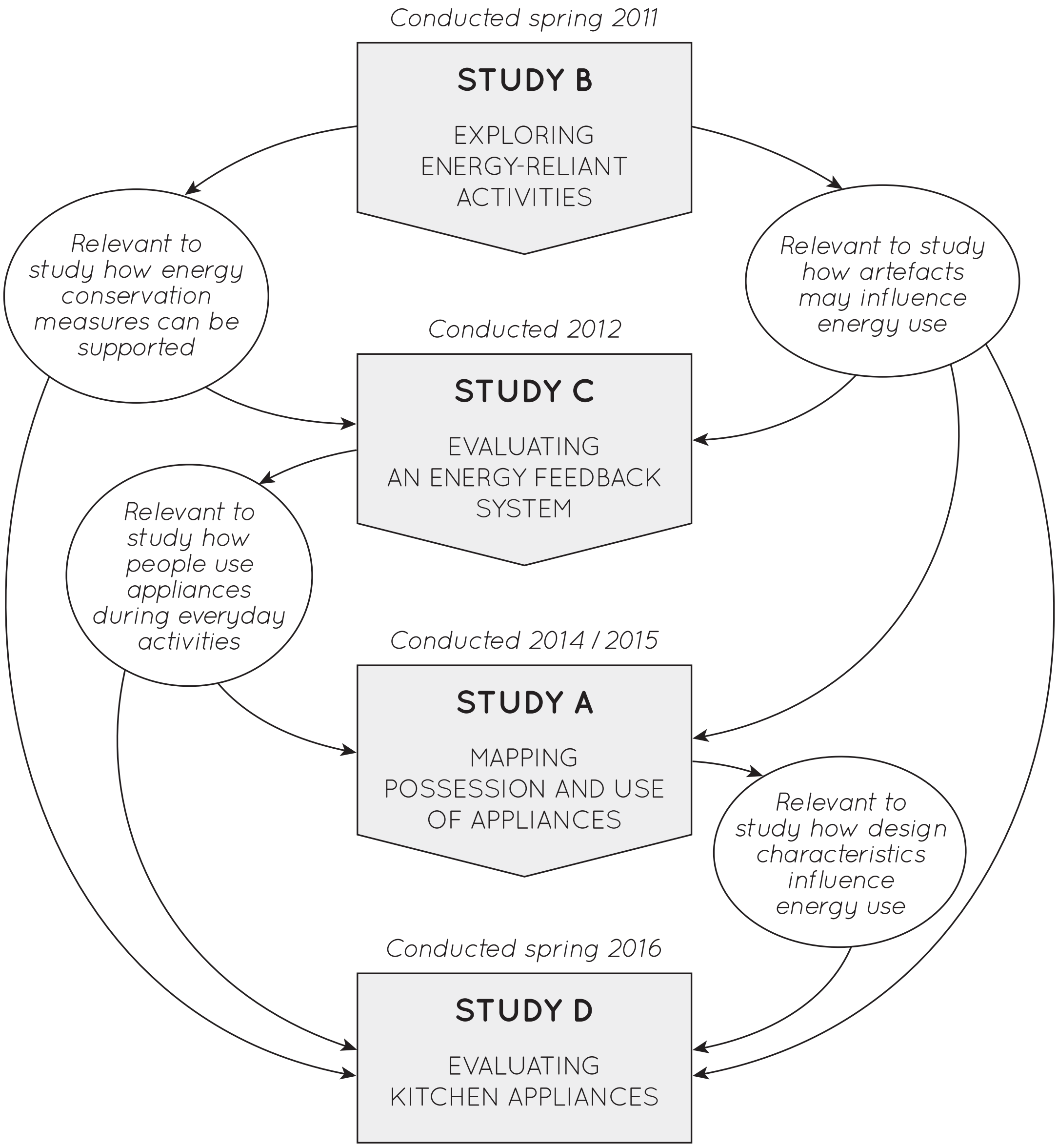

Figure 3.2. Overview of the research process

to address the two themes and research questions described in section 1.2, as well as to explore implications for design practice. The aim of the cross-study analysis was partly descriptive, to contribute to an increased understanding of people's energy use and how artefacts influence it, and partly prescriptive to propose ways of supporting energy conservation through design.

In addition to providing an overview of the empirical studies and the cross-study analysis, figure 3.1 also describes how the studies relate to the themes and specific research questions addressed in this thesis. Studies A and B contributed material to answer the sub-questions related to the first theme. Even though aspects related to the first theme were also highlighted in studies C and D, they primarily addressed the second theme and its sub-questions. Figure 3.1 also introduces the six appended papers that resulted from the studies and cross-study analysis.

The numbering of the studies and appended papers – from A to E – in figure 3.1 does not indicate the order in which they were carried out; the numbering was chosen to fit the structure of the thesis. The four studies were carried out sequentially as illustrated in

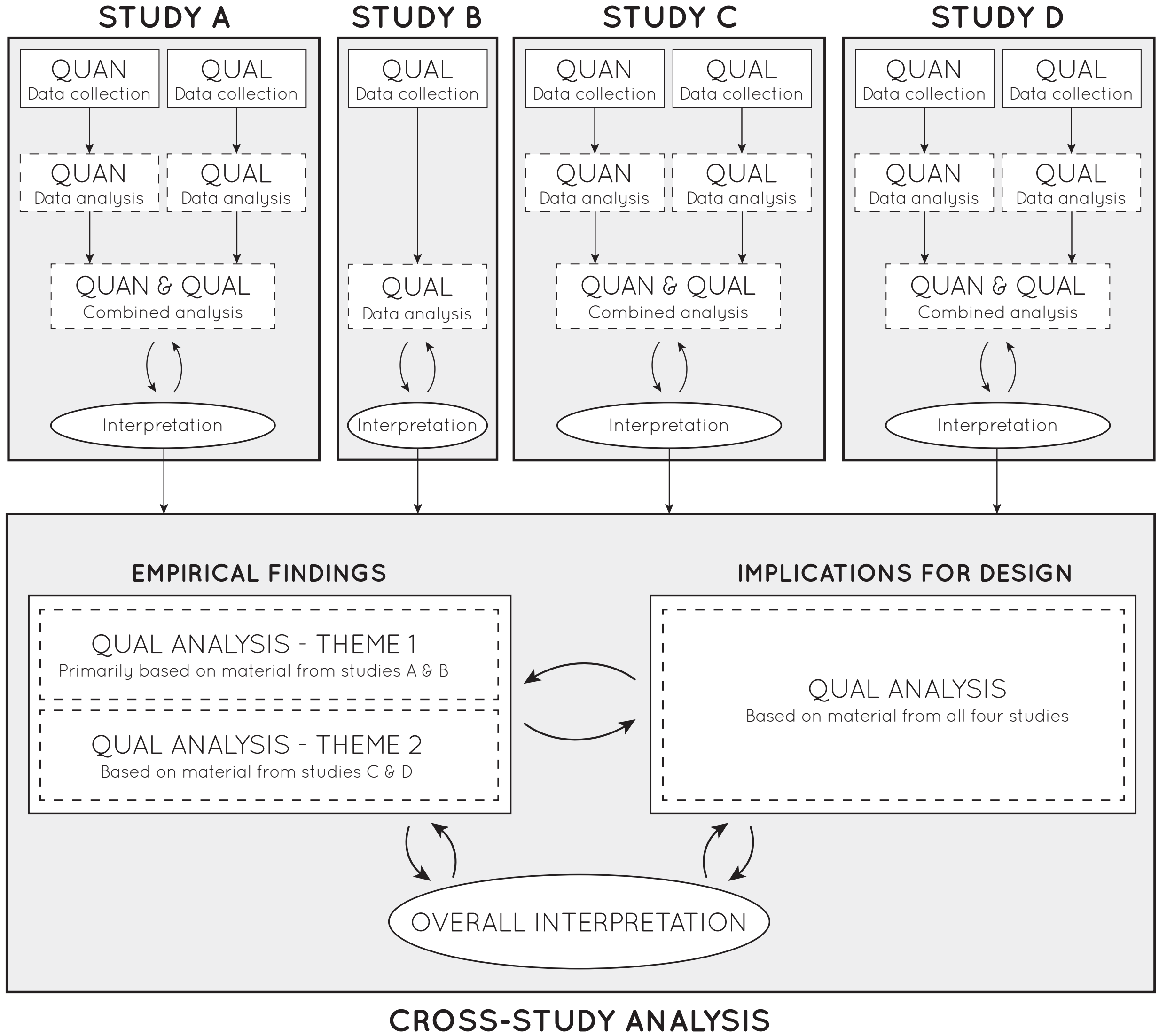

Figure 3.3. Overview of the research design

figure 3.2. The insights gained through the studies informed the choice of relevant types of studies and topics to explore further in subsequent studies. For instance, the findings of the first study conducted, referred to as Study B, made it relevant to conduct additional studies exploring the influence of energy-reliant artefacts on energy use as well as evaluating and assessing if, and how, energy conservation can be supported through design. Hence, additional studies were planned to address these aspects in suitable ways.

A mixed methods approach, incorporating both qualitative and quantitative approaches (Creswell & Clark, 2011; Johnson & Onwuegbuzie, 2004), has been adopted during this research to triangulate data collection and aid interpretation of the collected material. The research design can be referred to as a multiphase design (Creswell & Clark, 2011) as depicted in figure 3.3. The analysis process in the separate studies and the cross-study analysis included iterative stages of interpreting the material, and the primary focus was on an ideographic analysis process, i.e. analysing people's energy use in relation to particular cases. The specific aims and applied methods for each study and the cross-study analysis are further elaborated on in sections 3.2.1 – 3.2.5.

3.2.1 STUDY A: MAPPING POSSESSION AND USE OF APPLIANCES

Study A aimed to increase the understanding of how appliances influence people's energy use. Semi-structured interviews were conducted to investigate households' possession and use of appliances as well as people's experience of how design characteristics influence energy use during everyday activities. Energy data was also collected to explore patterns between households' use of appliances and energy use.

The recruitment of informants was carried out through distributing invitations via housing associations, the local newspaper, social media, and personal networks. In this study one-person households were targeted since they are growing in numbers and present a challenge from an energy conservation perspective. By targeting one-person households, data could also be documented per person rather than per family, so that the possession and use of appliances as well as the households' energy use could be allocated to individuals to a larger extent. In total, 81 persons from households in Gothenburg and nearby communities volunteered to participate.

A team, consisting of the author and eight master's students, conducted the interviews in the homes of the informants with the help of a tablet with a customised web application containing an interview guide. The team performing the interviews was initially briefed about the study, informed about the interview guide, and given instructions on how to use the tablet interface to ensure comparable procedures for all interviews. All data, including text and photographs, were documented via the application and stored in an online database. The length of each interview varied considerably, between 30-240 minutes, due to the different number of appliances in the households. In addition to the material from the interviews, data on the households' electricity use were retrieved for a subsample of 31 households.

The analysis of data included several parts combining both qualitative and quantitative analyses as described in figure 3.4. Thematic analyses of design characteristics and energy conservation measures were carried out following a procedure for analysing interview data described by Miles and Huberman (1994) in which material from all interviews was

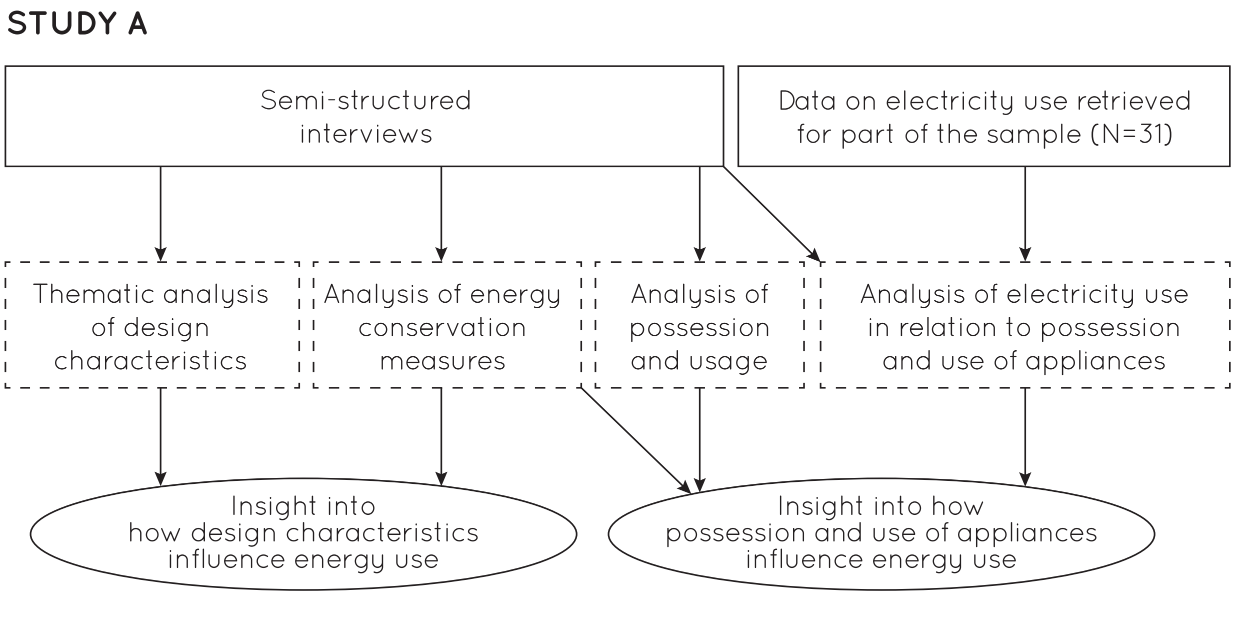

Figure 3.4. Overview of data collection and analysis for Study A

clustered into themes and subsequently grouped in subthemes. A qualitative analysis looking at the interview material in relation to the households' use of appliances and electricity use patterns was also carried out. In addition, to gain insight into aspects influencing the households' energy use, bivariate analyses were done to test how the variations in energy use related to the households' possession and use of appliances.

The overall insight gained from Study A is discussed in Chapter 4. The appended Paper A focuses on findings regarding design characteristics and discusses what preconditions the design of domestic appliances set for people's energy use.

3.2.2 STUDY B: EXPLORING ENERGY-RELIANT ACTIVITIES

Study B explored energy use from the perspective of everyday activities. Semi-structured interviews were conducted to explore aspects that people consider influence their energy use and energy conservation measures. The aim was to gain insight into people's everyday activities, preconditions for energy conservation, as well as energy conservation measures.

The recruitment process was undertaken in two steps; people were first approached in public and asked about their willingness to take part in the study; secondly, an advertisement was placed in a local newspaper along with a subsequent radio announcement. Care was taken to recruit not only people highly motivated to reduce energy use but also less motivated people. In total, 42 informants from households in Gothenburg and nearby communities volunteered to take part in the study. The interviews were conducted in a University setting and an interview guide was used during the interviews. Each interview lasted approximately 90 minutes and careful notes were taken during all interviews.

As illustrated in figure 3.5, the interview data were analysed through three thematic analyses in which emphasis was put both on individual experiences and common patterns for the group of informants. The material was analysed using an iterative thematic coding process as described by Miles and Huberman (1994). Each theme was analysed and condensed through a two-step coding procedure, in which different aspects and patterns were explored.

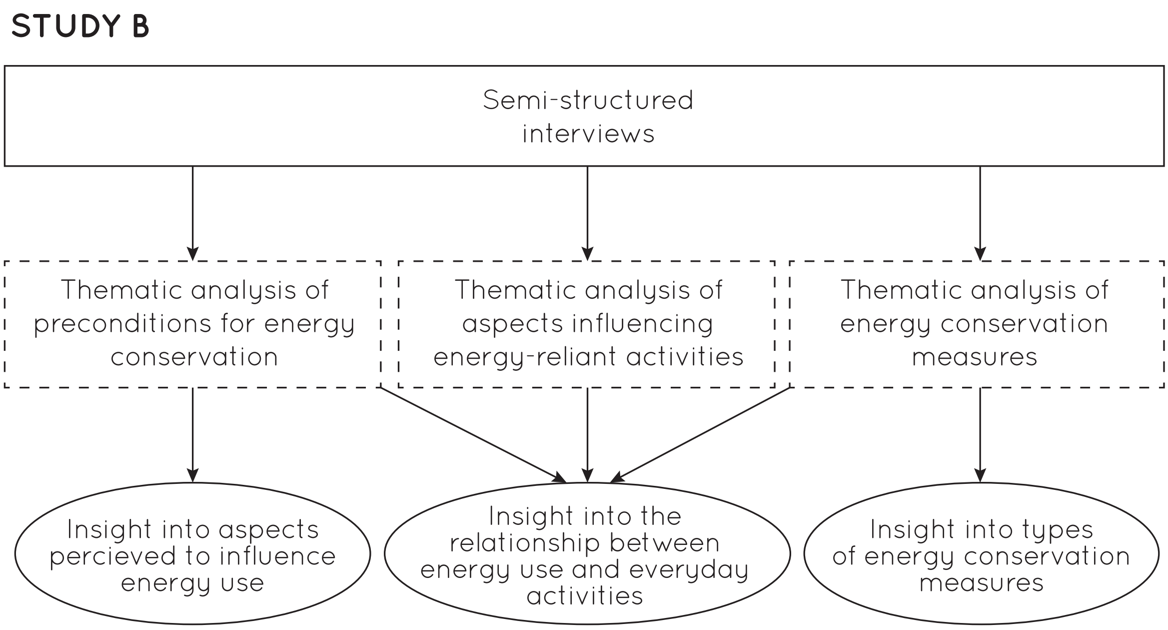

Figure 3.5. Overview of data collection and analysis for Study B

The overall insight gained is discussed in Chapter 4 while the appended Paper B specifically addresses findings regarding how motives and goals influence people's everyday prioritisations. A comprehensive account of the results can also be found in the Licentiate thesis *Understanding Energy Behaviour – A Necessity for Supporting Domestic Energy Conservation through Design* (Selvefors, 2014).

3.2.3 STUDY C: EVALUATING AN ENERGY FEEDBACK SYSTEM

Study C addressed the first approach for supporting energy conservation through design discussed in section 1.2.2, i.e. artefacts designed to support people in carrying out energy conservation measures in everyday life, to investigate whether such artefacts can support energy conservation. An energy feedback system with the potential to aid domestic energy conservation by increasing people's awareness and knowledge, inspiring discussions, and supporting energy conservation measures, was chosen for evaluation. The study was undertaken to evaluate the use and adoption of the system as well as potential effects on energy use, in order to add to the existing knowledge on the benefits and limitations of such energy feedback systems.

The study was carried out in collaboration with an industry partner, Exibea AB, and the first version of their energy feedback system, Eliq Online, was used for the field trial. The system consisted of three main parts. An add-on energy meter was used to gather data on electricity use for participating households directly from their main electricity meters. An energy hub in each household stored the energy data and transmitted it continuously to an online database. The energy data were available to the users through a web portal accessible via any web-based user interface. The web portal included several different functions displaying the data and providing the households with energy-related information. An overview of the main functions is provided in figure 3.6. In comparison to other systems on the market at the time, Eliq Online provided innovative functions such as real-time feedback and comparative challenges.

Following recommendations in literature (Dwyer et al., 1993; Niedderer et al., 2014a), the study was conducted as a longitudinal field study including follow-up observations and data from a control group to enable assessment of changes in energy use over time. The study was designed with a twelve-month baseline period prior to the test, a six-month test period during which the energy feedback system was installed in the households, and a six-month follow-up period; see figure 3.7. Twenty-three households in Gothenburg and nearby communities were recruited for the study by distributing invitations directly to individuals that took part in Study B supplemented by invitations distributed via personal networks. Care was taken to include households with both a low and a high prior commitment for energy conservation as well as households with both a low and a high prior interest in online social media, since the opportunity to interact with other users was one prominent feature of the system. In addition, a large sample of comparable households in the region was used as a control group (43,237 households during 2011 and 43,789 households during 2012).

As illustrated in figure 3.8, several types of data collection methods were used during the study. The households' electricity use during the test period was continuously monitored through the feedback system and the monthly electricity use for the households for the years

Figure 3.6. (Opposite page) The main functions of the web portal interface showing a) the home screen, b) the My Energy section, and c) the Energy Challenges section

HOME SCREEN

MY ENERGY

ENERGY CHALLENGES

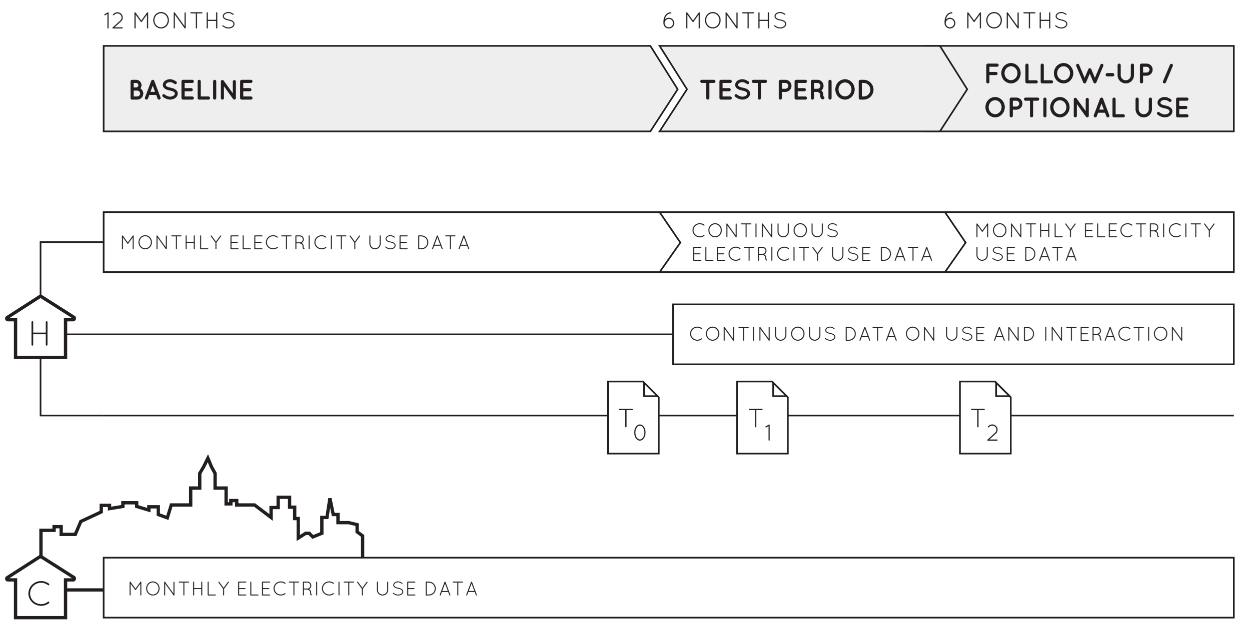

Figure 3.7. Study design for Study C

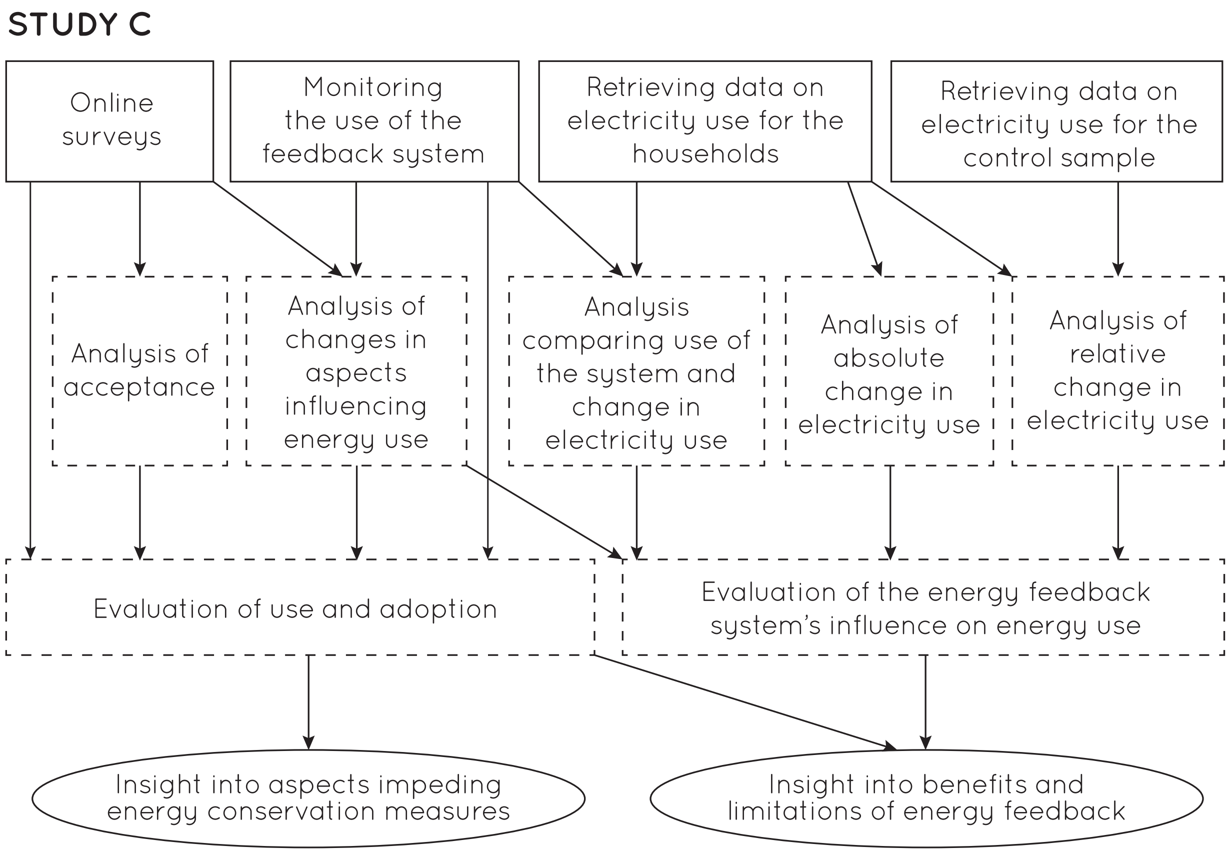

Figure 3.8. Overview of data collection and analysis for Study C

2011 and 2012 was also retrieved, either via self-reporting or through the system database. The participants' use of the feedback system and interaction with different functions was registered automatically. Data on the households' self-reported use of the system as well as changes in behaviour and influencing factors were collected via three online surveys; the first prior to the test period (T_0), the second two months after the start of the test period (T_1), and the third at the end of the six-month test period (T_2). Additionally, the electricity distributor in Gothenburg provided monthly household electricity use data for the control group.

