THESIS FOR THE DEGREE OF LICENTIATE OF ENGINEERING

# UNDERSTANDING ENERGY BEHAVIOUR

## A NECESSITY FOR SUPPORTING DOMESTIC ENERGY CONSERVATION THROUGH DESIGN

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Gothenburg, Sweden 2014

Understanding Energy Behaviour
A Necessity for Supporting Domestic Energy Conservation through Design
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Report no 86
ISSN 1652-9243

Published and distributed by
Department of Product and Production Development
Division Design & Human Factors
Chalmers University of Technology
SE-412 96, Gothenburg, Sweden
Telephone +46(0)31-772 1000

All photographs and illustrations by Anneli Selvefors.
Cover: The illustration represents the multitude of factors influencing domestic energy behaviour.

Printed by Chalmers Reproservice
Gothenburg, Sweden 2014

# ABSTRACT

**Understanding Energy Behaviour - A Necessity for Supporting Domestic Energy Conservation through Design**

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Domestic energy consumption is continuing to increase and the need to decrease consumption is growing more evident. In this research, two studies were conducted to further the understanding of domestic energy behaviour and increase the knowledge of how energy conservation can be supported. The first study was carried out as an interview study to explore both factors that influence people's energy behaviour and strategies people currently have adopted for reducing consumption. The second study was a field trial that assessed the extent to which an energy feedback system could support households in reducing their consumption.

The findings show that many different factors, i.e., factors related to the person, the activity, and the society, influence people's domestic energy behaviour as well as their engagement in reducing their energy consumption. As these factors collectively set the preconditions for people's energy behaviour, it is vital to take into account the interconnection of the different factors when aiming to support energy conservation. For systems and products to be successful in supporting energy conservation, they need to match the preconditions in a way that enables people to reduce consumption while still satisfying their everyday needs and goals. As this research have indicated, energy feedback systems can support motivated people who have the ability and possibility to reduce consumption, but will be a less successful support system for people whose consumption is governed by preconditions that they cannot, or will not, change. A holistic understanding of people's preconditions and their energy related activities is thus required in order to develop successful products, services, and systems that enable, facilitate, or encourage more people to reduce their domestic energy consumption.

**Keywords**
Energy conservation, domestic energy consumption, energy behaviour, energy feedback, design for sustainable behaviour

# ACKNOWLEDGEMENTS

There are a number of people that have contributed to and inspired this research. First, I would like to thank my main supervisor Ulrike Rahe for always believing in me and for letting me decide which paths to follow. I would also like to thank my co-supervisor MariAnne Karlsson for her support and valuable input throughout this research.

My warmest appreciation goes to my wonderful colleagues at the division Design & Human Factors for their encouragement, enthusiastic discussions, and for making my days at work more fun. I would also like to extend my thanks to the group of people in the Design for Sustainable Behaviour research community for many inspiring talks and interesting reads.

Additionally, I have been fortunate to meet and collaborate with many people throughout the studies presented in this thesis. I would like to express my gratitude to the people at Exibea for their engagement in this research and I am looking forward to future collaborations. Many thanks also go to the team at BOID for their contribution and our fun discussions. I would also like to thank all the participants in the studies for their time, effort and valuable input.

Finally, I would like to thank my family and friends for their support and love. I hope that this thesis will give you a glimpse of the world that has had me engulfed for the last couple of years.

# APPENDED PUBLICATIONS

PAPER A

Selvefors, A., Karlsson, I.C. M. & Rahe, U., (2014, Submitted). The Relevance of Goals – People's Perceptions of Competing Goals and their Effect on Domestic Energy Behaviour.

Selvefors planned the study, carried out the interviews, analysed the data, and wrote most of the paper with support from Karlsson

PAPER B

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. *Proceedings of the ERSCP-EMSU 2013 conference, 16th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP) & 7th Conference of the Environmental Management for Sustainable Universities (EMSU)*, Istanbul, Turkey.

Selvefors planned the study, collected the data, analysed the data, and wrote most of the paper with support from Karlsson and Rahe

PAPER C

Selvefors, A., Karlsson, I.C. M. & Rahe, U., 2013. Use and Adoption of Interactive Energy Feedback Systems. *Proceedings of the IASDR Conference 2013, Consilience and Innovation in Design, pp. 1771-1782*, Tokyo, Japan.

Selvefors planned the study, collected the data, analysed the data, and wrote most of the paper with support from Karlsson and Rahe

# ADDITIONAL PUBLICATIONS

Renström, S., Strömberg, H., Selvefors, A., 2013. Pathways of Sustainable Behaviours, *Proceedings of the ERSCP-EMSU 2013 conference, 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, *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. *Proceedings of Sustainable Innovation 2012, Towards Sustainable Product Design: 17th International Conference, pp. 242-249*, Bonn, Germany.

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

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# 1. INTRODUCTION

## 1.1 FRAMING THE RESEARCH

One of the main challenges stated when the Brundtland Commission (WCED, 1987) formulated the global agenda for change, with the aim to protect our common future, is to reduce society's consumption of resources. Even though sustainable consumption has been discussed for over 20 years (Jackson and Michaelis, 2003), the need to decrease our resource use is growing more evident (EU, 2006). Already in 1987, the Brundtland Commission identified energy consumption as one important area to target (WCED, 1987). However, domestic energy use is persistently increasing in the EU today (Bertoldi et al., 2012) and the global energy demand is predicted to continue increasing with world population growth and increased well-being globally. Increased energy consumption will intensify the strain on both the environment and available resources, and make the need to find new ways of reducing domestic energy consumption even more urgent.

Domestic energy consumption cannot be explained solely by the energy performance of a particular dwelling or artefact, instead research suggest that other aspects related to peoples' behaviour influence consumption (see e.g. Vassileva et al., 2012, Van Raaij and Verhallen, 1983b, Oliveira et al., 2012, Jensen, 2008). Elias et al. (2009) describe energy consumption inflicted by a user through the use of an artefact as a combination of three parts; the minimum theoretical amount of energy needed to perform the artefact's function, the intrinsic losses adherent to the technology and materials used, and the user-related losses that are influenced by how the artefact is used. To reduce energy consumption towards the theoretical minimum, both the intrinsic losses and the user-related losses must be addressed. From an engineering perspective, new efficient technologies that reduce the intrinsic losses of artefacts are often highlighted as the way forward and many innovative energy-efficient solutions have been introduced on the market to lower domestic energy consumption (Vergragt, 2006). However, energy efficient technologies may give rise to rebound effects and behavioural spill over effects that in some cases increase energy consumption, such as attainment of more electrical appliances (Hertwich, 2005), which makes it important to also address user-related losses. Moreover, Elias et al. (2009) argues that increasing the efficiency of technology will make user-related losses, as a percentage of the total losses, rise in proportion and importance. An understanding of both the technology dependent intrinsic losses and the behaviour dependent user-related losses are thus crucial in order to develop solutions that support people in reducing energy consumption during the use of particular artefacts. In recent years, many researchers have therefore highlighted the need to study the users' role in energy conservation and the extent to which people's everyday activities and interactions with artefacts influence energy consumption (see e.g. Gardner

and Stern, 2002, Rodriguez and Boks, 2005, Abrahamse et al., 2005, Carlsson-Kanyama and Lindén, 2002, Midden et al., 2007). Many products and services such as energy feedback systems and measuring devices have also been developed with the aim of supporting and encouraging people to reduce their domestic energy consumption. However, the use and actual effectiveness of these solutions are often uncertain and sometimes questionable. In order to develop effective and accepted solutions that can easily be adopted and that support people in reducing energy consumption, a deep understanding of how people use domestic energy is needed. It is of particular importance to understand what difficulties people face when trying to reduce energy consumption in everyday situations. Additional research is needed to assess the potential new solutions may have in reducing consumption, and to explore if these solutions can be adopted in society and contribute to energy conservation in the long run.

## 1.2 AIM AND RESEARCH QUESTIONS

The overall purpose of the research presented in this thesis is to contribute to the understanding of domestic energy behaviour in order to increase the knowledge on how energy conservation can be supported through the design of artefacts. The thesis aims firstly to shed light on different factors that people perceive to influence their energy behaviour and consequently their domestic energy consumption. Furthermore, current strategies used by people to reduce consumption are described and different ways of supporting them to behave energy efficiently are discussed. Finally, the thesis aims to describe to what extent a specific solution, i.e. an energy feedback system, can aid people in reducing energy consumption and discuss what potential feedback systems have for supporting energy conservation in the future. The research presented in this thesis focused on domestic energy behaviours and energy consumption in Swedish households. Two main research questions were posed and two sub-questions each were formulated to guide the research studies:

In what way do peoples' preconditions influence their approach towards energy conservation? (RQ1)

- What factors influence people's domestic energy behaviour?
- Do people have strategies for reducing their domestic energy consumption, if so, what strategies do people engage in and why?

Can the use of an energy feedback system influence people's domestic energy consumption, if so, to what extent and how? (RQ2)

- What effects can people's use of an energy feedback system have on their domestic energy behaviour and energy consumption?
- To what extent do people use and adopt energy feedback systems in everyday life?