The diverse data collected during Study C required an analysis approach mixing qualitative and quantitative methods. The average change in electricity use during the test and follow-up periods was assessed for the 15 participants for which complete energy use data had been collected. In addition, stratified Wilcoxon (Van-Elteren, Cochran-Mantel-Haenszel) tests were conducted by the Mathematics and Statistics Consultants group at Chalmers University of Technology to assess the 15 participants' relative change in electricity use compared to a sample of households from the control group by matching use patterns during the baseline period. Effects on behaviour and influencing factors were analysed using Spearman's Rank Order correlation test ($p<0.05$) to evaluate potential correlations between the use of the web portal and changes in activities and actions on the one hand, and between the use of the web portal and aspects influencing energy use on the other. Both tests were performed on a short term basis, i.e., comparing T_0 and T_1, and medium term basis, i.e. comparing T_0 and T_2. Additionally, parts of the survey data were interpreted qualitatively to provide meaning and explanation to the quantitative analysis. The attitudes towards, and acceptance of, the web portal were analysed in relation to their use of the system by assessing different constructs influencing acceptance.

The main findings of the study are presented and discussed in Chapter 5. The appended Paper C1 describes the effects of the energy feedback on the participants electricity use, activities and actions, and influencing factors and Paper C2 discusses the households' use, acceptance, and adoption of the system in more detail. A comprehensive account of the result can also be found in the Licentiate thesis *Understanding Energy Behaviour – A Necessity for Supporting Domestic Energy Conservation through Design* (Selvefors, 2014).

3.2.4 STUDY D: EVALUATING KITCHEN APPLIANCES

Study D aimed to investigate whether artefacts can support energy conservation from the perspective of the second approach discussed in section 1.2.2, i.e. artefacts designed in such a way that they mediate less energy-intensive use. Kitchen appliances were evaluated to assess if, and how, appliances designed to provide for less energy-intensive use influence energy use. The study addressed three common categories of appliances: coffee makers, electric kettles, and toasters. The categories were chosen based on a number of criteria: appliances people use on a daily basis, appliances with energy saving potential, appliances that do not require any installation, and appliances for which usage and energy use can be quantified. For each category, three distinctly different products on the market were chosen for evaluation, see figure 3.9a-c. The appliances were chosen based on their level of complexity and their level of automation and care was taken to ensure the inclusion of functions that in various ways and to different extents may mediate less energy-intensive

Figure 3.9 (Next three pages) a) Key functions of coffee makers A, B and C, b) Key functions of electric kettles A, B and C, and c) Key functions of toasters A, B and C

COFFEE MAKER A

Fill level indicator
Indicates max level and steps from 12 to 2

Hot plate
Enables coffee to keep warm until turned Off with On / Off switch

On / Off switch
Enables brewing to be started / stopped and indicates On / Off mode

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COFFEE MAKER B

Fill level indicator
Indicates levels for small and large cups

Fill level indicator
Indicates levels for small and large cups

Hot plate with auto Off after 40 min
Enables coffee to keep warm up to 40 min

On / off button
Enables brewing to be started / stopped and indicates ongoing brewing and active hot plate

Aroma settings
Enables aroma variation

COFFEE MAKER C

Fill level indicator
Indicates max level and levels for small and large cups

***On / Off switch** (on back)*
Enables the machine to be turned On / Off

Insulated jug
Enables coffee to keep warm at 70° up to 2 hours

Start button with auto Off
Enables brewing to be started / stopped and indicates ongoing brewing

ELECTRIC KETTLE A

Fill level indicator
Indicates max and min level and amount in L

On / Off switch
Enables boilg to be started/ stopped and indicates On / Off mode

Process indicator
Indicates ongoing boiling process with red light

ELECTRIC KETTLE B

Fill level indicator *(on front)*
Indicates max and min boil level and amount in ml

Process indicator *(on front)*
Indicates ongoing boiling process with blue light

Dual chambers with filling system
Allows small amounts of water to be filled and boiled

Fill level indicator
Indicates fill level with amount in ml

On / Off switch
Enables boilng to be started/ stopped and indicates On / Off mode

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ELECTRIC KETTLE C

End of process indicator
Indicates end of process with distinct sound

Fill level indicator
Indicates max and min level and amount in L

Process indicator
Indicates ongoing boiling process and temperature with light in changing colours

Temperature indicator
Indicates current temperature and ongoing boiling process

Keep warm function
Enables water to keep warm up to 40 min

Start/stop button
Enables ongoing process to be started / stopped

Temperature control
Enables heating of water to 37°/ 60°/ 80°/ 90°

TOASTER A

Toast rack
Enables bread to be thawed, reheated and kept warm

Start lever with auto Off function
Enables toasting to be started and stopped automatically

Cancel button
Enables process to be cancelled

Browning dial
Enables browning level to be defined between 1-7

TOASTER B

Browning dial
Enables browning level to be defined between 1-5.5 and enables toasting of frozen bread

Eco-slot button
Limits toasting to one of the toasting slots

Start lever with auto Off function
Enables toasting to be started and stopped automatically

Cancel button
Indicates ongoing process and enables process to be cancelled

TOASTER C

Two-fold lid over toasting slots
Limits heat loss

Cancel button
Indicates ongoing process and enables process to be cancelled

Frozen button
Enables toasting of frozen bread

Reheat button
Enables reheating of toasted bread

Lid release button
Enables the lid to be opened during use

Start lever with auto Off function
Enables toasting to be started and stopped automatically

Browning dial
Enables browning level to be defined between 1-9

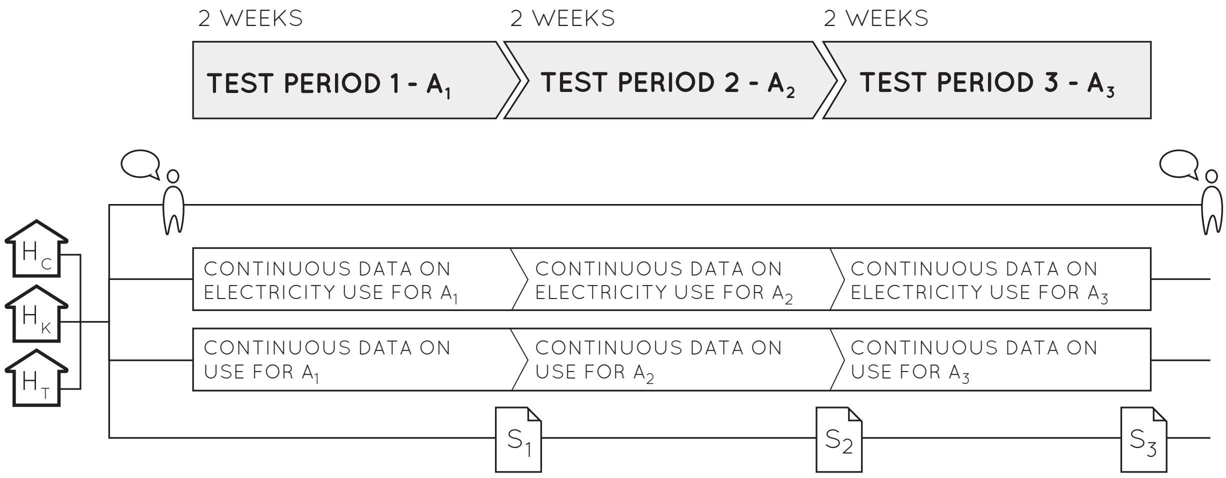


Figure 3.10. Study design for Study D

use. Some of the chosen appliances were specifically marketed with energy saving functions. Figure 3.9a-c provides overviews of the appliances' key functions influencing energy use.

The study was designed with three test groups corresponding to the three categories of appliances, i.e. H_C - coffee makers, H_K - electric kettles and H_T - toasters. Each test group evaluated the three specific appliances chosen for evaluation for that particular category of appliances. The three test groups followed the same test procedure, which included three test periods of two weeks each as illustrated in figure 3.10. The order in which the participants in each test group used the three appliances (A_1, A_2, A_3) was different for all participants. The test orders were determined in advance but randomly assigned to the participants. Six individuals were recruited for each test group by distributing invitations directly to individuals that participated in Study A and supplemented by invitations distributed via personal networks. In total, 18 one-person households in Gothenburg volunteered to take part in the study. Care was taken to ensure that the participants recruited into a specific test group were frequent users of the particular type of appliance that was to be evaluated by that group.

Figure 3.11 provides an overview of the different types of data collection methods used during the study. Initial brief interviews in the participants' homes were conducted in parallel with the installation of the measuring equipment to gain insight into the participants' preconditions and current use of the particular type of appliance they were to evaluate. Energy meters were installed in series with each appliance to monitor the use of the appliances as well as the resulting electricity use. Three online surveys (S_1, S_2, S_3), one for each appliance distributed at the end of each test period, were used to collect data on the participants' reported use and perception of the appliances. In addition, semi-structured interviews were conducted in the participants' homes to further explore the participants' experiences of using the different appliances as well as their understanding of the appliances' functions and energy use. Separate interview guides for the three categories of appliances were used during the interviews, which covered the participants' use of the appliances during everyday activities, the participants' understanding and use of particular functions, perceived benefits and drawbacks of the appliances, and the participants' understanding of the appliances' energy use. The interviews lasted 70 minutes on average. Summary sheets (cf. Miles & Huberman, 1994) were used to summarise highlighted aspects and important themes after each interview. All interviews were recorded and transcribed in full, except

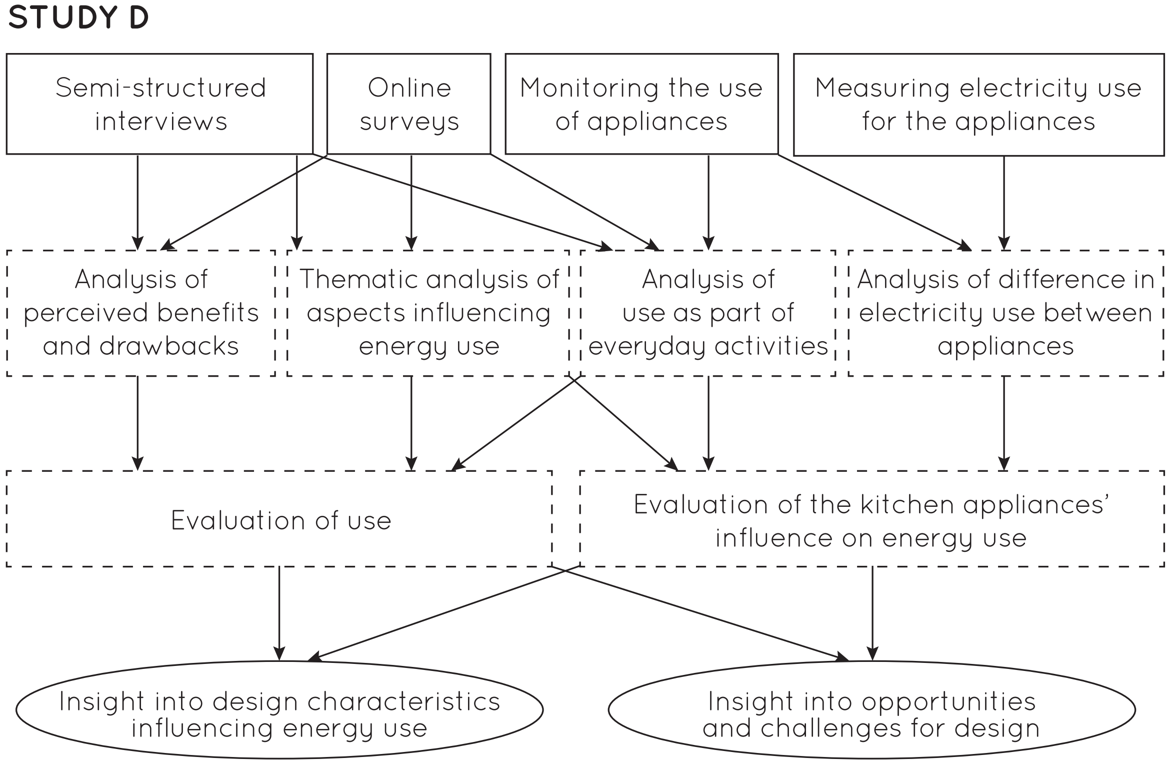


Figure 3.11. Overview of data collection and analysis for Study D

for one interview for which the participant requested that notes should be taken instead.

Due to the malfunctioning of some energy meters, logged data on the participants' use and electricity use for all appliances could not be collected for all participants. The unfortunate data loss limited the planned quantitative data analysis intended to assess variations in energy use. Instead, the recorded energy data were primarily interpreted qualitatively together with the data from the surveys and interviews to evaluate how the design of the appliances influenced energy use. Moreover, collected data on the participants' experiences and perceptions of the appliances were analysed to explore how the different appliances fitted the participants' needs and preferences. A cross-case analysis was carried out to compare the results of the three test groups and identify common design characteristics influencing energy use. Overall findings from Study D are discussed in Chapter 5. The appended Paper D describes the participants' use of the appliances in more detail and how different functions influenced the participants' energy use.

3.2.5 CROSS-STUDY ANALYSIS

The findings from the four studies were reviewed in a two-part cross-study analysis. The first part addressed the empirical material to answer the research questions formulated for the two themes introduced in section 1.2 while the second part addressed the implications that findings present for design practice in order to contribute to the overall aim. The analysis process included iterative stages of interpreting the material and the collected data were also contrasted to previous research within the field.

The first part of the analysis took on a descriptive stance in which the empirical material was analysed based on an activity-theoretical perspective to explore the two themes addressed within this thesis, see figure 3.12. The analysis for the first theme addressed how people's activities, everyday priorities and the energy-reliant artefacts used for carrying out activities influence energy use. The analysis for the second theme focused on how people used the artefacts evaluated and design-related aspects that influenced their use and adoption of the artefacts. In addition, the extent to which the artefacts evaluated could support energy conservation, and the reasons why, were also analysed.

The second part of the analysis had a prescriptive focus and addressed implications for design practice based on the four studies and the overall findings, see figure 3.13. Artefact-related aspects and characteristics influencing energy use as well as design implications that had been uncovered in the four studies were analysed to identify common topics. In addition, the analysis also explored how artefacts can be designed to successfully support energy conservation.

Insights from the first part of the cross-study analysis are presented in Chapter 4 and Chapter 5 while insights gained from the second part are discussed in Chapter 6 and in the appended paper E.

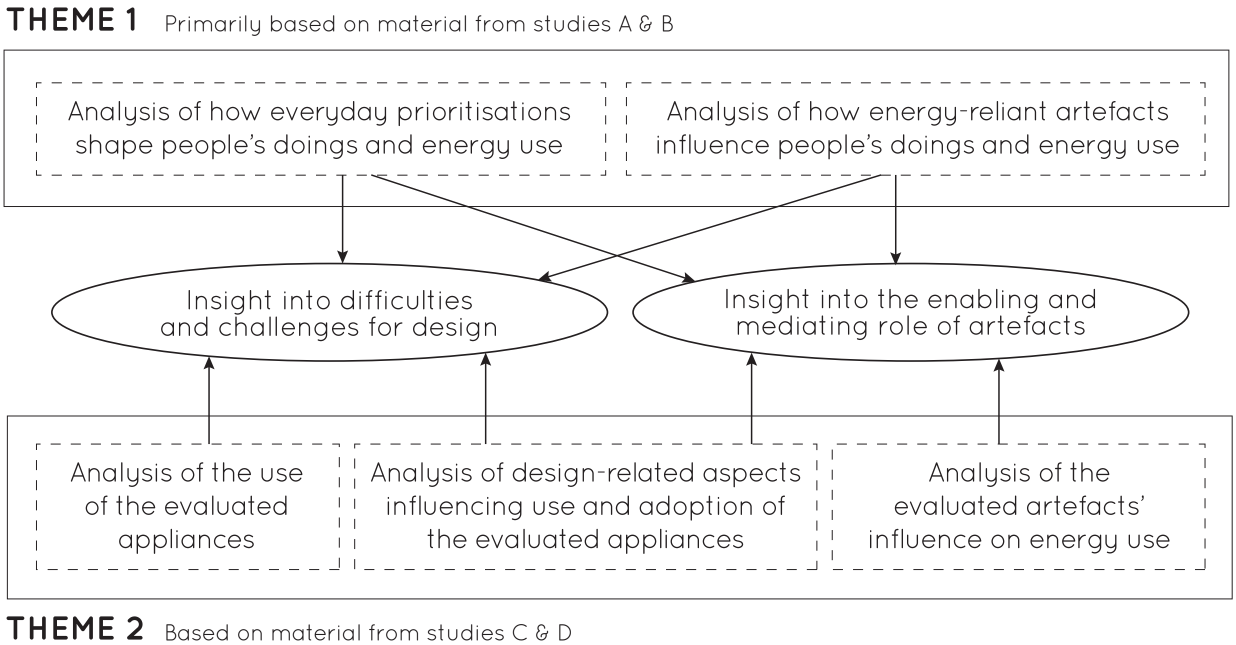


Figure 3.12. Overview of part 1 of the cross-study analysis

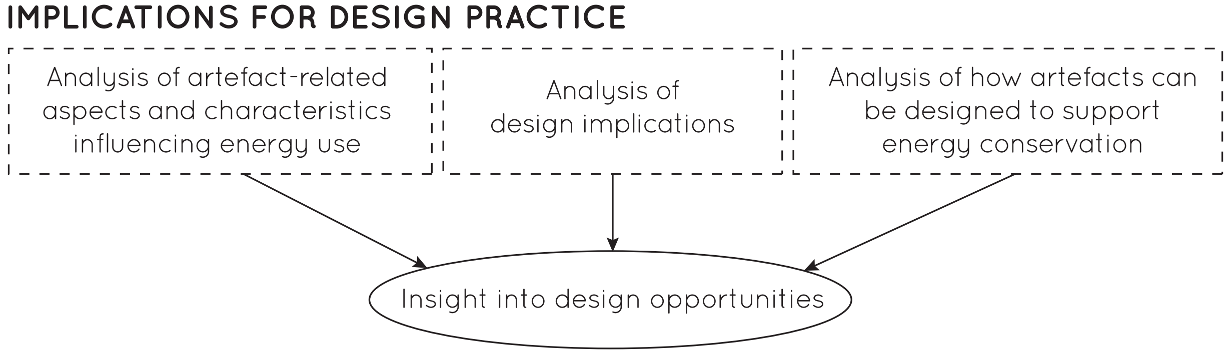


Figure 3.13. Overview of part 2 of the cross-study analysis

3.3 REFLECTIONS ON THE RESEARCH APPROACH AND METHODOLOGY

Many aspects related to the research approach and methodology are relevant for discussion. This section will however focus on addressing how different theoretical perspectives influenced the research, and the implications of the overall approach, the studies and the methods used.

3.3.1 THE INFLUENCE OF DIFFERENT PERSPECTIVES

It has been a challenge to dive into such a multidisciplinary research field. Research that addresses the topics of energy and design is not only associated with several different theoretical perspectives for understanding people's energy use in everyday life, but also represents part of an emerging design research domain that is trying to make sense of different theoretical perspectives in relation to design theory. During the course of the research work presented in this thesis, several different perspectives for understanding energy use and the ways in which design can contribute to energy conservation have thus been taken into consideration when exploring the topic.

Initially, the research was influenced to a high degree by frameworks and studies related to environmental psychology and DfSB (e.g. Dwyer et al., 1993; Lilley, 2009; Lockton et al., 2008), which set the research focus and influenced the approach and choice of methods for Study C and in part for Study B. As more insight into the topic was gained, the notion of behaviour as a unit of analysis was found to be too narrow for the scope of the research, and perspectives addressing everyday activities (e.g. Kaptelinin & Nardi, 2006; Karlsson, 1996) and practices (e.g. Gram-Hanssen, 2007; Scott et al., 2012; Shove et al., 2007) were considered instead. The theoretical framework of Activity Theory was found to be especially useful, particularly due to its focus on mediating artefacts, motives, and goals. Additionally, as discussed in section 2.4.1, it presented a perspective that is useful from a design perspective as it fitted well with traditional design theory and people-centred design. As such, it also presented new opportunities for exploring the ways in which energy conservation can be supported through design, compared to ways that are commonly discussed in DfSB literature. The latter studies were thus, to a greater extent than the initial studies, characterised by a more explicit focus on activities and mediating artefacts, and their influence on energy use.

As the theoretical perspective underpinning the research shifted over time, so did the understanding of the topic as well as the constructs and choice of wording used to describe the insights gained. The focus on activities, rather than behaviour or practices, and mediating artefacts, rather than contextual conditions or material artefacts as elements of practice, also shaped the types of design opportunities that have been identified and highlighted based on the findings.

3.3.2 THE OVERALL RESEARCH APPROACH

The overall research approach, *Research for design*, generated insights from which a tentative framework, design principles, and design guidelines were formulated that can be used to inform design practice in relation to how artefacts can be designed to support energy conservation. If another approach had been used, such as *Research through design* (e.g. Forlizzi et al., 2009; Koskinen et al., 2011; Zimmerman et al., 2010), the research process would have been very different. Such an approach includes using the design process as a method of inquiry into the near future to generate outcomes in terms of designed artefacts with the aim of transforming the world from its current state to a preferred state (Zimmerman et al., 2007). Even though a research though design process is often primarily focused on informing the development of a particular artefact, more general outcomes similar to the insights presented in this thesis could also have been gained (Forlizzi et al., 2009). However, as this research focused instead on explorative and evaluative studies that addressed a number of different artefacts, it can be argued that the insights gained are more generalisable for design practice than insights gained from one design case. *Research through design* however presents a valuable research approach that could be used in future research to try out the framework, design principles, and design guidelines suggested in this thesis in practical design cases to evaluate their usefulness and value for design practice. This has however been out of the scope of this thesis.

The multidisciplinary nature of the research domain, with proponents for both quantitative and qualitative research (Abrahamse et al., 2005; Lopes et al., 2015; Sovacool et al., 2015), encouraged the use of a mixed-methods approach to address the multifaceted topic and research questions posed. Different types of studies and several types of data collection methods were thus used to triangulate the data and avoid weaknesses or intrinsic biases that are often associated with single-method studies. For instance, Study C and Study D that aimed to evaluate effects on energy use did not rely solely on self-reported data but included measurements of energy use and use of the artefacts to increase the reliability of the findings. The use of several types of data collection methods, however, resulted in both large amounts of data as well as different types of data. This presented several challenges during the analysis of the material. As many interesting findings not related to the main research questions were uncovered in the large amount of data, it was difficult to keep focused on the particular topic under study. In addition, the diversity of the collected material sometimes made a joint analysis difficult and limited the possibilities of contrasting findings within one study as well as between studies. The collection and analysis of the quantitative data were also, to some extent, beyond the author's area of expertise, which required the assistance of specialists who could take on the required statistical analyses.

3.3.3 THE EMPIRICAL STUDIES REVISITED

The types of studies undertaken and the choice of aspects studied were influenced by the theoretical perspectives and traditions within the research field as well as the knowledge gaps addressed. Interview studies were conducted to address the first theme and gain qualitative insights into people's everyday energy use and influencing aspects. In comparison to surveys, which are commonly used in energy research, the informants in studies A and B could freely elaborate on aspects they considered relevant to the questions instead of being restricted to choosing between predefined answers. As such, the studies allowed for flexibility in terms of what aspects were highlighted by the informants and allowed exploration of additional topics not initially considered by the research team to be explored. Even though field observations were not carried out due to limited resources, they can prove beneficial for future studies as they, in combination with interviews, may present additional insights into people's activities in everyday life.

Studies C and D were carried out as field studies to address the second theme and gain insight into how design can support energy conservation. In contrast to laboratory experiments, they presented opportunities for exploring people's use of artefacts in everyday life settings and allowed evaluations over time. They thus generated data on people's use and acceptance of artefacts and longitudinal data that enabled evaluation of long-term effects, which is often missing in other studies (see reviews by Abrahamse et al., 2005; Coskun et al., 2015). Study C was especially designed with a six-month test period and a six-month additional follow up period to complement previous short-term studies evaluating energy feedback systems. Additionally, a large control group and a group of matching control households were used in Study C to enable evaluation of changes in energy use despite differences between households regarding their level of energy use and specific situational conditions.

The recruitment of participants differed in the four studies depending on the studies' scope, both in regard to the number of participants recruited and their characteristics. As Study A aimed to map people's possession and use of appliances, a large number of informants were recruited with different demographic characteristics to cover a broad group of people. For Study B, care was taken to ensure a mix of people with different levels of motivation for reducing energy use, as the study sought to explore energy-reliant activities and aspects that might influence people's approach to energy conservation. Similarly, participants recruited to Study C also differed in regard to their motivation for reducing energy use. Recruitment to Study D was, however, only dependent on how frequently people used one of the three types of appliances that were to be evaluated in the study. The number of participants recruited to studies C and D was lower compared to the other studies due to the complexity of the studies, limited resources as well as the limited number of appliances available to evaluate. The low number of participants in the two field studies limits the generalisability of the findings but nonetheless provide valuable insight that stresses the need for future studies with increased sample sizes.

The artefacts evaluated in studies C and D were chosen based on what types of artefacts it would be relevant to evaluate in relation to the second theme. The particular energy feedback system assessed in Study C was chosen as it provided new functions and a more simpler and user-friendly interface compared to other systems on the Swedish market at the time. An opportunity to collaborate with the producer of the system and the design team was also at hand. The particular appliances evaluated in Study D were chosen primarily for their functions, as discussed in 3.2.4. By choosing three particular appliances of the same type that differed in regard to their functions but not in regard to the type of technical approach used, it was possible to evaluate how design decision related to particular functions influence the appliances' design characteristics and people's energy use. If the appliances had differed in regard to their technical approach or even the type of artefact, the evaluation would have required an assessment of people's acceptance and adoption of the appliances in more detail and over a longer time in order to satisfactorily discuss how the different appliances influenced energy use. This was unfortunately not feasible with the resources at hand and the available time frame. Nonetheless, future studies addressing how different types of artefacts may enable less energy-reliant activities are very much needed.

As will be discussed in Chapter 7, the approach and studies undertaken provided new insight that complements previous findings. Nonetheless, other types of studies might have resulted in other interpretations of how design may support energy conservation depending on the particular contexts and constructs studied. In addition, other researchers might have interpreted the material presented in this thesis differently. This is, however, inevitable as a phenomenon cannot be studied completely objectively as researchers influence, and are influenced by, both the research process and the interaction with participants during the process (cf. Creswell, 2014). Moreover, as the understanding of the topic evolves throughout the process of gathering and analysing data, the constructs used for interpreting the material also become more specific, which influences the interpretation over time.

EMPIRICAL FINDINGS

04 THEME 1
EXPLORING ENERGY USE IN EVERYDAY LIFE

This chapter discusses the first theme addressed in this thesis, i.e. how people's doings in everyday life influence energy use. The findings presented in this chapter build primarily on results from Study A and Study B, but in part also on results from Study C and Study D.

People's energy use is discussed from an activity theoretical perspective and put in context with the energy-reliant activities people carry out in everyday life. The focus is placed on how people's priorities and use of artefacts influence energy use and energy conservation during everyday activities. The findings are subsequently reviewed in comparison to other studies and key findings are summarised to highlight what insights they provide into the ways in which people's doings in everyday life influence energy use.

4.1 ENERGY-RELIANT ACTIVITIES AND EVERYDAY PRIORITIES

Studies A and B clearly pinpoint people's needs and activities as key elements influencing energy use. In order to satisfy basic needs, fulfil desires, and ensure well-being, the informants engaged in many different types of activities that were often dependent on the use of energy. In these activities, energy-reliant artefacts were used as the mediating means to, for instance, ensure thermal comfort and personal health, preserve and prepare food, or communicate with other people. When looking at energy use from this perspective, people's energy use can be considered to be embedded in the many activities and actions that form everyday life and enable people to satisfy their everyday needs.

Study B highlighted that people's activities are influenced by competing and often conflicting motives and goals that may make energy conservation difficult or undesirable to prioritise. These competing motives and goals not only influenced the informants' prioritisations between different activities, but also the types of artefacts they used for

Figure 4.1. Examples of competing motives influencing type of activity

a certain activity as well as their actions when using artefacts during particular activities. The type and strength of these conflicts varied between informants and across situations depending on what the informants considered to be meaningful and desirable for particular circumstances during everyday life. As illustrated by the example in figure 4.1, the aspiration to reduce their environmental impact made some informants engage in particular energy conservation activities, while others instead had to prioritise everyday activities to, for instance, increase their overall well-being by engaging in an activity such as doing the laundry. Others strived to combine the motives by engaging in everyday activities in a less energy-intensive way.

For a particular everyday activity, such as doing the laundry, competing motives and goals also influenced which artefacts the informants made use of, which had implications for the resulting energy use. Figure 4.2 illustrates that the prospect of increasing well-being by increasing the softness of the laundry, reducing effort, and reducing the time needed may make some people prioritise the use of a tumble dryer instead of a non energy-reliant artefact such as a drying rack. Others, that want to reduce their environmental impact in addition to increasing well-being, may instead prioritise the use of the drying rack since it enables them to reduce their energy use. The drying rack may also be prioritised as it enables people to cut energy costs and may provide for a more pleasurable experience as it makes little noise compared to the tumble dryer, which may in turn increase people's well-being. The informants also highlighted that the prioritisations between competing motives and goals related to particular types of activities differed depending on the context: "*We always run the tumble dryer, we don't have an outdoor airer, it's too time consuming and it's not appropriate in the city. But we use one at our summer house*" (I-36 Study B).

The findings also show that even though some informants had an overall motive of reducing the environmental impact during a particular activity, competing goals influenced whether the informants prioritised energy conservation over other goals when carrying out particular actions. As exemplified in figure 4.3, many different competing goals may come into play when using a washing machine. A more energy-intensive setting or programme might be prioritised in order to ensure that the laundry ends up clean and soft or because it saves time when doing the laundry, or simply because it may require less effort to use an energy-intensive default setting compared to switching to another setting. However, a less energy-intensive setting or programme could be prioritised because it reduces energy use, but also if, for instance, it reduces wear on fabrics and energy costs.

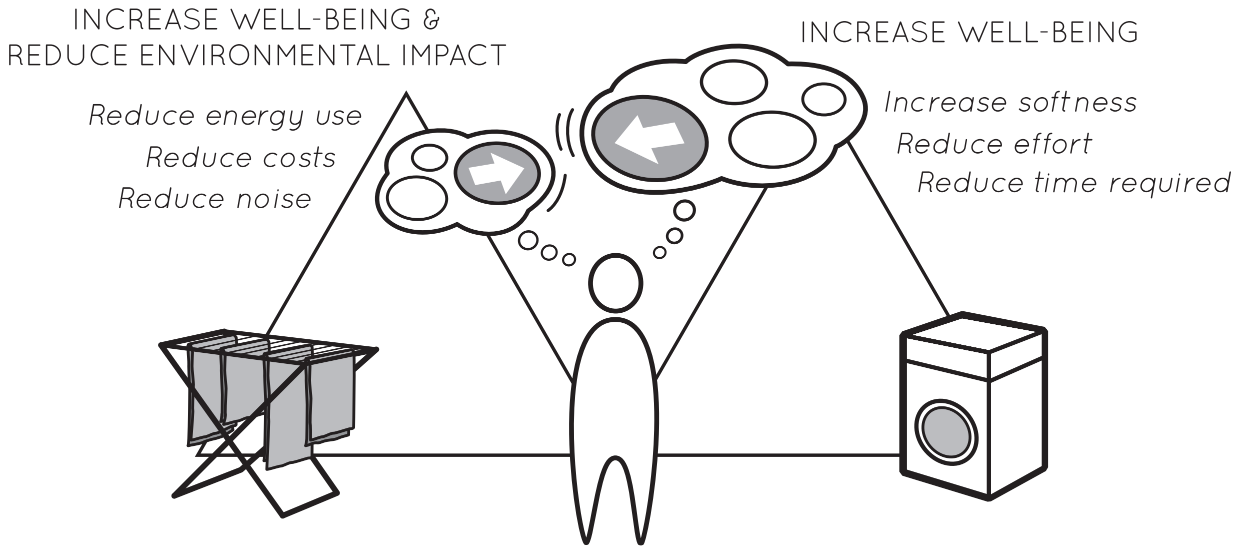


Figure 4.2. Examples of competing motives and conflicting goals influencing choice of artefact for drying laundry

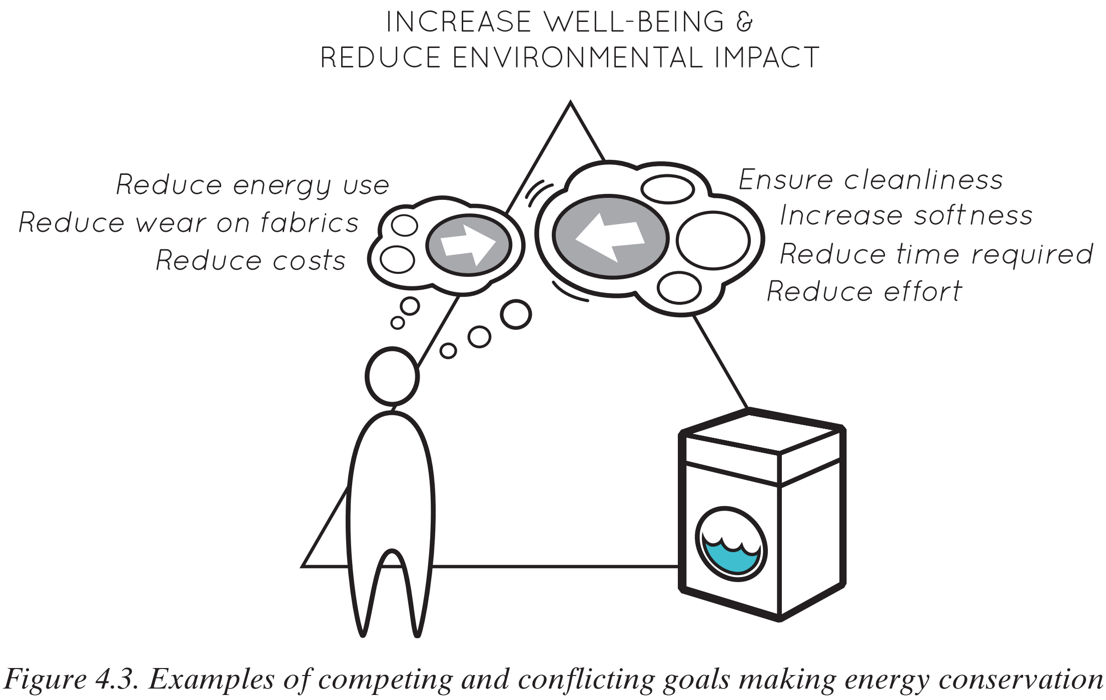


Figure 4.3. Examples of competing and conflicting goals making energy conservation more vs. less desirable to prioritise when using a washing machine

In general, motives and goals related to enhancing well-being, comfort and pleasure were frequently mentioned as conflicting with energy conservation. Many informants in both Study A and Study B experienced a great need of light and warmth, especially in winter time, which made them prioritise keeping their home warm, cosy and well lit, as well as specific activities for getting warm such as taking long hot showers. Additionally, goals such as reducing effort, time misspent, and safety risks were also found to have an adverse impact on energy use as measures to reduce energy use were generally considered to be inconvenient and cumbersome and thus undesirable or challenging to prioritise in everyday life.

4.2 ENERGY CONSERVATION PRIORITIES

It was evident in all studies that the informants' overall approach or stance towards energy conservation varied between individuals. While some informants had very explicit goals to reduce their energy use and actively sought to prioritise energy conservation in everyday life, others did not. As the informants' stance ranged from not at all concerned about reducing energy use to very concerned, the informants' activities and actions to reduce energy use varied. The most commonly mentioned types of measures are briefly describe below followed by a discussion regarding impeding preconditions that make it less likely that people prioritise these measures.

4.2.1 TYPES OF ENERGY CONSERVATION ACTIVITIES AND ACTIONS

The most commonly prioritised energy conservation measures were related to the informants' overall possession and use of appliances and systems, which were discussed extensively in Study A and Study B, and to some extent also in Study C and Study D. These measures included investing in new artefacts to either replace inefficient appliances or systems with efficient ones or to acquire appliances with features that would support less energy-intensive use, such as, appropriate Off buttons or energy-saving programmes. Additionally, a few informants in Study B mentioned a specific strategy to limit their possession of energy-reliant appliances and devices to facilitate energy conservation.

Informants in all four studies brought up several ways to reduce energy use when using artefacts during activities. For example, using appliances differently, adjusting settings to influence the energy use, limiting use, making sure appliances did not use energy when not in use, as well as maintaining appliances in good condition, were discussed in relation to many different types of appliances. Several informants in Study A and Study B mentioned using additional devices such as timers, sensors, and On/Off switches to make these types of measures more convenient and less time consuming and thus easier to prioritise in everyday life.

The majority of informants in Study B described activities through which the informants sought to increase their understanding of their energy use to enable and facilitate energy saving measures. Some analysed energy use and activity patterns by looking at their energy bills, using energy feedback displays, or compiling and comparing long-term data from the energy provider. Using wattmeters to assess energy-intensive appliances or asking for recommendations and advice were other common measures.

4.2.2 PRECONDITIONS IMPEDING ENERGY CONSERVATION

The most commonly mentioned measures were often not the most effective in contributing to substantial reductions from an energy conservation perspective. It was observed in Study A that many informants had changed or limited their use of certain appliances to a greater extent than other appliances, often focusing on the less energy-intensive appliances. The majority also talked about buying energy-efficient light bulbs while few mentioned investing in more efficient white goods. The findings highlight a number of preconditions that were observed to impede significant measures and reductions.

A lack of knowledge regarding significant activities and actions can make it difficult for people to understand which measures may be more effective in reducing the household's overall energy use. However, even informants that knew of relevant energy conservation measures did not always prioritise them. The findings suggest that the informants often carried out measures that were perceived as relevant and desirable based on their preconditions, and from the context of everyday life. For instance, a number of informants in Study B lacked the financial capacity to invest in new appliances and instead often tried to reduce energy use by behaving in a less energy-demanding manner when using artefacts in their everyday life. Others considered long-term investments to be easier and of more interest than changing how they used current appliances, as they found it tiresome to try to reduce energy use on a daily basis as it required constant attention and often forced them to forgo their own comfort.

Only a few informants in Study B mentioned that they were thinking about more radical measures such as renovating the house, or building a new house with energy efficient technologies and material. Many informants were however not able to prioritise such activities due to a lack of knowledge: "*I have considered investing in an air heat pump, but I'm unsure how to go about it and where I should install it to make it as efficient as it can be*" (I-5, Study B). Others mentioned low availability of appropriate artefacts on the market, biased market information, and ignorant and unreliable sales personnel and suppliers as reasons for why they had not been able to carry out radical measures. These types of aspects thus made it difficult for the informants to change their own preconditions. Additionally, these aspects also made many informants prioritise other aspects such as aesthetics, performance, and price when acquiring new appliances.

The preconditions for change that are related to a household or to a specific activity were also identified as crucial for energy conservation. Preconditions related to the overall infrastructure of the building and energy system may make it difficult, impossible or too costly for people to carry out radical systemic changes. For example, many of the informants lived in rental apartments in which the landlord was in charge of decisions regarding investments in more efficient white goods or adjustments of the heating system. These types of decisions were thus out of the informants' control and limited the types of measures they could carry out. Lastly, the energy-reliant artefacts people use in everyday life set particular preconditions for energy use and which energy conservation measures people can and want to prioritise. The influence of such artefacts will be discussed in the next section.

4.3 THE INFLUENCE OF ENERGY-RELIANT ARTEFACTS ON ENERGY USE

As described in section 4.1, people often use energy-reliant artefacts to satisfy needs and achieve their goals during everyday activities. People's activities can thus be considered both enabled and mediated by such artefacts, which makes energy use indispensable in everyday life.

It was observed in Study A that the number and types of energy-reliant artefacts people acquire and use vary depending on what people consider suitable and useful for satisfying everyday needs and desires. Study B revealed that interests, enjoyment, or encouragement from the family often spurred on the acquisition of new appliances and new energy-reliant activities, which increased the household's energy use. Similarly, informants in both Study A and Study B described how the acquisition and use of particular appliances were triggered by everyday activities and by the appliances they normally used during these activities. For instance, several informants highlighted how they had bought additional appliances to use in parallel with their television in pursuit of an enhanced experience or due to the digital television transition that required analogue televisions to be used together with converter boxes. The findings suggest that the acquisition of additional appliances not only increased the informants' energy use but frequent use of expanded artefact ecologies also made it increasingly more difficult and tedious to reduce the energy use: "*It is convenient to not do anything, there are many appliances to manage if you are to shut them all off*" (I-37 Study B).

However, Study A showed that due to disuse or infrequent use of many appliances, the number of energy-reliant artefacts owned says little about a households' energy use. Rather, the associated usage patterns in everyday life are more decisive. The ways in which the informants used artefacts depended not only on the everyday activities they engaged in and their underlying reasons for using particular artefacts, but also on the design of the artefacts. The informants in all studies stated that many artefacts did not enable frugal activities and that specific functions and design characteristics often led to undesirable and unnecessary energy use.

It was identified that people's energy use may increase due to three types of mismatches that a particular design may give rise to; see figure 4.4. The most commonly observed type of mismatch was between tool and object, i.e. between the artefact(s) used and the motives and goals that form the object of the activity. Depending on an artefact's type, size and its technical principles it may be more or less suitable for achieving the motives and goals of the activity in a frugal way. Unnecessarily energy-intensive ways of achieving the motive or goals of an activity often result from artefacts of a type that does not fit the user's needs, that are too big for the user, or that make use of a more energy-intensive technical principle than required. One informant mentioned the mismatch between her needs and the design of her washing machine: "*I always have small loads of laundry and as I have only a few items to wash, the washing machine is never fully loaded*" (I-31, Study B). The mismatch between tool and object was also mentioned in relation to artefacts designed to aid energy conservation measures. One informant in Study B described how a particular design of an energy meter was not suitable for assessing the energy use of old appliances: "*I have an energy meter, but have not managed to get it going yet. I want to assess certain appliances to tell when it's time to change the old appliances. But in order to use the energy meter it's necessary for me to creep under the freezer to read it*" (I-6, Study B).

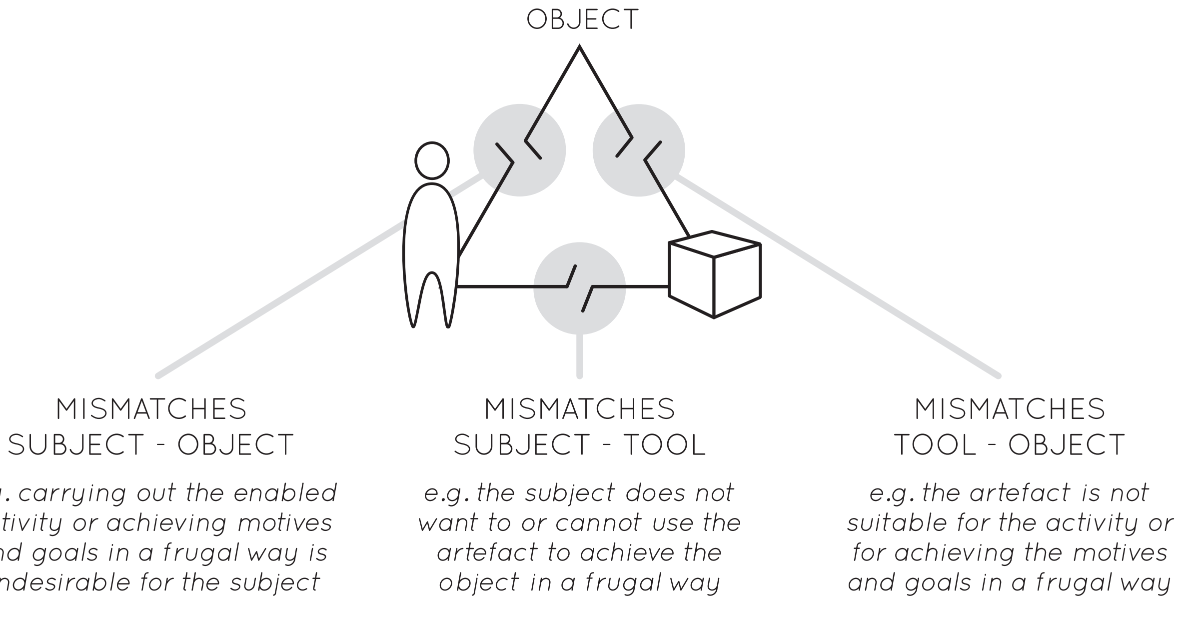


Figure 4.4. Types of mismatches the design of an artefact may give rise to and that influence energy use during everyday activities

Mismatch tool-object

"It's not reasonable to use the stove to make dinner for one person, for one midday meal, I think it's wasteful" (I-72, Study A)

Mismatch tool-object

"The design of the dishwasher is faulty. Sometimes you have to run it even though it is only filled with cups" (I-15, Study B)

Mismatch subject-tool

"When it comes to standby power, the TV channel box discourages me from turning it off completely. The start-up process is not worth it (...) it's often problematic, I don't have the time and it requires a lot of effort" (I-12, Study B)

Photographs: Anneli Selvefors, Frida Hagelberg, Frida Johansson, and Julia Stensson

Mismatch subject-tool

"There's no direct switch, I'm still looking for it, but I don't think that I can turn the TV on or off, I have to use the remote ... I have accepted that this is how it's made. In the beginning I was annoyed with it, but now I have come to terms with it" (I-22, Study) A)

Mismatch subject-tool

"It turns on when I turn on the computer. So to avoid it I shut it off via the switch on the multiple socket. We do not really agree" (I-60, Study A)

Mismatch subject-tool

"It consumes a lot, so I have to recharge it every night. So the charger is always plugged-in next to my bedside table" (I-22, Sudy B)

Another common mismatch was between subject and tool, i.e. between the user and the artefact. The informants in Study A and Study B described how the design and functions of some appliances did not mediate less energy-intensive use as specific functions were not adapted to the activity enabled nor to the informants' needs, preferences, and capabilities. This type of mismatch was particularly reported in relation to actions and operations. For instance, many informants argued that appliances often lacked relevant functions that would enable them to carry out actions to achieve goals in a more frugal way and that poor usability gave rise to breakdowns that made it cumbersome to use appliances in less energy-intensive ways.

A third mismatch was identified between subject and object. It concerns whether people find the activity that is enabled by the artefact needed and whether they consider it desirable to carry out the activity in a frugal way. This type of mismatch is closely linked to the competing and conflicting motives and goals discussed in the previous sections. For example, if an artefact is designed in a way that makes it difficult for people to both prioritise energy conservation and other more desirable everyday motives and goals, the artefact will most likely be used without consideration of its energy use.

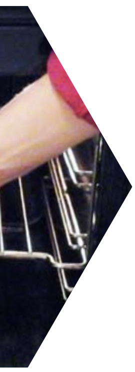
Even though the design of a particular artefact may give rise to the three types of mismatches described above, the mismatches are dependent on the activity as a whole as they emerge in a certain situation and context in which a particular person uses the artefact to achieve a specific object.

4.4 DISCUSSION IN RELATION TO PREVIOUS RESEARCH

As highlighted in the introduction, research on energy use has traditionally emphasised the importance of studying the effects various socio-economic factors and psychological aspects have on people's energy use. In conformity with a growing number of scholars from different fields and theoretical viewpoints (e.g. Aune, 2007; Lutzenhiser, 1993; Wilhite, 2008), the findings presented in this thesis instead stress the value of understanding how people's activities in everyday life and use of energy-reliant artefacts influence energy use. To review the findings additional to this emergent view, this section will discuss findings regarding people's everyday activities and use of artefacts in relation to previous research addressing energy use and energy conservation in everyday life.

4.4.1 ENERGY-RELIANT ACTIVITIES AND THE INFLUENCE OF ENERGY-RELIANT ARTEFACTS ON ENERGY USE

Recognising everyday needs and activities as the source of people's energy use is not novel. Many previous studies have highlighted different purposes for which energy is used and describe energy use as an inescapable consequence of everyday activities and practices (e.g. Gram-Hanssen et al., 2004; Morrison & Gladhard, 1976; Steg, 2008). Furthermore, in ways similar to the findings presented in this thesis, it is often argued that energy use results from a combination of intertwined activities (Aune, 2007; Palm & Ellegård, 2011). Even though others have also described energy use as embedded in everyday activities, few discuss the challenges people's everyday priorities may present for energy conservation.



In contrast, by taking an activity theoretical perspective, this research has described how competing motives and goals that arise within specific activities, as well as within a larger web of activities, influence why people do, or don't, prioritise energy conservation in everyday situations. Other studies addressing energy use do not explicitly discuss the conflicts that may arise between competing motives and goals, even though some discuss people's prioritisations in everyday life. For instance, it has previously been suggested that people prioritise activities that provide for a desired lifestyle or immediate pleasure (Hanratty, 2015; Richetin et al., 2012; Wallenborn et al., 2011). Gatersleben (2001) and Crosbie and Baker (2010) similarly argue that people do not mind minor measures to reduce energy use as long as they do not need to make changes that could compromise their comfort, freedom, and pleasure. But while Gram-Hanssen et al. (2004) suggest that these aspects weigh more heavily than energy conservation for "energy spenders" specifically, the findings in this thesis indicate that they may be prioritised regardless of people's level of energy use. However, as suggested by Lutzenhiser (1993), Morrison and Gladhard (1976), and van Raaij and Verhallen (1983) and also identified in Study B, one aspect that may influence people's prioritisations is the dependency on energy and particular appliances associated with different stages of life and household configurations. As people's actions are part of an ever-changing web of activities, people's needs, goals and associated conflicts may develop or fade over time and make energy conservation more or less desirable to prioritise.

Another aspect seldom discussed in detail in literature is the way in which artefacts influence energy use. Traditional energy research that takes behaviour as the unit of analysis does not often consider what role artefacts play in people's energy use, or it addresses artefacts in terms of contextual factors at most (Abrahamse et al., 2005; Steg, 2008). In contrast, research that addresses practices often views artefacts as one of the many elements that form practices and seldom discusses functions or design characteristics in detail (Gram-Hansen, 2002; Wilhite, 2008). Even though these perspectives might be useful for their respective fields of inquiry, they offer little insight into why and how artefacts influence energy use in particular situations, which may prove valuable from a design perspective. The findings presented in this thesis highlight how the specific functions and characteristics of appliances not only enable what types of activities that can be carried out, but also mediate particular actions and outcomes, which both have direct consequences for a household's energy use.

Additionally, the findings have shed light on how mismatches between the design of an artefact and the activity it enables may lead to increased energy use. For instance, mismatches between the needs and goals of the intended users and the functionality of certain appliances may lead to multiple appliances being used to attain a desired outcome, which results in increased energy use. Likewise, Ellegård (2010) highlights how conflicts within households may lead to the acquisition of several appliances of the same type, which are then often used in parallel by different household members.

The findings also contribute new insights into a variety of design characteristics – which will be presented in more detail in Chapter 6 – that may make energy conservation difficult or undesirable for people in everyday life. As these characteristics were identified in relation to a variety of different design-related aspects there is ample opportunity to address these challenges through design. Even though some characteristics have been discussed previously from a design point of view, most focus on either describing general aspects, a minor set of characteristics, or characteristics related to particular appliances. For instance, Thornander et al. (2011) suggest that energy wastage can be attributed to people's understanding of a product, partly as a consequence of the product functionality and design. But they do not go into details of the specific design characteristics that influence people's understanding.

4.4.2 ENERGY CONSERVATION IN EVERYDAY LIFE

The identified energy conservation measures are in line with those identified in similar studies. For instance, previous research has discussed measures such as investing in energy efficient appliances and systems (Niemeyer, 2010; van Raaij & Verhallen, 1983), changing the use of appliances (IMU-Testologen, 1991; Niemeyer, 2010), and limiting the use of appliances (IMU-Testologen, 1991; Niemeyer, 2010). Similarly to these studies, the extent to which the informants carried out the different types of measures in the four studies varied between informants.

In line with conclusions in other studies (e.g. Gram-Hanssen et al., 2004; Niemeyer, 2010), the findings in general indicate that people often overlook important measures that might have had a more significant impact than the ones they employed. As different types of actions have different potentials for reducing energy use and thus the overall environmental impact of the activity (Gifford et al., 2011; Stern, 2000), it is relevant to discuss why less substantial conservation measures are often carried out instead of more significant ones. The findings suggest that the informants either had a limited view of the strategies they could adopt, that they did not know which of them would be more effective in reducing their household's overall energy use, and/or that they found some measures impossible or difficult to carry out from their perspectives. Impeding preconditions were highlighted that limit action, which concur with aspects discussed in literature, such as lock-ins related to the building and the technologies used (Niemeyer, 2010), as well as strong habits (Maréchal, 2010). Furthermore, the findings indicate that people interested in acquiring new appliances were frustrated with the low availability of less energy-intensive alternatives on the market and the lack of information and guidance. These results support previous assumptions by Steg (2008), Niemeyer (2010) and Hargreaves et al. (2010) that propose low availability or poorly designed appliances as hindering the investment in and adoption of new energy efficient technologies. As it is difficult for an individual to influence these factors, Faiers et al. (2007) argue that it is the responsibility of the players on the market to provide appropriate technologies and solutions that facilitate energy conservation for people in different contexts.

Another crucial aspect that may explain why certain actions were not carried out is whether people considered the particular action desirable or not. Strengers (2011b) point out that particular social, technical and institutional configurations may give rise to non-negotiable practices that people may not only find difficult to change but may also be unwilling to change. Similarly, the findings highlight the point that energy-intensive activities and actions can be considered to be appropriate if they contribute to satisfying specific needs and functions within a household, which has also been suggested by Wallenborn et al. (2011). This not only holds when considering actions related to energy-reliant activities but also for investments in energy-efficient appliances. The findings from Study B also indicate, in accordance with previous research (Crosbie & Baker, 2010; Steg, 2008) that investments can be highly dependent on the design and functionality of the artefact, which may limit adoption. Similarly, Kaplan (2000) and Guerin et al. (2000) argue that desirable choices must be available for people in order for them to carry out less energy-intensive actions that do not counteract their own perceived interests. Actions that fulfil multiple goals, e.g. performing major weatherproofing to both reduce energy use and to improve comfort, may not only eliminate conflicts but may also be perceived as highly desirable by some people.

Since many actions related to energy conservation are often unknown, difficult, undesirable, or even impossible for people to carry out in everyday life, it is not surprising that only some actions are taken. If people are strongly constrained by preconditions such as technology or infrastructure, positive attitudes and motivation will not be sufficient for people to reduce their energy use (cf. Steg, 2008). If people are to succeed in transitioning to a less energy-reliant everyday life, they must have suitable preconditions for doing so. If people's preconditions strongly facilitate energy conservation, and if energy conservation were to be naturally integrated in everyday technologies and activities, energy reductions would follow without the need for people to be highly motivated.

4.5 SUMMARY OF KEY FINDINGS FOR THEME 1

Findings related to the first theme partly confirm findings reported by others and partly provide new insight that can increase the common understanding of people's energy use. In particular, the findings provide new insight into how everyday activities influence energy use by highlighting how people's priorities and use of energy-reliant artefacts in everyday life influence their approach to, and possibilities for, reducing their energy use.

The findings show that people's energy use rarely has a purpose of its own; it is embedded in the actions and activities that form everyday life. In those activities, people are commonly confronted with competing motives and goals that force them to prioritise between energy conservation and other motives. If actions to reduce energy use jeopardise people's possibilities to achieve their primary motives and goals and satisfy their everyday needs and desires, they will most often not be prioritised. Instead, people may find activities or actions that contribute to higher energy use more desirable.

It was observed that energy-reliant artefacts, and their design, influenced people's everyday priorities by mediating their activities and actions and by setting preconditions for what measures that could be carried out. As the design of artefacts shapes people's activities and influences the outcomes of the activities both in terms of achieved motives and goals, and resulting energy use, they may either enable and mediate substantial energy reductions, or impede energy conservation. Depending on the artefacts people use, they may be locked into energy-intensive use patterns, which can make it difficult, impossible or undesirable for them to substantially reduce their energy use. In order to be able to reduce energy use, people must have enabling preconditions that allow for less energy-reliant activities in which reduced energy use is possible, desirable, and makes sense from the perspective of everyday life.

The next chapter addresses artefacts designed to support energy conservation and discusses whether they can provide preconditions that enable energy conservation and/or whether they make reduced energy use desirable in daily life.

05 THEME 2 INVESTIGATING ARTEFACTS DESIGNED TO SUPPORT ENERGY CONSERVATION

This chapter discusses the second theme addressed in this thesis, i.e. how energy-reliant artefacts designed to support energy conservation influence energy use. Based on insights from Study C and Study D, the chapter discusses the two types of artefacts discussed in the introduction: artefacts designed to aid energy conservation measures or activities in everyday life and artefacts designed to mediate less energy-intensive use. As touched upon in the previous chapter, people use both types of artefacts in everyday life and both design approaches thus offer potential for supporting energy conservation. However, as the two types of artefacts support energy conservation in fundamentally different ways, they will initially be addressed separately. The first type of artefact will be discussed in section 5.1 based on findings from Study C regarding the evaluated energy feedback system. The second type of artefact will be discussed in section 5.2 based on findings from Study D regarding the evaluated kitchen appliances. The findings are compared to other studies within the field and key findings are summarised to discuss what insight they provide for increasing the understanding of how energy-reliant artefacts designed to support energy conservation influence energy use in everyday life.

5.1 EVALUATION OF AN ENERGY FEEDBACK SYSTEM

Study C was undertaken to evaluate a particular energy feedback system, Eliq Online, designed to aid domestic energy conservation measures and activities. This section summarises the main findings of the study. Findings addressing the twenty-three participating households' use and adoption of the energy feedback system are initially presented and changes in energy use and energy conservation measures are subsequently addressed. Identified challenges from a design perspective are presented next and the findings are also related to previous literature on energy feedback.

5.1.1 USE AND ADOPTION OF THE SYSTEM

The use of the system and its functions was found to vary considerably between households. The content most frequently accessed was real-time feedback, historical comparisons, energy challenges, and energy reports. Most households used the web portal initially but decreased or even ceased using it after the first couple of months. Six households, all initially highly motivated to conserve energy, were identified as having used the web portal more frequently and more regularly compared to the other households. This group was more interested in increasing their knowledge and awareness compared to the other households, and was also keener on assessing what effects different energy conservation measures might have on their energy use.

The households' general impression of the energy feedback system was mostly positive. However, several impediments limited the use of the web portal, lowered the users' acceptance, and hindered adoption. As illustrated in figures 5.1, the three types of mismatches discussed in section 4.3 were all highlighted. However, the extent to which the households experienced the mismatches varied between the households. In households with low motivation for energy conservation, the mismatch between the motive for using

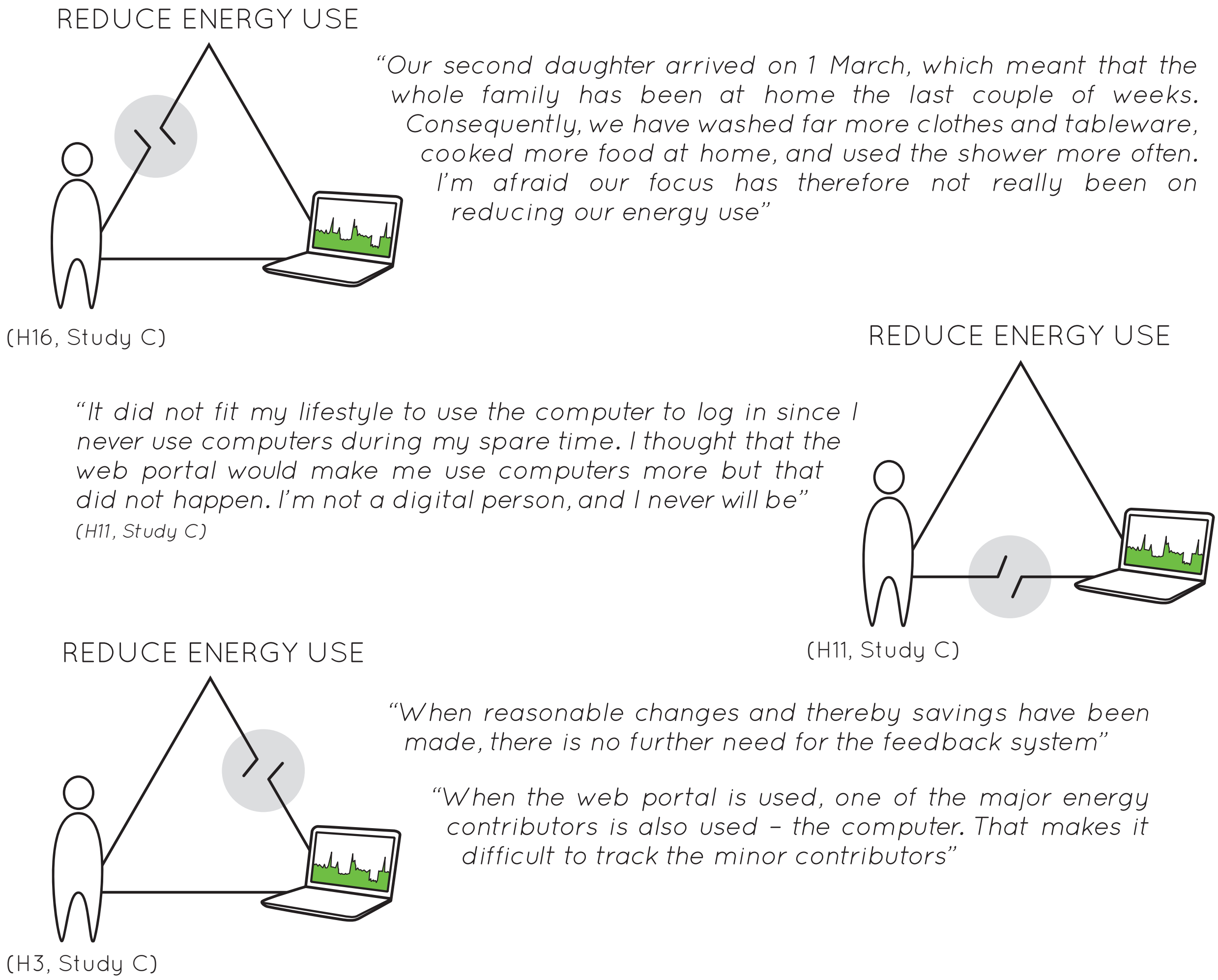


Figure 5.1. Examples of reported mismatches identified as influencing the potential of the energy feedback system to support energy conservation. From top to bottom: a) a mismatch between subject and object, b) a mismatch between subject and tool, and c) mismatches between tool and object

the energy feedback system and their needs and desires was apparent. These households were just not interested in reducing their energy use. Engaging with the system to reduce energy use was thus not part of their preferred everyday activities and they prioritised other activities instead of using the system.

The households with a higher initial motivation for energy conservation instead experienced mismatches between subject and tool and between tool and object to a higher extent, which inhibited long-term adoption of the system. Even though they considered it important to reduce energy use, the mismatch between subject and tool made a couple of households avoid using the energy feedback system. They considered it undesirable to use a computer, tablet or phone to access the web portal. The findings indicate that, even though the portable devices might have been accessible, the households were reluctant to access the web portal as the use of the devices was not part of current or desired domestic activities and routines. Some also considered the usability, reliability and trustworthiness of the interface to be poor, which led to misfits during use. Other households experienced a mismatch between the tool and object that made it difficult to use the energy feedback system to reduce energy use, which made them consider the type of artefact ill-suited for the overall object of the activity. Additionally, a number of technical and practical issues related to the design of the system were highlighted and a couple of participants considered the system lacked important functions and did not offer them enough control.

5.1.2 THE ENERGY FEEDBACK SYSTEM'S INFLUENCE ON ENERGY USE AND ENERGY CONSERVATION MEASURES

A stratified Wilcoxon test found a significant difference (W=6, p=0.0143*) between the medium term average change in electricity use, i.e. comparing the six month test period 2012 with the corresponding period 2011, for the households compared to that of a group of matching control households. As the control households and test households displayed similar electricity use patterns during 2011, the results suggest that the introduction of the energy feedback system in 2012 supported the test households in reducing their energy use in the medium term. When looking at the long-term changes in average electricity use, i.e. comparing the full year 2012 with 2011, no significant difference (second half of 2012: W=0.7352, p=0.3912; full year: W=0.1651, p=1.9267) was found between the households and the matching control households. This indicates that the households as a group managed to decrease their energy use initially, but were not able to maintain the decrease in the long run. The influence of the energy feedback system on energy use, relative to similar households, thus seem to be rather short-lived after temporary use of the system.

Additionally, a Spearman's Rank Order correlation test found a statistically significant positive correlation between the use-frequency and savings attained in the medium term (r_s(13)=-0.626*, p=0.012) and the long-term measures (r_s(13) =-0.567*, p=0.028). The results thus indicate that households that used the web portal regularly managed to reduce their energy use to a greater extent than the other households. Indications that prolonged use of the web portal may result in sustained effects were also seen. Two households continued to use the system regularly during the six month follow-up period and managed to reduce their average electricity use by an average of 9.9% during the full year (corresponding to a total decrease of 1,906 kWh).

Although changes in electricity use were observed, no significant correlations were found between the use of the web portal and self-reported energy-related actions and

"A radical change is needed to reduce my energy use further, e.g. changing the direct electrical heating to, for instance, geothermal heating. Buying a new fridge and freezer. But I have no financial means to do so now." (H15, Study C)

"Since we already are aware of our energy consumption and its environmental impact, Eliq Online has not influenced us that much. However, I believe that it has great potential for households that are not already enlightened" (H16, Study C)

intentions for engaging in energy conservation measures. Several reasons for this, as well as for the increase in energy use for some households, were identified. Not everyone felt that they were able to reduce their energy use even if they would have liked to. For instance, some experienced difficulties in decreasing use when the number of household members increased or when more time than before was spent at home. Others mentioned aspects such as structural preconditions and financial limitations as hindering them from carrying out particular energy conservation measures. Additionally, some households mentioned that they had not been able to report positive changes since their level of motivation or knowledge was already high at the start of the study. As highlighted by one household, previously accomplished cutbacks in energy use also made further reductions difficult: "*I have worked on energy conservation a long time. We have reduced our energy use by 50% since we built the house in 1995. We have invested in new appliances and heating systems but we have now come to the end of the road*" (H10, Study C).

The results indicate a possible shift in opinion over time amongst the households that used the web portal frequently; they found it more difficult to continue reducing their energy use over time without compromising their quality of life. This implies that the households that frequently used the web portal and managed to reduce their energy use initiated acceptable changes during the test period but did not feel that they were able to instigate any additional measures later on.

5.1.3 CHALLENGES FROM A DESIGN PERSPECTIVE

Study C uncovered both benefits and limitations of energy feedback systems and provided insights into aspects impeding energy conservation measures. Although the households generally found the web portal useful, many did not consider it made energy conservation measures more easy or convenient to carry out. Understanding the information, the terminology used, and how to act based on the provided feedback were issues expressed as particularly problematic.

Many also considered it difficult to take measures without gaining the proper task knowledge of relevant energy conservation measures and some felt that the data offered by the feedback system did not provide enough details for them to learn how to go about reducing their energy use. Thus, even though the feedback system triggered new learning and exploration activities that increased awareness and general knowledge for some, it did not necessarily facilitate or provide preconditions for energy conservation during everyday life.

Even though the energy feedback system did support energy conservation for some of the households, few used and adopted the system into their daily life. Designing energy feedback systems that are accepted and adopted is necessary in order for the systems to reach their full potential for supporting energy conservation. To succeed in developing systems that are adopted it is essential to consider the everyday activities and expectations of the intended target group so that the system provides feedback and other functions in a relevant and attractive way that fits the users' needs, as well as their preferences regarding the use of different media in everyday life. Furthermore, in order to reduce mismatches related to technical and practical issues as well as lifestyle aspects, it is vital that the design increases understanding, ease of use and provides lifestyle benefits rather than incites extra obligations. Implications for design will be discussed further in Chapter 6.

5.1.4 DISCUSSION IN RELATION TO PREVIOUS RESEARCH

The findings from Study C are in line with many studies discussing the benefits and effects of energy feedback. The reduction in energy use during the test period corresponds to levels observed for other feedback systems (Abrahamse et al., 2005; Darby, 2006; Fischer, 2008; Grønhøj & Thøgersen, 2011; Ueno et al., 2006a). Moreover, in line with other studies, the findings also indicate that energy feedback systems have the potential to motivate and support learning activities that increased awareness and knowledge (Broms et al., 2010; Grønhøj & Thøgersen, 2011; Hargreaves et al., 2010; Schwartz et al., 2015; Wallenborn et al., 2011; Wilson et al., 2016), and social influence processes through which the household members are given the opportunity to encourage other members of the household to reduce their energy use (Grønhøj & Thøgersen, 2011; Hargreaves et al., 2010; Kleinschafer & Morrison, 2014; Schwartz et al., 2015; Ueno et al., 2006a).

However, the findings also point to a number of disadvantages and limitations of these types of systems. While some studies have observed that feedback may encourage people to reduce their energy use by limiting or changing their use of appliances (Abrahamse et al., 2007; Grønhøj & Thøgersen, 2011; Ueno et al., 2006a), this study was not able to add to these findings. Instead, the results indicate no significant changes in self-reported energy use related to everyday activities or energy conservation measures. Additionally, the findings indicate that it may be difficult to reach sustained conservation effects with these types of systems, which support previous conclusions (e.g. van Dam et al., 2012; van Houwelingen & van Raaij, 1989). Recent literature discusses a general overconfidence in energy feedback, and several aspects highlighted as potentially limiting the effect of energy feedback systems have also been observed in this study. First, it can be argued that no changes in energy use can be anticipated if the feedback systems are not utilised and the feedback information not accessed. A decline in use over time, which has been observed in this and other studies (Hargreaves et al., 2010; Ueno et al., 2006a), suggests that people do not find some energy feedback systems interesting to use or worthwhile in the long run, which limits the potential effect of these types of systems. In addition, energy feedback systems seem to attract and support only a limited target group that is already motivated to reduce their energy use (Fischer, 2008; van Dam et al., 2010; Wallenborn et al., 2011).

Second, various technical and practical limitations related to the design of the systems or interfaces may make them difficult to use or hard to understand (Strengers, 2011a; van Dam et al., 2010; Wever et al., 2008; Wilson et al., 2015; Wood & Newborough, 2007a; Yang et al., 2014). As Study C has shown, inadequate functionality and lack of relevant information may also limit learning and prevent the task knowledge needed to carry out specific energy conservation measures from being obtained. Strengers (2011b) also highlights that there is a risk that the information provided by energy feedback systems will alert people to practices considered non-negotiable, and thus be viewed as irrelevant as they can't do anything to reduce the associated energy use. This aspect is also brought up by Hargreaves et al. (2010) who discuss the conflicts people experience when encouraged to reduce the use of essential appliances or the energy use associated with having a warm and cosy home. Similarily, this study has shown that people are less keen on changes related to non-negotiable use of different appliances if it might compromise their quality of life or everyday goals. Furthermore, Strengers (2011a) argues that the way feedback is usually presented risks potentially legitimising existing practices and sustaining energy use instead of questioning what level of energy use is necessary.

Third, as observed in Study C, there are certain preconditions that energy feedback systems cannot affect, such as individuals' cognitive and physical capabilities, financial means, or other contextual and societal aspects that may inhibit energy conservation measures. Energy feedback, it would appear, is only as successful as the preconditions of everday life allow it to be. Hargreaves et al. (2010) similarily argue that if the potential of feedback systems is to be realised it is vital that all preconditions support possibilities for change. Without supportive preconditions, energy feedback will leave people frustrated and demotivated instead of empowered. As energy feedback systems cannot influence people's current set of energy-reliant appliances used in daily life, they are limited in the extent to which they can aid people to change their everyday activities (cf. Strengers, 2011b). Consequently, energy feedback will only be beneficial for those who use the system, embrace and make use of the feedback, are willing to reconsider their energy use and related actions, and have the possibility to make relevant and appropriate changes.

5.2 EVALUATION OF KITCHEN APPLIANCES

Study D was undertaken to evaluate whether the design of appliances may mediate less energy-intensive use in everyday life. Three categories of kitchen appliances were assessed

– Coffee makers, Electric kettles, and Toasters – each including three appliances designed to mediate less energy-intensive use in different ways and to different extents. This section summarises key findings regarding the eighteen participating households' use of the appliances. The appliance's influence on energy use is discussed next, as well as challenges and limitations for mediating less energy-intensive use through design. The findings are subsequently discussed in relation to associated research.

5.2.1 USE OF THE APPLIANCES

The use of the appliances evaluated in each test group varied between participants. Depending on how useful and suitable the participants perceived the appliances and specific functions to be, the participants used them differently and in some cases increased or decreased their daily use. In addition, the participants also appreciated the appliances to varying degrees and preferred different appliances depending on the fit or mismatch with their needs, preferences and capabilities. For instance, in regard to coffee makers, some preferred coffee maker C due to the insulated jug that enabled them to keep the coffee warm and easy accessible when sitting down to enjoy their coffee for a longer period. One participant also argued for other positive benefits of not having to use a hot plate: "*I don't understand why all coffee makers don't use thermos jugs, it is really good. Partly from an energy conservation perspective but also because the coffee gets better if it is allowed to sit for a while. It keeps its temperature and increases the aroma. It doesn't get burnt. If coffee is left on one of those hot plates it turns sour*" (H_C5, Study D). In contrast, others rejected coffee maker C as they considered an insulated jug uncalled for since they usually finished their coffee quickly.

In regard to use of specific functions, few made use of functions beyond the basic functions necessary to brew coffee, boil water, and make toast. For instance, the temperature settings for electric kettle C and toaster B's option to toast one slice were seldom used. It became apparent during the interviews that the participants that had not made use of these types of functions had not felt the need to use them, not understood how to use

"How often do you really need 60-degree water? What should I use if for? Perhaps if I make instant coffee, then I can drink it straight away. That would use slightly less energy" (H_W3, Study D)

them or simply not noticed them. Study D thus suggests that the appliances designed to mediate less energy-intensive use were not appreciated by all participants, and their functions were often not used to any greater extent in daily life.

5.2.2 THE APPLIANCES' INFLUENCE ON ENERGY USE

The participants' energy use differed both between appliances and participants as their use of the appliances and functions varied. In addition, apparent differences between the appliances were noted for coffee makers and toasters in regard to variations in energy use between different use events. For example, variation in energy use was greater for coffee makers A and B, compared to coffee maker C. Large variations in energy use between different use events indicate that some appliances were successful in supporting less energy-intensive use in particular situations while contributing to more energy-intensive use in other situations. For the three coffee makers specifically, the manual and automatic off functions influenced how long the appliances were switched on during each use event. In regard to coffee maker C, the participants' energy use did not differ much due to its automatic off function that ensured that none of the participants kept it on longer than necessary to complete the brewing.

The findings suggest that the observed differences in energy use are related to the design of the evaluated appliances. The overall design and presence of specific functions determined the amount of energy needed to reach a desired outcome, i.e. brewed coffee, hot water, and toasted bread. Additionally, the design of the functions influenced, for instance, interaction possibilities, ease of interaction, and interpretation, which all determined the extent to which energy conservation was facilitated or impeded during use. The different combinations of functions as well as the design of specific functions thus formed particular design characteristics that mediated energy use in different ways. Depending on the design and its fit or mismatch with the participants' needs, goals and preferences when carrying out particular actions, some appliances were used in a less energy-intensive way but others in a more energy-intensive way.

Less energy-intensive use was facilitated when the appliances and functions was fit for purpose. In such cases, the appliances not only had functions that allowed the participants to reach a desired outcome in a less energy-intensive way, but also allowed the participants to attain other goals that made less energy-intensive use attractive and desirable. For instance, the participants mentioned aspects such as time saving, convenience, enjoyment, and the quality of the result. The lid that covers the toasting slots for toaster C presents one example. The lid made the toasting process more efficient by default and toaster C required the lowest energy use while, according to some participants, providing the fastest toasting process and tastiest toasts. However, other participants experienced mismatches, which either impeded less-energy intensive use or led to rejection. As indicated by the examples in figure 5.2, mismatches between subject and tool as well as between tool and object were reported by several participants.

Similarly, even though electric kettle B was designed to mediate less energy-intensive use by allowing people to boil small amounts of water, all participants perceived mismatches that limited their use and acceptance of the kettle, see figure 5.3. The few participants that had a specific goal to boil a small amount of water experienced difficulties in using the kettle and dosing accurately due to poor usability. One participant described why: "*To fill water in the container you need to put it down, turn it 180 degrees, and then push the knob, which is actually quite inert and I understand why. So you really push and it makes it wobble*

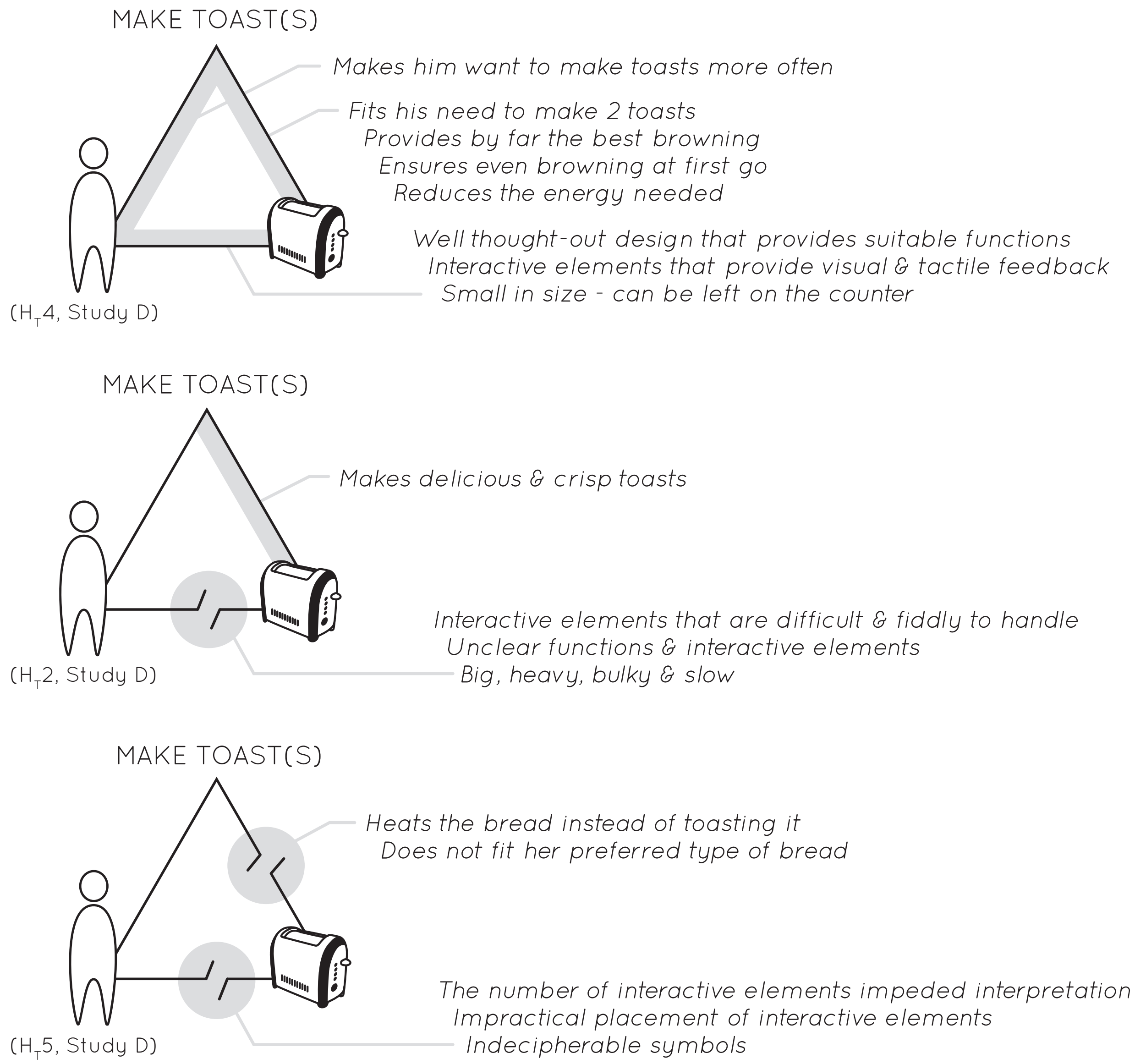


Figure 5.2. Examples of aspects contributing to fits and mismatches reported by the participants when using toaster C.

back and forth. It can be a bit difficult to hit the minimum mark, you have to stop a bit early, but it might not get filled all the way to the mark, so you have to push some more and there's way too much" (H_K4, Study D). The participants that wanted to boil a large amount did not consider the kettle as fitting their needs and also regarded the kettle's integrated filling system as unnecessary and cumbersome. One participant shared her frustration with the design of kettle B: "*This one was not so easy to understand. I poured water in and then pushed it down* (the On/Off switch). *But it did not go down, it flipped back up again, because there was no water in the boiling chamber. It took me a while to understand how to push it down* (the valve knob). *And it was also very difficult to see how much I had filled. I pushed it down but when I went to fill a teapot it was only enough for half a pot, how was I supposed to see that?*" (H_K6, Study D).

A variety of design characteristics were identified, in relation to the nine evaluated appliances, which exemplify how inadequate design influenced the participants' use of the appliances and contributed to higher energy use than necessary. For example, appliances

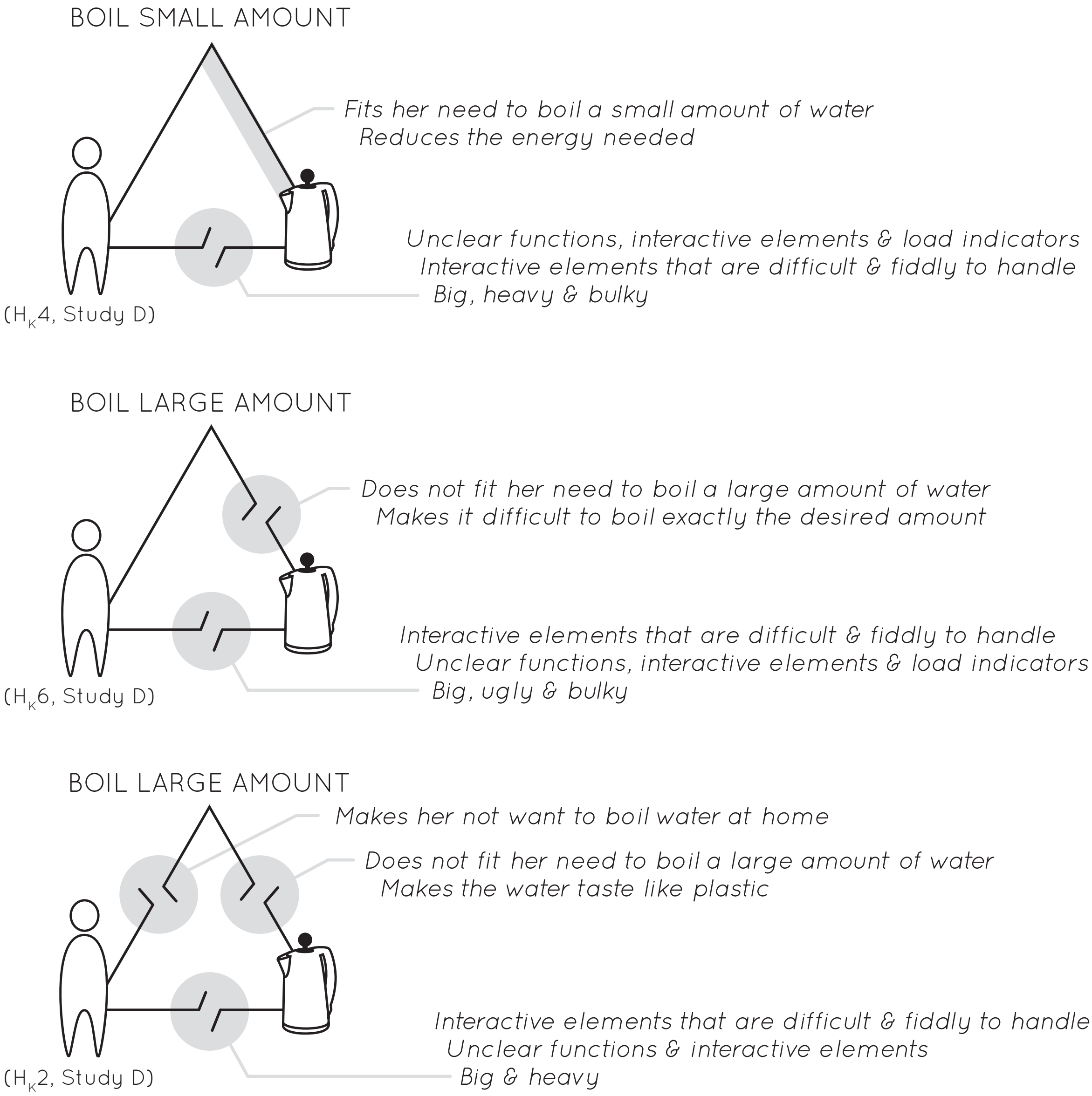


Figure 5.3. Examples of aspects contributing to fits and mismatches reported by the participants when using kettle B.

designed in such a way that small loads are hindered, adjustments of settings or loads are difficult, available functions are unclear, and energy use is poorly communicated, may risk impeding energy conservation or contribute to more energy-intensive use.

5.2.3 CHALLENGES FROM A DESIGN PERSPECTIVE

Study D highlighted that less energy-intensive use can be mediated through design in many different ways. However, as stressed above, a particular appliance and type of function that supported and facilitated less energy-intensive use for some participants did not necessarily do so for all nor did everyone appreciate it. The reasons identified for discrepancies in energy use present a number of challenges for design. Identifying suitable functions that are relevant and useful for people is essential in order to design appliances that mediate desirable activities but in less energy-intensive ways. To avoid mismatches it is crucial to consider what people want to achieve and recognise how dissimilarities in regard to needs, preferences and capabilities may influence use in different ways.

Moreover, it is important to consider what use patterns particular functions may give rise to, so that the most appropriate out of several conflicting functions may be prioritised. Considering all functions of an appliance from a holistic perspective is necessary to avoid impeding energy conservation due to aspects such as cumbersome interaction and poor communication. Furthermore, a holistic perspective may increase the likelihood of an appliance being chosen, appreciated and adopted in daily life, which will influence its potential for supporting energy conservation in the long term. Implications for design will be discussed further in Chapter 6.

5.2.4 DISCUSSION IN RELATION TO PREVIOUS RESEARCH

The findings from Study D highlight, in accordance with many other studies, that the design of appliances plays an important role in people's energy use. Even though few studies have been carried out to systematically compare the design of several appliances, some exceptions exist, such as the works by Sauer and colleagues (e.g. Sauer et al., 2002). They have observed the positive effects of improved design regarding, for instance, enhanced labelling, visibility of labelling, and proximity of controls, which have also been identified as important aspects influencing energy use in Study D. In regard to electric kettles and dosing specifically, Sauer and Rüttinger (2004) found improved scale markings and transparency to be correlated with reduced water use, which again are in line with the findings of Study D related to dosing, both when it comes to kettles and coffee makers. They argue for smaller kettles since their results suggest that people do not overdose water to the same extent with smaller kettles compared to larger ones. Since Study D did not include different sizes of kettles, these findings cannot be verified. However, the findings indicate that the recommended minimum water level is also crucial for dosing as it may even instruct people to overfill when smaller amounts of water would have been sufficient. To reduce overfilling, Sauer et al. (2003) recommend a double reservoir kettle that allows a smaller amount to be boiled, with the argument that it would reduce the physical effort of filling the kettle often. However, as the findings of Study D show, such a design may on the contrary increase the physical effort, inhibit filling of a sufficient or desirable amount, and lead to rejection.

Sauer, Wiese and Rüttinger (2003; 2004; 2009) also discussed automation of functions and manual control options and observed that automatic off functions facilitated energy savings compared to full manual controls. Similarly, Oberascher et al. (2011) concluded that in regards to coffee makers, an automatic Off function combined with a thermos jug is an effective option both for smaller and larger volumes regardless of whether the coffee is to be kept hot for a longer period or not. Even though the findings from Study D are in line with these results, Study D also suggests that automatic functions may increase energy use in particular cases, making it essential to question when automation is beneficial for energy conservation. Additionally, in line with the findings in this study, Sauer et al. (2003) also highlight that in order to attain user acceptance for automatic functions, users must have the option of overriding the appliance if needed.

Although literature systematically evaluating the design of several appliances is limited, studies disucssing design-related aspects impeding energy conservation in regard to particular appliances are plentiful. A variety of common reasons as to why people may use appliances in a more energy-intensive way are thus discussed in literature. One such reason also observed in Study D is mismatches between available functions and relevant functions. Other studies on domestic appliances have also observed mismatches such as the lack of desirable and useful functions in regard to a particular activity (Rodriguez & Boks, 2005; Sauer & Rüttinger, 2000; Tang & Bhamra, 2012), the lack of suitable functions to satisfy a particular need (Rodriguez & Boks, 2005; Tang & Bhamra, 2012; Thornander et al., 2011), as well as the lack of relevant functions from an energy conservation perspective (Rodriguez & Boks, 2005; Sauer & Rüttinger, 2000). Moreover, in line with the findings of Study D, others have highlighted inadequate design as an aspect that influences energy use as it may make appliances and functions difficult to understand (Oliveira et al., 2016; Sauer & Rüttinger, 2000; Zandanel, 2011) and difficult to interact with (Tang & Bhamra, 2012; Zandanel, 2011). Lack of communication regarding the energy use of appliances and different settings is another aspect commonly discussed (e.g. Oliveira et al., 2016; Zandanel, 2011) that was also apparent in Study D.

The findings from Study D show that it is essential that the primary functions influencing energy use mediate use in a less energy-intensive way if energy conservation is to be truly supported. Supplementary functions, such as information or optional settings, aimed at facilitating energy conservation, can never contribute to changes as fundamentally as primary functions, as it is the primary functions that set the main preconditions for use (Elias et al., 2009; Faiers et al., 2007; Sauer & Rüttinger, 2004). Nonetheless, as Study D has shown, primary functions designed to support energy conservation might not do so in all situations. Focusing solely on one or more functions will thus not be sufficient, as the inadequate design of other functions might impede energy conservation. The findings indicate that energy conservation will not be supported unless the appliance as a whole supports energy conservation.

In sum, appliances designed to mediate less energy-intensive use may not necessarily lead to savings. However, if an appliance and its functions are fit for purpose and support energy conservation holistically, it has great potential to do so. In contrast, if appliances are not deliberately designed to mediate less energy-intensive use they risk inducing more energy-intensive use instead, since preconditions for use are always implicit in the design, whether intended or not (cf. Lockton et al., 2010).

5.3 SUMMARY OF KEY FINDINGS FOR THEME 2

The two types of artefacts evaluated, i.e. energy feedback systems designed to aid energy conservation measures or activities and kitchen appliances designed to mediate less energy-intensive use, represent different ways design can contribute to supporting energy conservation. A number of fundamental differences have implications for the way in which they may contribute to energy conservation in everyday life.

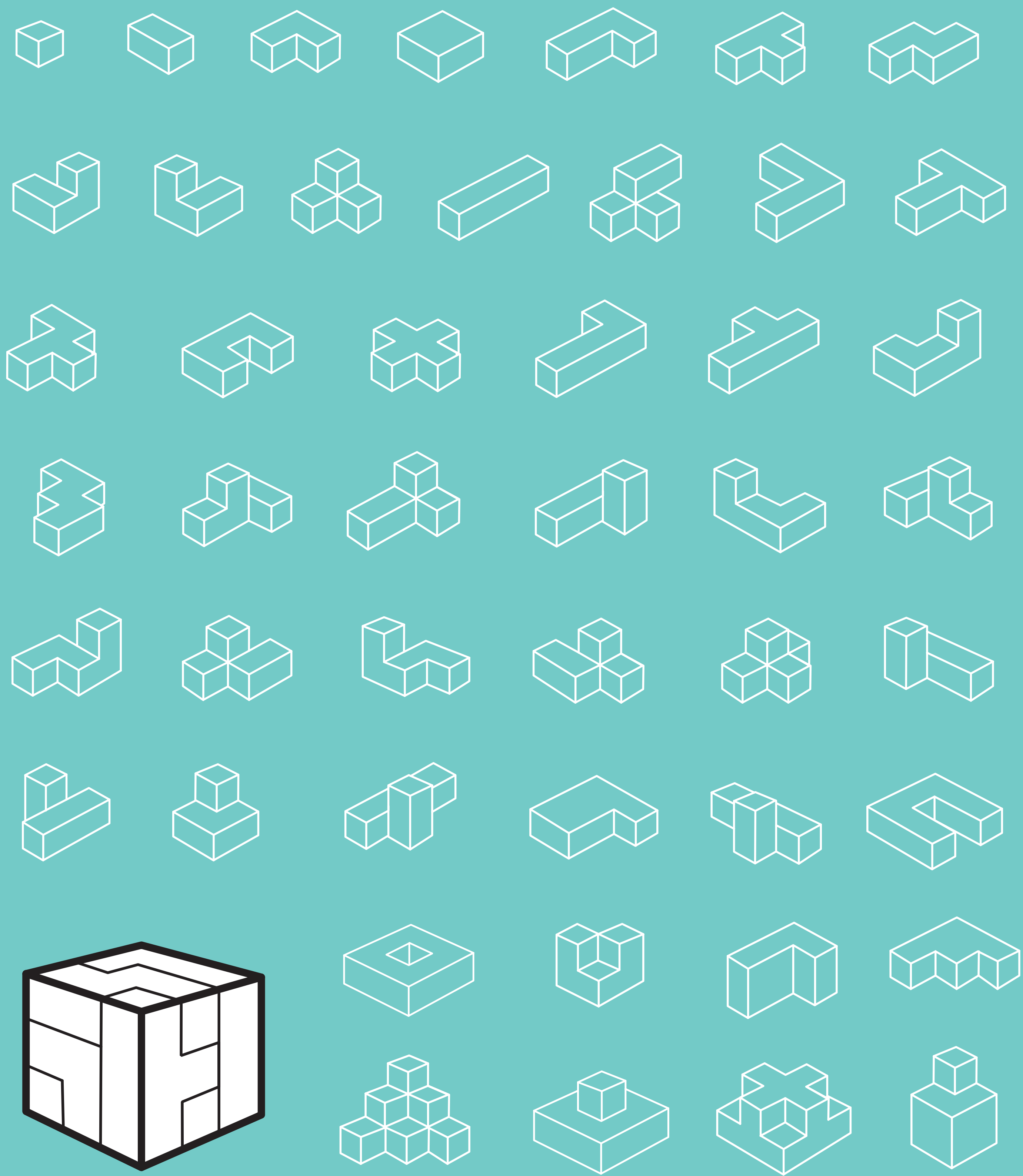
First, the type of artefacts differ in regard to the type and level of support they offer. Energy feedback systems may encourage people to engage in new activities or measures for reducing energy use, but seldom facilitate the implementation of such measures. Additionally, as they usually do not change the contextual preconditions that influence people's energy use during everyday activities, they require people to make an effort and engage in additional energy conservation activities in order to reduce energy use. In contrast, the second approach may both enable and facilitate energy conservation during everyday activities by providing suitable functionality and interaction possibilities that mediate less energy-intensive use. Appliances designed to mediate less energy-intensive use may thus directly change people's preconditions for using energy and provide a high level of support for using less energy in particular situations.

Second, the artefacts also differ in how they influence people's prioritisations between energy conservation and competing goals in everyday life. Energy feedback systems aim to enlighten people and spur them on to prioritise energy conservation through different incentives. Appliances designed to mediate less energy-intensive use, on the other hand, can eliminate conflicts between competing goals, and make energy conservation convenient, beneficial and desirable.

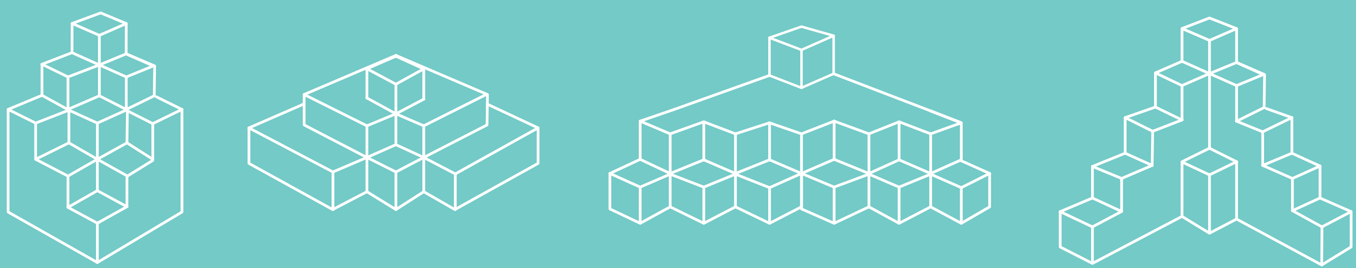
Moreover, the difference between the two approaches also influences whether or not the associated types of artefacts are relevant and desirable to use in everyday life. Energy feedback systems commonly provide the energy feedback through a medium not everyone wants to use on a daily basis and thus only attract a limited target group interested in conservation. In addition, there is a risk that people will lose interest over time as the perceived usefulness of energy feedback for facilitating energy conservation measures is low. In contrast, the second approach can be applied when designing any energy-reliant artefact, including types of appliances that are already desirable for people to use in everyday life. If appliances are designed in such a way that they are relevant, fit the intended activity and users, and mediate less energy-intensive use, they have potential both for being adopted and contribute to less energy-intensive everyday activities.

The extent to which the two types of artefacts can contribute to energy conservation long term is still uncertain and requires further research. However, the findings presented in this thesis indicate that both show potential for supporting energy conservation under certain conditions. Energy feedback systems can support energy savings if they are utilised over extended periods by people who are willing to reduce their energy use. The systems can inspire reductions and energy conservation measures, but only to the extent that people find acceptable and manageable in regard to their specific preconditions. Artefacts designed to mediate less energy-intensive use may do so regardless of whether people are interested in reducing energy use, but only if the artefacts and functions fit in with the activity-to-be and people's needs, preferences and capabilities. Even though such an artefact has great potential to be adopted and mediate less energy-intensive use over a long period of time, energy conservation is primarily limited to the use of the specific artefact, which presents little opportunity for supporting energy conservation in a wider sense.

In sum, both types of artefacts show potential for supporting energy conservation, but in different ways, for different target groups, and to different extents. However, in order for artefacts to provide preconditions for less energy-reliant activities in everyday situations, the artefacts have to be designed to fit the intended activity and target group, and support energy conservation from a holistic perspective. The next chapter will discuss this in more detail by addressing challenges and design opportunities that can be considered when designing artefacts with the aim of supporting energy conservation in everyday life.



IMPLICATIONS FOR DESIGN



06 | DESIGN OPPORTUNITIES FOR SUPPORTING LESS ENERGY-RELIANT ACTIVITIES

This chapter addresses what implications the empirical findings discussed in Chapter 4 and Chapter 5 present for design. Challenges for supporting energy conservation identified in the cross-study analysis will be highlighted initially and followed by design opportunities identified for supporting less energy-reliant activities. The implications are subsequently discussed in relation to the literature and key insights are summarised.

6.1 CHALLENGES AND OPPORTUNITIES FOR DESIGN PRACTICE

The four empirical studies highlighted a multitude of aspects that in different ways influenced the participants' possibilities and actions to reduce their energy use. Study B revealed aspects related to the participants' preconditions in a broad sense while studies A, C, and D highlighted aspects specifically related to the artefacts the participants used in everyday life. Hence, a large number of the aspects identified present challenges that can be addressed through design. Table 6.1 presents an overview of key challenges for design practice that were identified in the four studies. The challenges have been categorised into five main topics: *Difficulties to attain substantial reductions*, *Lack of enabling preconditions*, *Mismatch design-activity*, *Lack of holistick design thinking*, and *Lack or user understanding*.

The first topic points out the design of everyday appliances, services and structural preconditions as one of the reasons for why it is challenging for people to substantially reduce their energy use. The remaining topics address why the design of such artefacts often does not support energy conservation, which in turn highlights specific challenges for design. The empirical material suggests that the availability and use of artefacts that provide preconditions that enable people to reduce their energy use are poor. Additionally,

Table 6.1. (Next spread) Key topics identified that present challenges for design practice

	DIFFICULTIES TO ATTAIN SUBSTANTIAL REDUCTIONS	LACK OF ENABLING PRECONDITIONS
 STUDY A	The design of appliances sets the main preconditions for how energy-intensive everyday activities are, it is therefore difficult for people to substantially reduce energy use without limiting or changing their use of the appliances	The design of appliances is often defective in enabling energy conservation Appliances designed to enable energy conservation are often difficult to use
 STUDY B	Radical changes are impeded by infrastructure preconditions related to buildings, inefficient energy systems and heating technologies Limiting the use of energy-reliant appliances is often not desirable in everyday life if it conflicts with other everyday goals A high number. of appliances and a high frequency of use make reductions hard	Preconditions such as building infrastructures, inefficient energy systems and heating technologies often lock-in energy intensive use patterns instead of enabling energy conservation Appliances and their design often do not enable energy conservation Low availability of artefacts that enable energy conservation
 STUDY C	Only households that are interested in, and have the preconditions to, reduce their energy use can be supported to attain substantial reductions by energy feedback	Energy feedback can enlighten people or provide incentives for reducing energy use but does not enable energy conservation or make reductions easier
 STUDY D	An appliance's energy use is to a large extent determined and influenced by aspects outside the user's (perceived) control Using an appliance in a less energy-intensive way will reduce energy use but only to the extent that is possible and desirable during everyday activities	Even appliances designed to enable people to reduce their energy use may not enable energy conservation for everyone when used in everyday life since people's needs, preferences and capabilities differ

MISMATCH DESIGN-ACTIVITY	LACK OF HOLISTIC DESIGN THINKING	LACK OF USER UNDERSTANDING
The functionality of many appliances does not allow people to acheive outcomes in preferable ways Mismatches lead to the use of extra appliances and devices	An appliance's energy use is influenced by a multitude of design characteristics; commonly, some facilitate energy conservation while others impede less energy-intensive use	Appliances designed to address user needs and provide user benefits often do so at the expense of increased energy use Appliances often lack desirable functions
Appliances with functionality that does not fit people's needs lead to undesirable and unneccessary energy use The design of many appliances can make energy conservation difficult to prioritise in everyday life Mismatches lead to the use of extra appliances and devices	Even though some appliances can partly enable energy conservation, other aspects of their design often make energy conservation difficult or undesirable The participants felt that developers and producers lack a systems perspective	Appliances often lack desirable functions that would facilitate everyday use and make energy conservation easier The type and design of many appliances suggest that they are designed based on a limited understanding of people, their needs, and what is considered desirable in everyday life
The design of the energy feedback system – its interface, functions, usability, terminology, and the type of information provided – was not helpful or interesting for all households, which reduced use	Even though the interface was designed to facilitate use and interpretation, the available functions did not facilitate energy reductions nor were possible information channels desirable for everyone	The design of the energy feedback system requires people to engage with the system as a seperate activity – that many are not willing to prioritise over other activities – which limits adoption
Functions designed to support energy conservation but are irrelevant, useless, and undesirable for people, reduce the potential for energy conservation Different people perceive different mismatches	Appliances designed to support energy conservation through suboptimisations, or through one or more key functions only, often fail to support less energy-intensive use as a whole or lead to rejection	The design of some appliances are not designed based on user insights nor user tested in situ Appliances designed despite a lack of basic insight into user needs, goals and preferences limit acceptance and adoption

people often experience mismatches between the design of available artefacts and activity-related aspects, which makes energy conservation difficult and undesirable to prioritise in everyday life. Even though some artefacts have functions that can support energy conservation, findings in all studies suggest that many artefacts are not designed to support energy conservation holistically nor are they designed based on a rich understanding of the intended users.

These topics not only present challenges for design but also point to opportunities for addressing energy conservation more holistically through design. The following sections will discuss these opportunities by presenting a categorisation of different layers of design and by introducing identified design principles and guidelines.

6.2 TENTATIVE FRAMEWORK EMPHASISING DIFFERENT LAYERS OF DESIGN

The four studies all highlighted the fact that the design of artefacts not only influenced people's energy use directly but also set preconditions for use and interaction that influence the possibilities and potential for energy conservation. It was observed that different design-related aspects influenced energy use in distinctly different ways. Hence, distinct categories of artefact-related aspects were identified and hierarchically arranged into a tentative framework – *Layers of Design* – comprising five main layers of design, see figure 6.1. Each of the layers points to particular design decisions that can be considered to create preconditions that influence people's energy use.

The overarching layer in the categorisation concerns what activity an artefact enables and what motives and needs it supports. Design decisions related to this layer concern why an artefact should be designed and which activities it should make possible. The decisions thus set preconditions for what activities people can engage in, and determine whether there are one or more alternatives that allow people to satisfy their needs and accomplish their goals.

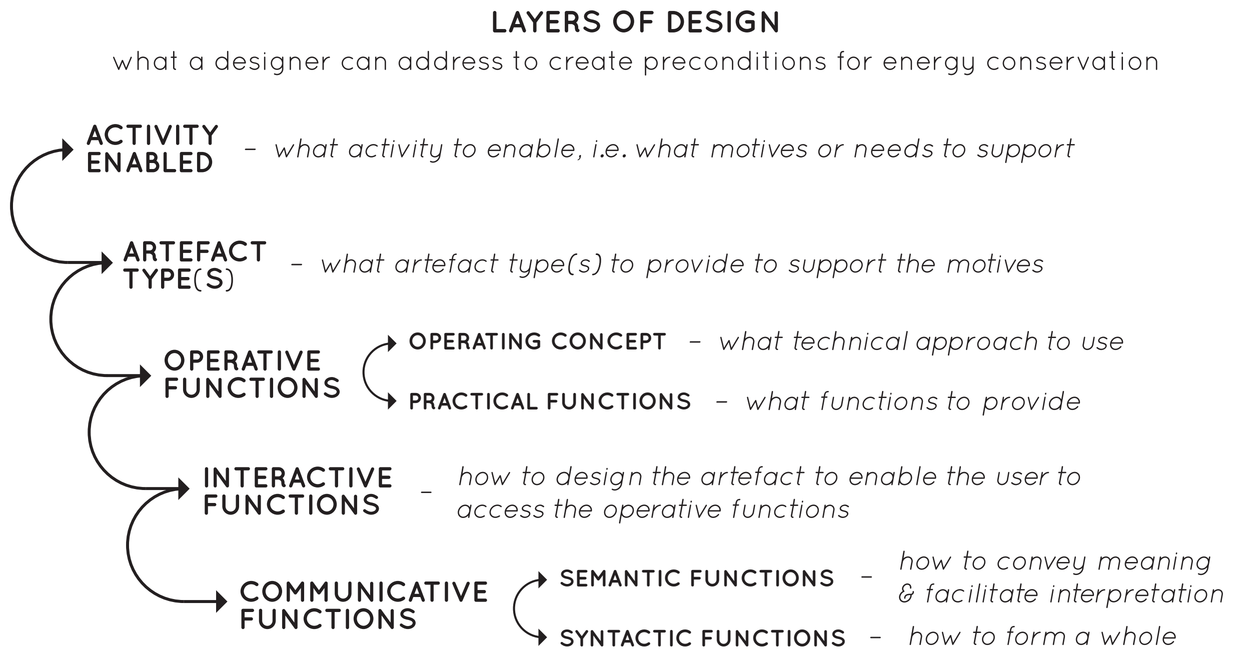


Figure 6.1. Layers of design that can be addressed to create preconditions for energy conservation

The second layer addresses what type of artefact to design. At this layer, design decisions concern making types of artefacts available that enable people to satisfy their needs in less energy-reliant ways, so that people can find ways that suit them and their preferred way of life.

The third layer is divided into two sublayers, which both set preconditions for use and for the resulting energy use. Design decisions related to an artefact's operating concept deal with the technical approach that is taken to provide the artefact's main function, which not only determines the type and amount of resources needed but also what is required of the user to utilise the artefact. Design considerations regarding an artefact's practical functions include considering what primary and supplementary functions would be relevant to allow a user to benefit from the artefact. Such decisions more directly set preconditions for use and determine what the user should be able to do with the artefact as well as how the use of the artefact influences energy use.

The fourth layer concerns an artefact's interactive functions, which determine people's possibilities for accessing and making use of the operative and practical functions. Design decisions linked to this layer include how interaction sequences should be structured, what level of user control to offer, which types of interaction elements to provide (e.g. buttons, displays, or sensors), and how to position them. These types of decisions not only set preconditions for the interaction itself, but also for the possibilities for using an artefact in less energy-intensive ways.

Finally, an artefact's communicative functions, which include both semantic and syntactic functions, set preconditions for users' perception of the artefact. Design decisions concern ordering perceptual elements to convey meaning and facilitate interpretation, as well as ordering perceptual elements to compose a whole. Such decisions influence not only users' understanding of the artefact's purpose, properties and how to use it, but also their experiences during interaction and their perception of the resulting energy use.

Even though the different layers of design influence energy use in distinctly different ways, the layers are interconnected. As indicated by the arrows in figure 6.1, design decisions related to a hierarchically higher layer influence the relevance and scope of possible design decisions that can be considered on the subordinate layers. Thus, when dealing with a concrete design of an artefact it is essential to first determine what needs are

DESIGN CHARACTERISTICS INFLUENCING ENERGY USE

characteristics that can be addressed to create preconditions for energy conservation

ACTIVITY ENABLED	*Purposefulness; Multiplicity; Transformability; Frugality*
ARTEFACT TYPE(S)	*Attractiveness; Usefulness; Supportiveness; Independence*
OPERATIVE FUNCTIONS	*Suitability; Effectiveness; Technical efficiency; Performance; Reliability; Energy utilisation; Fitness for needs; Operability; Diversity; Flexibility*
INTERACTIVE FUNCTIONS	*Controllability; Interactive clarity; Guidance*
COMMUNICATIVE FUNCTIONS	*Accuracy; Consistency; Explicitness; Status clarity; Transparency; Honesty*

Figure 6.2. Design characteristics influencing energy use in relation to different layers of design

to be supported and what artefact type(s) is(are) to be designed, before considering which operative, interactive, and communicative functions to include.

Design characteristics that facilitate, instead of impede, conservation can be attained by making deliberate design decisions from an energy conservation perspective on each layer of design, see figure 6.2. In addition to the characteristics identified in studies A and D which are described in detail in the appended papers A and D, the cross-study analysis identified further characteristics: an artefact's *Purposefulness* determines its ability to enable meaningful and desirable activities; its level of *Multiplicity* defines whether it can be used to satisfy several needs; its *Frugality* determines what level of energy is required to achieve desired outcomes; its *Attractiveness* concerns whether or not people consider the artefact type to present an attractive alternative that provides lifestyle benefits; its *Supportiveness* determines whether it can mediate frugal activities without creating conflicts between everyday goals; and its *Reliability* determines whether people can trust it to produce the same outcomes on each use occasion.

6.3 DESIGN PRINCIPLES FOR ADDRESSING ENERGY CONSERVATION

The cross-study analysis identified five main design principles that can be applied to address the challenges discussed in section 6.1. The design principles highlight important insights that have been gained through the research presented in this thesis and represent perspectives that are key when addressing energy conservation through design. Each principle will be introduced briefly and important considerations that may aid design work will be highlighted. The principles will also be related to the tentative *Layers of Design* framework that was introduced in the previous section.

6.3.1 DESIGN PRINCIPLE 1: STRIVE FOR SUBSTANTIAL REDUCTIONS

To increase the potential for substantially contributing to energy conservation, designers and the decisions they make should strive to create preconditions that support greater, instead of minor, reductions in energy use. As highlighted in the empirical studies, preconditions set on the hierarchically higher layers of design often make relevant energy conservations measures impossible or impede actions that could have resulted in considerable reductions. Consequently, the potential for contributing to greater reductions in energy use may increase if aspects related to the higher layers are addressed during the design process. It is thus important to (re-)consider what types of artefacts to design and how these may contribute to less energy-reliant everyday activities in order to create preconditions with the potential to substantially contribute to energy conservation.

Addressing reductions related to the activity enabled and artefact type(s) involves considering a number of aspects such as: *What do people want to achieve during everyday activities and how do they currently satisfy their needs? How can current energy-intensive ways of satisfying needs be made considerably less energy-intensive? How can people satisfy their needs and achieve their goals in other substantially less energy-intensive ways?* These considerations point towards two main design directions.

The first design direction entails addressing current ways of satisfying needs and finding ways of supporting reductions related to the energy-intensive appliances and systems already available and in use in society. This commonly involves providing supplementary artefacts that change people's preconditions for reductions, which is common on the market today. For instance, air source heat pumps and extra insulation are examples of supplementary artefacts that make it possible for people to attain a desired level of thermal comfort while reducing their energy use despite energy-intensive heating systems or inefficient building structures. These types of artefacts can lead to significant reductions in the short term. However, their potential for contributing to a less energy-reliant society long term is limited since they are often developed to improve a design that is fundamentally flawed due to its energy-intensive character.

In contrast, the second design direction entails addressing the everyday technologies and activities of tomorrow with the aim of "creating better artefacts" rather than "making less good artefacts better". By addressing the role technology plays for energy use in people's everyday life and questioning current energy-intensive ways of satisfying needs, new alternatives that substantially reduce energy use can be identified. Through identifying and developing new types of artefacts that allow people to engage in new types of activities and satisfy their needs in less energy-reliant ways, a new foundation can be laid for the energy use of tomorrow.

6.3.2 DESIGN PRINCIPLE 2: CREATE ENABLING PRECONDITIONS

Energy conservation should be approached from an enabling perspective with the aim of creating new preconditions that make it possible for people to satisfy their needs in less energy-intensive ways. Taking solely an interventionist design stance, which commonly focuses on informing and encouraging energy conservation, will not lead to energy reductions for all, as not everyone is interested in reducing energy use or is able to reduce their energy use due to impeding preconditions. Instead, preconditions can be created by developing and designing artefacts so that energy conservation is enabled, either by making less energy-intensive use of the artefacts possible or by enabling new activities and ways of life that are less reliant on energy.

Even though all layers of design can be addressed to enable energy conservation, it is vital to consider what activity to enable and which role particular artefacts may play. This includes addressing primarily the artefact type(s) and the artefact's primary functions. Applying an enabling stance thus entails designing particular artefacts in such a way so they, including their primary functions and design characteristics, make it possible for people to use less energy.

To identify relevant opportunities for types of artefacts that can enable less energy-reliant activities, several aspects can be explored, for instance: *Why is energy conservation difficult in everyday life? In what ways do current preconditions impede energy conservation during everyday activities? What changes are needed for people to be able to satisfy their needs in less energy-reliant ways? Is energy use essential for people to be able to achieve a particular outcome or can people be enabled to achieve their goals without using energy?*

Additionally, given a certain artefact type, alternative primary functions and design characteristics can be considered in regard to how they may enable energy conservation by, for example, questioning: *What functions can enable people to satisfy their needs and achieve their goals by making use of only a sufficient amount of energy during interaction? What functions are needed to enable users to adjust and/or turn off energy use when relevant? What level of user control is suitable and how will a certain level influence patterns of use and the resulting energy use?*

6.3.3 DESIGN PRINCIPLE 3: MAKE THE DESIGN FIT FOR PURPOSE

To succeed in enabling substantial reductions in energy use through design, it is crucial that artefacts and their functions are designed to be fit for purpose. As the research presented in this thesis has emphasised, mismatches that arise in particular activities between the design of an artefact and aspects related to the intended users and their motives and goals risk leading to increased energy use or people rejecting the artefact. As mismatches arise within an activity, the design of an artefact must be considered in relation to the activity as a whole, rather than solely to one of its components such as the characteristics of the intended users. If artefacts are designed with the activity as a whole in mind, mismatches that often impede energy conservation could be eliminated and make energy conservation less challenging in everyday life.

To avoid mismatches, all layers of design should be considered in regard to how they correspond to and fit aspects related to the object of the activity, the context, and the intended users; see figure 6.3. As described in section 6.2, design decisions related to the different layers of design set preconditions for: how people can satisfy their needs; what ways of life are made possible; what people can do with an artefact; what usage patterns are supported during interaction; how people may interpret and understand an artefact. Consequently, artefacts should be designed to enable activities through which people can pursue their motives and satisfy their needs in less energy-reliant ways in particular contexts. Type(s) of artefact(s) that present an attractive alternative for satisfying needs and fit in with the lifestyle preferences of the users are thus preferable. Operative functions should be chosen and designed to provide relevant and useful ways for people to attain everyday goals and to cater for preferences regarding desirable actions and outcomes. Interactive functions should be designed based on the intended users' interaction capabilities and in a way that reduces effort so that less energy-intensive use is not only enabled but is also easy and convenient. Lastly, to increase people's understanding of the artefact and increase the potential for intuitive use, the intended users' capabilities for perceiving information and interpreting it under specific conditions should inform the design of communicative

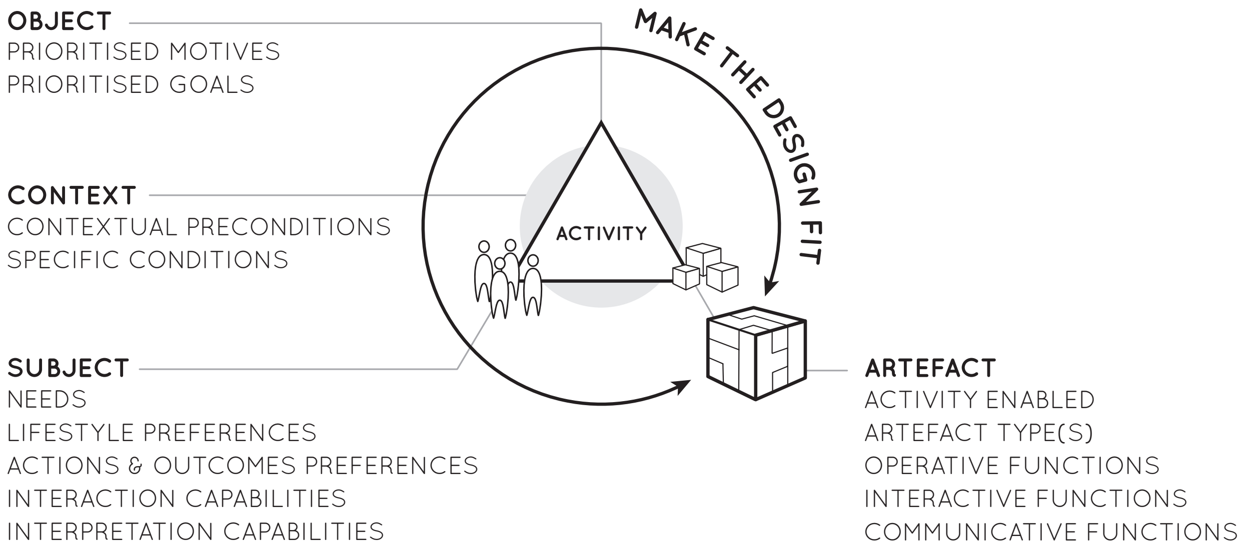


Figure 6.3 Aspects that can be considered to make the artefact and its functions fit for purpose

functions.

In order to avoid mismatches between an artefact and the activity it enables, and increase the potential for supporting energy conservation, it is vital to make all aspects of the design fit for purpose. In doing so it is important to recognise that dissimilarities in regard to the characteristics of different users may present challenges for eliciting requirements and identifying opportunities for design. Thus, it is valuable to consider several questions prior to and during the design process, such as: *Who is the artefact for? In which situations will the artefact be used? How do the motives, goals, needs, preferences and capabilities vary within the intended user group? Can the artefact be designed to fit a variety of users or should multiple artefacts be designed to target particular subgroups? Can shifts in prioritised motives and goals, as well as shifts in needs, preferences and capabilities between contexts and over time be catered for?* Additionally, designing an artefact that is fit for purpose requires a design process that involves users and iterative evaluations of close-to-market prototypes through activities carried out in an everyday context so that the fit between the artefact and the activity as a whole can be explored in context and subsequently improved.

Artefacts designed to enable energy conservation in a way that fits with the activity have the potential not only to reduce mismatches and conflicts between energy conservation and other everyday goals, but also to make actions that contribute to energy conservation desirableIf a design enables less energy-reliant use patterns that present lifestyle benefits, provides desirable outcomes and allows people to achieve their motives and goals, using the artefact in a less energy-intensive way would make sense and be desirable from the perspective of everyday life. Such designs can mediate everyday activities in a way that both provides for and contributes to energy conservation. Additionally, if mismatches are avoided, there is a greater potential for the artefact to be appreciated, adopted, and used in everyday life, which is a prerequisite for it to contribute to energy conservation in the long term.

6.3.4 DESIGN PRINCIPLE 4: APPLY A HOLISTIC DESIGN PERSPECTIVE

When designing for energy conservation, a holistic design perspective is needed that: addresses all layers of design influencing energy use; considers design opportunities in relation to the full solution space; and assesses design decisions from a holistic resource perspective. Approaching the design of artefacts from such a holistic design perspective has the potential for producing appreciated artefacts that can provide for and contribute to substantial reductions in energy use.

As highlighted in the previous sections, functions and design characteristics on all layers of design jointly set preconditions for energy use and influence the potential for energy conservation, making it important to systematically address the design of an artefact as a whole from an energy conservation perspective. By addressing the hierarchically higher layers, the potential for energy reductions may be increased, but to also provide suitable preconditions and increase the potential for user adoption, an attractive design is required that provides for energy conservation in every layer – from the overarching activity enabled down to the lowest level of perceptual influence. If some aspects are not considered, the design may risk impeding energy conservation due to particular aspects such as inadequate usability or an inefficient operating concept.

If only a few of the layers of design are addressed, the risk of sub-optimisation and of overlooking alternatives also increases. As discussed in Chapter 5, sub-optimising or focusing to narrowly on one or more functions risks resulting in artefacts that fail to support energy conservation. By considering all layers of design from a holistic perspective, the potential solution space can be expanded and opened up to new design opportunities that can create preconditions for long-term transitions and substantial reductions in energy use. Several considerations can help expand the solution space, for instance: *What opportunities are there for mediating new and less energy-reliant types of activities? What alternative, less energy-reliant, artefact types and operating concepts could be suitable to provide desired outcomes? Can multiple artefacts be designed so that the artefact ecology as a whole creates preconditions for people to use significantly less energy?*

Lastly, to increase the potential for an artefact to contribute to reduced energy use and an overall reduced environmental impact, it is of great importance to consider potential side effects of the design that may increase energy use or increase the artefact's environmental impact. Considering how a particular design or specific decisions may influence resource use throughout the artefact's entire lifespan is needed in order to assess whether a particular design is justifiable from a holistic perspective.

6.3.5 DESIGN PRINCIPLE 5: BASE THE DESIGN ON RICH USER INSIGHT

In addition to approaching the design of artefacts from a holistic design perspective, it is also essential to base the design on a rich understanding of the intended users and the activity that is to be enabled. Basing the design on user insight is not equivalent to designing an artefact in a way that corresponds to what the intended users say that they want, rather it is a matter of understanding their needs, preferences and capabilities to elicit requirements and opportunities for design. Rich user insight can be gained through different types of user studies that, for instance, explore activity-related aspects such as: *Which activities contribute the most to people's energy use, and why? How do people's energy-reliant activities and needs shift over time? How do people's everyday goals influence their energy use? Do people have an interest in actively cutting back on their energy use? Do people have strategies to reduce their energy use and, if so, what measures do they carry out?*

Depending on what is needed to reduce energy use in particular activities as well as what is desirable for specific target groups, energy conservation can be supported through design in different ways. For instance, in some cases people may want to take a very active stance towards energy conservation and can thus be aided to reduce their energy use through types of artefacts that encourage or enable them to engage in new energy conservation activities. Typical examples of such artefacts currently on the market are energy feedback systems and energy meters that open up new learning and analysis activities through which relevant and potentially more effective energy conservation measures can be identified.

Other people may already know of relevant and effective energy conservation measures that they want to carry out, but they might not be able to do so due to impeding conditions. In such cases, artefacts can be designed to create enabling preconditions that facilitate these energy conservation measures. For instance, many smart home energy management systems available on the market enable people to more easily manage and turn off the multitude of appliances and lights in their home.

There may, however, also be cases in which not everyone, or even no one, is interested in actively cutting back on their energy use. In such cases, designs that rely on people actively engaging in energy conservation activities and measures will not be very successful in supporting energy conservation. Instead, design opportunities for embedding energy conservation into everyday life are more relevant to pursue as they can set new preconditions for the energy use of tomorrow. By enabling alternative and less energy-intensive ways of satisfying needs that do not conflict with people's everyday goals and that are desirable in the context of everyday life, people's dependence on energy-intensive artefacts and activities can be reduced. If such alternatives create satisfying experiences and do not run counter to people's perceived self-interest, they have the potential to cultivate new and less energy-reliant ways of life. For instance, alternatives to energy-intensive washing machines – that people often use frequently not only to clean dirty clothes but also to make sure that non-dirty clothes are perceived as clean – with functions that make less energy-intensive use possible and intuitive are now available and less energy-reliant types of artefacts for refreshing non-dirty clothes such as garment steamers have also recently entered the market. Another example related to cooking activities is the increasingly more popular induction hobs that make use of a less energy-reliant operating concept. Such hobs can present a desirable alternative for many people as, in addition to energy reductions, they provides great preconditions for convenient, safe, and fast cooking.

6.4 GUIDELINES FOR DESIGN WORK

In addition to the tentative Layers of design framework and the design principles presented in the previous section, the cross-study analysis identified a range of more explicit design opportunities to support energy conservation based on insights from the four empirical studies. These opportunities were formulated into design recommendations in the form of guidelines to aid practical design work. Figure 6.4 presents an overview of the design guidelines in relation to the different layers of design. Guidelines related to the hierarchically higher layers are more generally formulated to open up the solution space, which may be beneficial early in the design process. As the degrees of freedom decrease when the design gets more and more defined, more concrete recommendations are provided in regard to the design of operative, interactive and communicative functions to inform specific design decisions.

The proposed guidelines represent insights that have been gained by approaching energy conservation from an activity-oriented perspective. As such, they do not cover all aspects that should be considered when designing for energy conservation. For instance, they do not go into detail regarding recommendations for the choice of technical components or suitable artefact architecture. Moreover, as the guidelines primarily address how artefacts can be designed to create preconditions that allow for and mediate energy conservation during everyday life, their relevance and applicability depend on the type of artefact that is to be designed and its intended usage. Since the proposed guidelines are yet to be tested and evaluated in practical cases, they should be considered advisory and tentative until validated. Nevertheless, the guidelines may provide a valuable starting point for design practitioners as they highlight a number of opportunities that can be addressed to support energy conservation through design.

6.5 DISCUSSION IN RELATION TO PREVIOUS RESEARCH

The implications identified provide a slightly different view on how design can contribute to energy conservation compared to what is most commonly emphasised in the literature. This section will therefore address the implications highlighted in relation to previous research and discuss what insights they provide for the common understanding of

Figure 6.4 (See next spread) Overview of design guidelines

DESIGN GUIDELINES FOR SUPPORTING ENERGY CONSERVATION

in regards to 1) Activity enabled, 2) Artefact type(s), 3) Operative functions, 4) Interactive functions, and 5) Communicative functions

1 ACTIVITY ENABLED

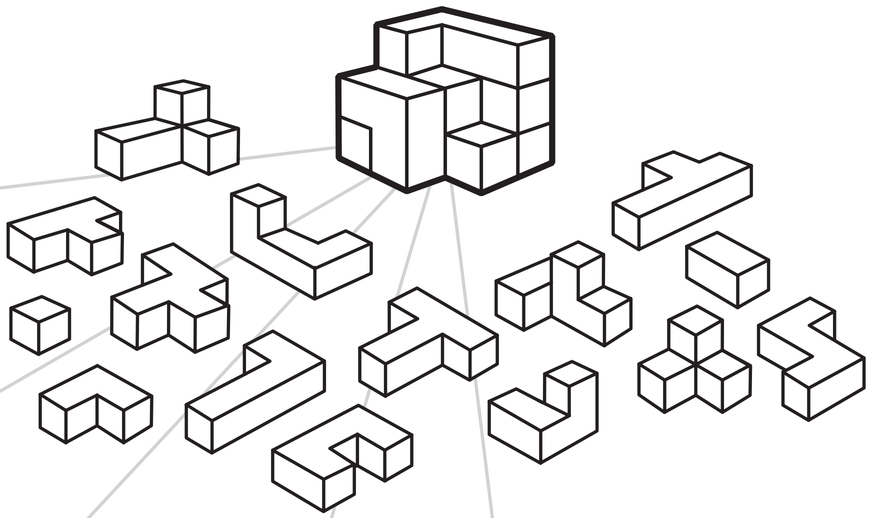
Enable frugal activities through which people can satisfy their needs
Enable people to pursue their motives in desirable ways
Create preconditions for meaningful and pleasurable activities
Make prioritising energy conservation possible and desirable
Cater for shifts in needs, preferences and capabilities over time

2 ARTEFACT TYPE(S)

Provide an artefact type that allows people to meet their needs in a frugal way
Provide an artefact type that supports energy conservation in a way that suits the intended users
Provide an artefact type that does not bring about unwanted obligations in everyday life
Provide an attractive artefact type that offers lifestyle benefits
Provide an artefact type that is useful and desirable to use in everyday life
Provide an artefact that does not require additional energy-reliant artefacts

3 OPERATIVE FUNCTIONS

Use frugal technical approaches that can produce desired outcomes
Make component types, whose efficiency increases over time, upgradable or replaceable
Provide functions and settings that enable different users to achieve desired outcomes
Use default settings that require only the energy needed to achieve a desired result
Provide functions and settings that enable adjustment of energy use
Provide settings that enable processes to be limited to what is needed in specific situations
Provide power modes with different energy intensities suitable for different purposes
Use technology that does not require a start-up process or allow for quick starting
Use automatic functions that turn the appliance off after use or when process completed
Allow the appliance to be turned off manually
Facilitate maintenance or replacement of components influencing energy use
If heat processes are required, improve heat utilisation
If important to retain heat after process is completed, insulate relevant parts
If consumables are required, allow the smallest amount or volume needed to be loaded
If consumables are required, provide load containers suitable for low-sized or low-volume loads
If consumables are required, provide load indicators specifying current load
If consumables are required, allow load adjustments



INTERACTIVE FUNCTIONS 4

Make the use of energy-intensive functions optional
Make the use of less energy-intensive functions straightforward, the default option, or automatic
Allow default settings to be adjusted
Limit the number of functions and interactive elements
Reduce the number of actions required to achieve desired outcomes
Guide the choice of settings to the least energy-reliant setting leading to desired outcomes
Provide interactive elements that are easy, effortless and time efficient to use
Position interactive elements so that they are easy to see
Position interactive elements so that they are easy to reach and convenient to use
Position setting indicators so that they are easy to read during use
If consumables are required, place load containers so that they are easy to load
If load indicators are provided, place them so that they are easy to read during loading

COMMUNICATIVE FUNCTIONS 5

Make functions, interactive options and settings explicit
Make sure the utility of all functions is clearly understandable
Use standardised or common symbols to communicate utility
Communicate how to manually turn the artefact off
Make both active and inactive settings explicit
Make the process transparent and communicate process status
If consumables are used, communicate load in a consistent and accurate way
If consumables are processed, clarify expected outcomes
Communicate how functions, settings and loads influence energy use
Communicate current power mode as well as additional power modes
Communicate energy use

how energy conservation can be addressed through design as well as specific design considerations.

6.5.1 OVERALL STANCE FOR ADDRESSING ENERGY CONSERVATION THROUGH DESIGN

As discussed in Chapter 2, energy conservation is commonly approached from an interventionist design stance with the focus on designing interventions with the aim of changing people's doings and the outcomes of those doings. The common conceptualisation of interventions in research that addresses the topics of energy and design has encouraged design approaches in which people's doings are often viewed as problems that can be solved through an intervention (e.g. Cash et al., 2017; Hanratty, 2015; Ohnmacht et al., 2017; Withanage et al., 2016). This stance is evident in the majority of DfSB studies as well as in literature that addresses persuasive design (Fogg, 2009) and the concept of Choice Architecture, which is commonly referred to as Nudging (Thaler et al., 2014).

Even though the concept of interventions and processes of creating and evaluating artefacts in a research context (as commonly done in *Research through design* (Forlizzi et al., 2009; Koskinen et al., 2011; Zimmerman et al., 2007)) are valuable, the concept of interventions is less suitable when discussing how artefacts can be designed to contribute to energy conservation in everyday life. A number of disadvantages of taking an interventionist design stance were highlighted in section 2.3.1 and additional disadvantages from a design perspective have been emphasised by the empirical findings presented in this thesis.

Most importantly, an interventionist design stance commonly bases the design on an ambition to change people's doings, from a state that is perceived as problematic to a predefined and preferred target state, but often with little consideration as to what people need in order to pursue their motives or satisfy needs. Thus, in many intervention studies, the overarching goal of design – which Papanek (1985) describes as to design artefacts that help people satisfy everyday needs in a better way – has been overshadowed by the ambition to change behaviour. Such a behaviour change objective often results in design concepts and artefacts that may potentially support people to reduce energy use but risk not being relevant or desirable for people to use in everyday life.

This dilemma is often demonstrated in energy and design literature by design concepts that make everyday activities more cumbersome or require additional actions or activities that not everyone wishes to engage in (see for instance the *Stroppy kettle* designed to reduce overfilling through the use of punishment tasks (Cowan et al., 2013) and the *FlowCook app* that is designed to be used during cooking to prompt and encourage energy reductions (Oliveira et al., 2016)). It has also been demonstrated by the research presented in this thesis, which revealed, for instance, that the participants did not find the ECO kettle valuable or desirable to use in daily life. Even though people may consider these types of artefacts as fun or interesting initially, they risk being rejected after a short use phase if they are not useful in the context of everyday life. If not used at all, the interventions would contribute to a waste of resources rather than contributing to energy conservation.

An interventionist design stance commonly also leads to a primary focus on people's doings and how these can be changed through intervention strategies, rather than on the design of artefacts. This is problematic from a design perspective as traditional approaches, methods and tools used by designers risk being seen as subordinate in favour of new types of approaches adopted from fields such as sociology or psychology. Relying primarily on intervention strategies, and less on structured design thinking, risks reducing the potential for designing useful artefacts that enable desirable and meaningful experiences in everyday life. Discussing interventions from a design perspective also shifts the implicit responsibility for energy conservation from the design profession, the production industries, and society, to the end user who often does not have the preconditions to act differently.

In contrast, by understanding energy conservation from an activity-oriented perspective, which has been highlighted in this thesis, a different stance for addressing energy use through design emerges. By understanding people's use of energy-intensive artefacts as part of everyday activities, it becomes relevant to design artefacts directed at enabling less energy-reliant activities with a focus on designing for people and their needs. Taking an enabling stance may result in artefacts that support energy conservation in everyday life and make it possible for people to substantially reduce their energy use. Enabling energy conservation through design is thus not about designing to change people's behaviour to a predefined and preferred state; it is fundamentally about exploring and facilitating alternative ways of life that are desirable for people but less energy-reliant.

Since people's motives and needs change as society develops, such alternatives cannot be prescribed but must be explored, evaluated and enabled over time in order to turn out desirable for people and contribute to energy conservation in the long term. An enabling stance may not only result in artefacts that make it easier for individuals to use less energy when interacting with particular artefacts, but may also contribute to transforming society by supporting the introduction of new types of artefacts that allow less energy-intensive ways of life to emerge. This requires designers to address particular interaction challenges but also to question and re-imagine everyday life in order to open up the solution space to new possibilities (cf. Strengers, 2014). In doing so, traditional design approaches (e.g. Cross, 2008; Roozenburg & Eekels, 1995) that stress the need for structured exploration of opportunities are crucial as well as people-centred and activity-centred design approaches (e.g. Abras et al., 2004; Flach & Dominguez, 1995; Norman, 2006) for exploring and evaluating opportunities with people. Co-creating and prototyping artefacts and alternative ways of life together with people, which has been highlighted as valuable in POPD literature (Kuijer, 2014; Kuijer & Jong, 2012; Scott et al., 2012), may also prove essential.

Even though an enabling stance does not aim to persuade or convince people to act in particular ways, ethical issues are still important to address. As often highlighted in literature in relation to interventions, it is important to considered if a particular artefact is morally and ethically acceptable (e.g. Lilley et al., 2005; Lilley & Wilson, 2013). Any design has implications for people and the environment and designers therefore need to make conscious and deliberate decisions that take relevant aspects into account. Therefore, it is always relevant to question the underlying design intent (i.e. what to accomplish), the motive (i.e. why this should be accomplished), as well as the implications (i.e. what can be expected from this). As designers can be considered to be agents for change that, whether intentionally or not, design artefacts that contribute to transforming society, they have an implicit responsibility to design with intent so that the potential for trajectories that benefit society increases.

6.5.2 DESIGN OPPORTUNITIES FOR SUPPORTING ENERGY CONSERVATION

The overall stance on how to address energy conservation through design influences the design opportunities that are perceived as relevant and commonly highlighted. Literature taking an interventionist stance primarily discusses design opportunities in the form of design intervention strategies (Lidman et al., 2011; Tang & Bhamra, 2008; Wever et al., 2008) or in relation to dimensions of behaviour change (Daae & Boks, 2014) and product attributes (Sohn & Nam, 2015). The intervention opportunities are often related to aspects influencing behaviour change processes, for instance, some are considered to target people's intentions and habits or limit user control (Tang & Bhamra, 2008). Even though the differentiation of strategies is important for expanding the perceived range of design opportunities, discussing opportunities in terms of specific strategies or a combination of strategies is to drastically simplify what is required from a design perspective in order for people to be able to live their lives in less energy-reliant ways.

In contrast, the set of design principles and design guidelines proposed in this chapter highlight the complexity and multitude of aspects that need to be considered. In order to design artefacts that set preconditions for desirable activities that satisfy people's needs and enable great reductions in energy use, a holistic design approach is needed in which all layers of design are considered from an energy conservation perspective in a way that fits the activity enabled and suits the intended users. These insights highlight both a wider range of design opportunities and more detailed guidelines compared to previous recommendations for how to support energy conservation through design. For instance, White et al. (2013) suggest that artefacts should be designed to encourage low-consumption behaviour and to reduce energy use during use but provide not recommendations for how to apply these strategies. Brezet and Van Hemel (1997) provide more specific rule-of-thumbs for how to address energy use in the utilisations phase, but only highlighted five particular rule-of-thumbs.

Even though this research provides a wider range and more detailed guidelines than previous research, some of the aspects have been highlighted by others emphasising similar design opportunities. Questioning what type of artefact to design has, for instance, been argued by Elias et al. (2009) who suggest that radical new products can be designed to achieve the same end function but in a different way and by Scott et al. (2012) who argue that innovative products should be designed to enable innovative sustainable practices, not simply so that fewer resources are used. Addressing different design-related aspects, such as the efficiency of the technology used and what types of interaction possibilities an artefact provides, has also been argued for (Elias et al., 2008; Oberender et al., 2001; Thornander et al., 2011).

A few others have also stressed the need not only to assess artefacts based on reductions in energy use but also to evaluate artefacts from a holistic life-cycle perspective. Even though an artefact may contribute to energy reductions it may not necessarily contribute to a net reduction in overall environmental impact (Sauer et al., 2003; Telenko & Seepersad, 2010). For instance, after evaluating energy feedback systems from a lifecycle perspective, van Dam et al. (2013) concluded that if a system is used only for a short period and if the achieved savings are small, the benefits do not always outweigh the environmental costs of producing and using the energy feedback system.

In addition to designing and evaluating particular artefacts from a holistic perspective, designers can also approach energy conservation from a system perspective by considering artefact ecologies (i.e. the artefacts that a person own, have access to, and use, as described by Bødker and Klokmose (2011), Bødker and Klokmose (2012), and Jung et al. (2008)). Similar to the insights described in this thesis, Tang and Bhamra (2012) argue that it is important to not consider a specific product in isolation, but instead consider it in relation to other appliances and the physical context that influence its energy use. Addressing energy conservation from a systematic perspective through the design of artefact ecologies, however, present many practical challenges for design and may require many agents to join forces, such as different product manufacturers, interior designers, housing suppliers, construction companies, urban developers, and policy makers. Even though design principles and guidelines for approaching energy conservation from such a systematic perspective are greatly needed, this is outside the scope of this thesis.

6.6 SUMMARY OF KEY INSIGHTS

Insights from the cross-study analysis point to several challenges for addressing energy conservation through design. To successfully contribute to energy conservation, the empirical material suggests that it is crucial not only to address how the design of artefacts mediates everyday activities and energy use, but also to consider what types of appliances are made available to people and which types of activities they enable. By considering energy conservation and the design of artefacts from a holistic perspective in regard to the proposed layers of design, it becomes relevant to address both efficiency and sufficiency aspects. In addition, in order to contribute to energy conservation, designers should strive to design artefacts that create preconditions that enable substantial reductions and that fit the intended activity and the intended users.

In contrast to an interventionist stance that focuses on the use of intervention strategies, an enabling approach has the potential to support the design of artefacts that make energy conservation desirable in everyday life. Moving beyond interventions and designing for everyday life may also increase the potential for artefacts to be adopted and used long term.

CONCLUSIONS & OUTLOOK

07 | CONTRIBUTION AND REFLECTIONS

This chapter provides answers to the research questions, discusses the contribution of the research and expands on the implications of the findings. The conclusions are summarised and relevant directions for future research are briefly highlighted.

7.1 REGARDING THE CONTRIBUTION OF THE WORK

As the specific contributions of each study are discussed in the appended papers, this section discusses the main contribution in relation to the overall aim. The two themes and associated research questions will be addressed first followed by a reflection regarding the contribution that proposed ways of supporting energy conservation through design may present for the research community and for design practice.

7.1.1 CONTRIBUTION RELATED TO THEME 1

To explore the first theme and specifically address the knowledge gaps identified for the theme, the thesis sought to address the overarching research question (*How do people's doings in everyday life influence their domestic energy use?*) by answering the two operationalised sub-questions outlined in the introduction:

RQ1.1: *In what ways do people's everyday prioritisations shape their doings and energy use?*

RQ1.2: *In what ways do energy-reliant artefacts influence people's doings and energy use during everyday life?*

The overall insights gained emphasise that people engage in a web of activities that commonly involve the use of energy-reliant artefacts to satisfy their needs or accomplish everyday goals. Energy use is thus embedded in people's everyday life through various coexisting activities and through the energy-reliant artefacts people use and often depend upon. In regard to RQ1.1, the findings stress that people's doings and energy use are greatly influenced by what they want to achieve and find desirable in particular situations in everyday life. In a certain situation, people often experience conflicts between competing motives and goals that make it difficult and often undesirable to prioritise energy conservation. Such conflicts may influence not only what activities people engage in, but also what artefacts they make use of and how energy-reliant artefacts are used during activities. The types of conflicts that people experience vary between particular situations and contexts and they are also dependent on the individual and the energy-reliant artefacts used. Additionally, in answer to RQ1.2, the insights gained show that the energy-reliant artefacts people use influences their doings and energy use in several ways. The design of a particular artefact influence people's energy use by determining the minimum amount of energy that is required in order for people to be able to achieve a particular purpose; by influencing what activities and actions it is possible to carry out and what actions are considered desirable during particular activities; and by directly mediating people's actions during use. Depending on an artefact's design characteristics, which are determined by its overall design and functions, as well as by the fit between the design of the artefact and the activity it enables, the artefact may either facilitate or impede energy conservation when used in everyday life. If the design of an artefact is not fit for purpose it will give rise to mismatches between the subject, the object of the activity, and the artefact, which may make energy conservation difficult or undesirable during everyday life.

The findings related to the first theme provide valuable insights for the research community that address topics of energy and design as they point to a new perspective for understanding people's energy use. In comparison to energy research that takes behaviour as a unit of analysis with the aim of finding correlations between a specific behaviour and its influencing factors (e.g. Abrahamse et al., 2005; Gatersleben et al., 2002), this research has instead emphasised the importance of studying how different activities and energy use are interdependent in everyday life.

Viewing people's energy use as embedded in the many activities and actions of everyday life is similar to the perspective stressed in many studies exploring energy use from the perspective of practices, which commonly discusses how practices co-exist and co-evolve over time alongside other practices (e.g. Kuijer, 2014; Warde, 2005). However, taking activities as the locus of study, instead of practices or behaviour, has provided additional insight into people's energy use. For instance, the identified influence of competing motives and goals on people's activities and actions increases the understanding of why energy conservation may not be prioritised in everyday life and why people may find actions to reduce energy use undesirable in particular situations and contexts. Even though a few others have argued that people prioritise between different goals during particular doings (e.g. Lindenberg & Steg, 2007) and that different sets of goals are considered for different types of doings (e.g. Richetin et al., 2012), this research has pointed to more specific insights regarding different types of prioritisations in relation to energy use. These insights suggest that people's energy use must be understood in the context of an activity, as people's prioritisations of motives and goals in a particular situation jointly form the overall object of the activity; which in turn determines what the person will strive to attain through the activity, and how the activity will be carried out.

Additionally, the insights point to the importance of acknowledging the meaning that activities and energy use contribute through the fulfilment of needs. The prospect of desirable outcomes that satisfy needs influences people's motives for engaging in particular activities and the extent to which people prioritise energy conservation in particular situations. Taking an activity theoretical perspective to understanding people's energy use thus entails understanding energy use as a means for people to carry out purposeful everyday activities in which they interact with artefacts to achieve specific motives and goals in particular situations and contexts. Only by addressing the activity as a whole, and the needs that form it, can insights be gained into how people's prioritisations and the design of artefacts influence energy use.

While the research presented in this thesis suggests that different types of artefacts bear with them a potential for certain activities in line with discussions founded in a practice-oriented perspective (e.g. Gram-Hanssen, 2008; Kuijer, 2014; Shove et al., 2007; Wilhite, 2008), the findings also emphasise that a particular artefact's design characteristics directly mediate activities, actions and outcomes. In order to better understand people's energy use and explore how energy conservation can be supported, it is thus vital not only to understand what potential transitions artefacts may contribute to, but also what practical preconditions artefacts set for people's activities and energy use. Acquiring these types of insights is important as they may point to new opportunities for design and highlight how the design of artefacts can contribute to the creation of new preconditions that support less energy-reliant activities in the everyday, instead of creating mismatches within activities that lead to increased energy use.

To sum up, the findings related to the first theme contribute insights into how people's activities influence their everyday energy use primarily by highlighting how people prioritise between motives and goals as well as how the design of energy-reliant artefacts may influence energy use by giving rise to different types of mismatches related to the activity it enables.

7.1.2 CONTRIBUTION RELATED TO THEME 2

To explore the second theme and specifically address the knowledge gaps identified, the thesis sought to address the overarching research question (*How do energy-reliant artefacts designed to support energy conservation influence domestic energy use in everyday life?*) by answering the three operationalised sub-questions outlined in the introduction:

RQ2.1: ***In what ways and to what extent do people use artefacts designed to support energy conservation?***

RQ2.2: ***What design-related aspects influence people's use and adoption of artefacts designed to support energy conservation?***

RQ2.3: ***To what extent, and why, do artefacts designed to support energy conservation influence people's energy use?***

Turning first to RQ2.1, the findings show that people's use of energy-reliant artefacts designed to support energy conservation varies greatly. As described in Chapter 5 and in more detail in the appended papers, the participants in studies C and D used the particular artefacts evaluated in different ways and to different extent. For instance, only a few participants used the energy feedback system frequently and regularly to monitor their household's energy use; most of the others used it a few times initially to get an overview of their energy use and/or to assess which appliances were contributing the most to their energy use. Studies C and D suggest that the participants' use of the particular artefacts evaluated in the studies not only differed in terms of frequency but also in regard to the purpose of use, the functions that were utilised, and how the participants interacted with the artefacts and particular functions. The findings show that the way in which the artefacts were designed to support energy conservation and their overall design influenced people's use and adoption of them. More specifically, in answer to RQ2.2, an artefact's design characteristics related to all layers of design influence how people will use the artefact, and the overall design may also give rise to fits and/or mismatches that influence people's use of it. Fits or mismatches between the design of an artefact and a particular activity, either experienced prior to or during the activity, will influence whether people will use the artefact or reject it. Furthermore, in regard to RQ2.3, fits and mismatches are also relevant to consider when discussing whether and why an artefact designed to support energy conservation may influence energy use. While fits may create new preconditions that facilitate energy conservation, mismatches may lead to increased energy use. Moreover, the findings suggest that aspects related to all layers of design influence the extent to which an artefact designed to support energy conservation may influence energy use. For instance, an artefact type such as an energy feedback system designed to increase awareness and knowledge, has the potential to spark new conservation activities but is limited in the extent to which it may influence energy use as it does not directly change people's preconditions for reducing their energy use. In contrast, appliances designed to mediate less energy-intensive use have the potential to facilitate frugal activities by reducing mismatches and conflicts between competing goals. However, the extent to which such artefacts can influence people's energy use beyond the energy use resulting from the use of the particular artefact is limited.

The findings related to the second theme not only provide examples that clearly demonstrate that the design of artefacts influences people's energy use but also present valuable insights for the research community into the ways in which artefacts designed to support energy conservation may influence energy use and what is required of an artefact to successfully support energy conservation. The findings highlight a variety of design-related aspects influencing energy use and emphasise that the artefacts' functions and design characteristics, as well as their interrelatedness, must be considered in order to understand how and why particular artefacts may support energy conservation (or not) in particular activities. Furthermore, it is essential to consider the design of the artefact in the context of everyday activity, as its functions and design characteristics must fit the activity as a whole (cf. Karlsson, 1999). From a design perspective this may not be a novel observation, but this is however seldom discussed in DfSB and POPD literature. For instance, DfSB researchers commonly discuss the influence of other aspects, such as attitudes, habits and norms, on energy use and how these aspects can be influenced through design (e.g. Hanratty, 2015; Wilson, 2013) but place little focus on how different design-related aspects, their interrelatedness, as well as their fit with the activity influence energy use. Similarly, within POPD literature the role of artefacts in contributing to change is discussed in relation to the elements and links that shape practices (e.g. Kuijer, 2014; Scott et al., 2012) but less attention is paid to the properties and characteristics of the material elements. The findings of this research thus point to the importance of considering the design of artefacts in more detail and in relation to the activity enabled.

The findings also shed light on a number of issues that can be considered problematic with an interventionist design stance. First, as illustrated in studies C and D, artefacts aimed at encouraging or facilitating energy conservation based on behaviours identified as wasteful may have the opposite effect when utilised in other situations or for purposes other than those intended. The findings thus support previous claims by Kuijer and Bakker (2015) that highlight the risk of optimising an artefact for specific use scenarios which may result in unintended use when utilised in other situations, which in turn may reduce the potential for decreased energy use or lead to increased use.

Second, the findings demonstrate that encouraging energy conservation without also enabling it (as is commonly done in design intervention studies, see for instance Cowan et al. (2013) and Oliveira et al. (2016), and especially in studies on energy feedback, see for instance Broms et al. (2010) and Foster et al. (2010)) will not support energy conservation for everyone since not all are interested in reducing energy use or have the ability or preconditions to do so. Focusing only on designing for "resource man" (i.e. a person that ideally wants to be in charge of their energy use and responds rationally to energy related information (Strengers, 2014)) to reduce energy use may thus risk drawing the focus away from other design opportunities that can make it possible for the everyman to carry out everyday activities in less energy-reliant ways.

Third, the findings reveal the drawbacks of design interventions utilising design strategies for sub-optimising energy use. The studies show that add-on functions related to the hierarchically lower layers of design aimed at motivating or guiding people to reduce their energy use can support energy conservation in some cases, but not if other functions or design characteristics make less energy-intensive use challenging or undesirable. The idea that design intervention strategies should be used for designing particular functions for influencing use (as commonly discussed in DfSB literature, see for instance Cor et al. (2014), Hanratty (2015), Tang (2010), Wilson et al. (2013), and Withanage et al. (2014)) is thus problematic as it overshadows the importance of considering how the interrelatedness of functions and design characteristics influence energy use.

The findings for the second theme provide additional insight into whether artefacts can be designed to support energy conservation and highlight aspects that influence whether or not artefacts may successfully enable and mediate less energy-reliant activities. In addition, the insights gained stress the need for future design approaches to focus less on creating interventions and more on creating preconditions for less energy-reliant activities.

7.1.3 CONTRIBUTION RELATED TO IMPLICATIONS FOR DESIGN PRACTICE

To not only provide new insight to the research community but also insight valuable for design practitioners, the overall aim of the thesis involved proposing ways of supporting energy conservation through design. Through analysis of the empirical material, a number of challenges and design opportunities were identified. A tentative framework – *Layers of Design* – was synthesised to provide an overview of different artefact-related aspects and highlight how design characteristics and design decisions on different layers influence people's preconditions for energy conservation. Based on the design opportunities identified, five main design principles as well as key design guidelines related to each layer of design were formulated to aid design practice.

In contrast to an interventionist design stance, the insights presented in this thesis emphasise the need to move beyond interventions and instead focus on how to design useful artefacts that can help people to go about their everyday activities in less energy-reliant ways. Instead of discussing how to design for behaviour change, this research stresses the value of discussing how to design artefacts that not only provide preconditions for energy conservation but are also desirable to use and lead to meaningful and pleasurable experiences in everyday life.

This view of what role design can play in contributing to energy conservation puts the focus primarily on the design of the artefact, and its purpose, rather than on intervention strategies and theories for understanding people's doings. This stance may be valuable for future research as well as for design practice. A focus on the artefact in combination with the proposed design principles and guidelines highlights a variety of practically applicable design opportunities for supporting energy conservation at all layers of design, from the overarching considerations down to the smallest details. Such a focus may be valuable for industry, which today tends to address energy conservation primarily on one layer at a time (Ramirez, 2016).This perspective is in line with product design theory (e.g. Cross, 2008; Jones, 1992) that often argues the need to question the nature of the artefact and its essential functions if one aims to create a radically new artefact that contributes to new use patterns.

Additionally, highlighting a variety of design opportunities may be helpful for design practice in overcoming barriers in addressing issues related to sustainable interaction. For instance, industry's lack of awareness of interaction-related impacts, which is one of the main barriers identified by Boks et al. (2015), would play a less significant role if energy conservation were systematically considered in relation to all layers of design instead of merely in regard to technical principles and main functions, which might often be the most obvious issues to address.

However, depending on the scope and aim of the project it might not always be possible to address all layers during a particular product development project. In order for designers to be able to address energy conservation holistically, companies must be willing to question how they contribute to society's energy use and take responsibility for the design of the artefacts they offer (cf. Lilley, 2009). Additionally, Pettersen (2013) identifies designers' limited strategic influence during front end explorations and the pre-specification stage as an obstacle to the development of innovative artefacts with potential for contributing to change. In order to identify new opportunities early in the design process, designers must thus also be in a position to take fundamental strategic decisions or be able to collaborate closely with others that have strategic influence, such as business strategists.

The proposed framework, principles and guidelines should be considered tentative, as they have not yet been applied in any concrete design projects. Their potential for aiding the design of artefacts that can support energy conservation and limit the risk of rebound effects must be assessed before they can be validated. This however requires additional studies, which are outside the scope of this thesis. Nevertheless, the proposed framework, principles and guidelines already have the potential to support design work in their current form.

To sum up, the proposed design opportunities not only contribute new knowledge for the research community, but also present insights relevant and valuable for design practitioners. Hopefully, these insights will help to pave the way for new types of artefacts that enable people to live their lives in less energy-reliant ways.

7.2 CONCLUDING REMARKS

By exploring people's energy use in relation to everyday activities and people's use of artefacts, the research presented in this thesis provides new insight into how the design of energy-reliant artefacts shapes people's energy use and priorities in everyday life. The findings highlight energy use as embedded in everyday activities and suggest that the design of energy-reliant artefacts mediates the actions and outcomes of those activities, including the resulting energy use. Depending on an artefact's functions and design characteristics as well as the artefact's fit (or mismatch) with the activity in which it is used, the artefact may either facilitate or impede energy conservation. The findings show that even though an artefact is designed with specific functions to support energy conservation, it may nonetheless be used in an energy-intensive way or risk being rejected if it is not easily understandable and easy to use, and if it does not provide suitable functions that enable people to use it for a particular purpose in a certain situation. Design interventions with one or more functions aimed at motivating or guiding people to reduce their energy use, as commonly discussed in DfSB literature, thus risk impeding energy conservation if the combination of design characteristics makes less energy-intensive use challenging or undesirable. In addition, if less energy-intensive use is only encouraged, but not enabled, it will be difficult for people that do not have the preconditions to use less energy to actually reduce their energy use.

To increase the potential for supporting energy conservation through design, it is crucial to move beyond interventions and instead design suitable and relevant artefacts that enable less energy-reliant everyday activities and that make it possible and desirable for people to attain their goals in less energy-reliant ways. To do so, it is important to gain a rich understanding of the intended activity and users, and to address the design of artefacts holistically by considering what preconditions and design characteristics functions on all layers of design may give rise to. Such an approach can reduce potential mismatches between the design and the activity, which in turn may increase the potential for less energy-reliant artefacts to be used in less energy-intensive ways and be accepted and adopted long term.

In conclusion, the research presented in this thesis presents valuable insights into how people's activities and the artefacts used during those activities influence people's energy use. The findings thus contribute a new piece of the puzzle, which increases the overall understanding of the variety of aspects influencing energy use. Additionally, the insights gained highlight opportunities for design practitioners to create enabling preconditions for less energy-reliant activities in the everyday.

7.3 DIRECTIONS FOR FUTURE WORK

Even though the research presented in this thesis provides new insight into people's everyday energy use and ways for design to contribute to energy conservation, much remains to be done. The findings point to many possibilities for future work – both for research and for design practice.

Research will need to continue to bring together, contrast, and further explore different perspectives for understanding energy use, so that a more in-depth overall understanding can be gained. The activity-oriented perspective for understanding energy use, which has influenced the interpretation of the findings in this thesis, seems like a fruitful perspective that should be further explored in additional studies. To increase the understanding of people's energy use and the potential for design to contribute to energy conservation, it would be advantageous if future research continued to explore how people's preconditions, as well as their motives and goals, influence daily prioritisations, activities, and energy use in everyday life. Such studies should address a wider range of activities and people from different contexts and demographic backgrounds than has been possible during the four empirical studies included in this thesis.

Additional studies that measure energy reductions should also be conducted so that the degree to which different artefacts may influence energy use, and thus the potential for design to contribute to substantial reductions, can be assessed. The research agenda should also include studies that to a greater extent address and compare the influence of different types of artefacts and artefact ecologies in order to explore how design decisions related to the hierarchically higher layers of design influence energy use.

To validate the proposed framework, design principles and design guidelines, research is needed that applies an enabling stance and explores how artefacts designed based on the recommendations influence people's preconditions for energy conservation and whether or not they may contribute to reductions. Such a research venture requires new artefacts to be designed and thus necessitate the involvement of design practitioners and product manufacturers. It is essential that the artefacts are iteratively evaluated in situ and over a sufficiently long timescale so that people's use and adoption of them in everyday life can be studied and the artefacts' influence on energy use during everyday activities can be assessed.

The applicability of the proposed framework, design principles and design guidelines in a business context also needs to be explored. By engaging design practitioners to address energy conservation based on the recommendations, the potential value for design practice can be explored. Such endeavours can also provide insights into the applicability of the recommendations and indicate whether they make sense from a design practitioner's perspective in their current form.

Another primary task for future research is to identify additional design opportunities. Evaluative studies addressing the design of particular artefacts can be carried out to identify additional design recommendations that can be added to the list of proposed guidelines. Last but not least, exploratory studies must be conducted to gain insight into new windows of opportunity for designing artefacts that can contribute to cultivating less energy-reliant activities and ways of life.

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