## 1.3 TERMINOLOGY

It is necessary to clarify the terminology used in this thesis as the vocabulary often differs between the multiple disciplines working within the domains of behaviour change and energy conservation research. Table 1 provides an overview of some of the terms used.

| | |
|---|---|
| ATTITUDE | An expression of favour or disfavour towards an attitude object, e.g. towards a behaviour, event, person, or artefact |
| ENERGY BEHAVIOUR | Behaviours that result in energy consumption due to the use of artefacts that requires energy to function |
| ENERGY CONSERVATION | An umbrella term for different approaches aimed at reducing the amount of energy that is used for different purposes |
| ENERGY CONSUMPTION | Energy consumption does not refer to consumption de facto but to the use of energy for a particular purpose during which energy is transformed from one form to another |
| NORMS | Norms are formed through values and beliefs and give direction on how to behave. Norms are socially constructed and consist of descriptive (perceptions of which behaviours are commonly performed) and injunctive (perceptions of behaviours that are commonly approved or disapproved of in a culture) norms. Injunctive norms can be internalized as personal norms. |
| PERCEIVED BEHAVIOURAL CONTROL | An individual's perception of the perceived ease with which a particular behaviour is conducted |
| PERCEIVED SELF-EFFICACY | An individual's perception of their ability to accomplish a certain level of performance or a particular behaviour |
| PRO-ENVIRONMENTAL BEHAVIOUR | Environmentally attuned behaviours that are conducted in such a way that avoidable resource consumption is evaded |

Table 1. Terminology

# 2. FRAME OF REFERENCE

This chapter provides an overview of the theoretical frameworks and previous studies on energy conservation that formed the basis for the research described in this thesis. The theoretical context will be further explored in relation to the results and other related literature in Chapter 6 Discussion & Implications.

The first section of this chapter addresses theoretical approaches to pro-environmental behaviour and influencing factors proposed to explain behaviour. The second section reviews research on pro-environmental behaviour and research on energy conservation including underlying factors that have been suggested to mediate energy behaviour, as well as different ways of supporting domestic energy conservation.

## 2.1 APPROACHES TO PRO-ENVIRONMENTAL BEHAVIOUR

Many different disciplines such as environmental psychology, consumer research, and design have over the years contributed to an increasing understanding of behaviour in general and pro-environmental behaviour in particular. Several different types of pro-environmental behaviour have been distinguished (see e.g. Gardner and Stern, 2002, Ölander and Thøgersen, 1995, Van Raaij and Verhallen, 1983a) and summarised from a design perspective in five main behaviour categories by Renström et al. (2013): changing use of an artefact to reduce consumption, using a secondary artefact to facilitate reduced consumption, modifying or regulating an artefact through the use of a secondary artefact to reduce consumption, maintaining an artefact in good condition to reduce consumption, and choosing an artefact that requires less resources or less harmful resources. Distinguishing between different types of pro-environmental behaviour is important for three reasons. First, different types of behaviour vary in terms of environmental impact and environmentally significant behaviours are more important to address than others (Gifford et al., 2011, Stern, 2000). Second, different underlying factors may influence different types of behaviour (Gifford et al., 2011, Abrahamse and Steg, 2009). Third, strategies for supporting conservation may vary in effectiveness depending on the type of behaviour addressed (Ölander and Thøgersen, 1995). It is thus vital to understand the underlying factors that influence or determine different kinds of behaviour in order to explore ways of supporting conservation (Steg and Vlek, 2009).

Researchers have suggested different approaches and models to explain how various factors influence peoples' behaviour. The suggested approaches are characterised by the different disciplines they originate from and the various models have, despite their differences, been proven successful in explaining pro-environmental behaviour in some contexts. Three main lines of research have been explored from a behavioural perspective: motivational aspects, habitual behaviour, and contextual

aspects (Steg and Vlek, 2009). The remainder of this section will provide a brief overview of the main theories and conclusions from these research areas. For a more comprehensive overview of theoretical approaches to pro-environmental behaviour see e.g. Steg and Vlek (2009), Jackson (2005) or Vining and Ebreo (2002).

A number of perspectives on motivation have been brought forward by different disciplines. One perspective assumes that people make choices by weighing the costs and benefits of different alternatives. One example of such a rational choice model is the Theory of Planned Behaviour (TPB) based on (Ajzen, 1991), which has been proven successful in explaining some behaviours by studying attitudes towards the behaviour, subjective norms, and perceived behavioural control. Another perspective focuses on the motivational role of peoples' values and environmental beliefs, environmental concern, moral obligations, and the influence of social norms. Two of the important frameworks here are Schwartz's norm-activation model (NAM) (see e.g. Jackson, 2005) and the value-belief-norm theory of environmentalism (VBN) (Stern et al., 1999). While the NAM and VBN theories appear more successful in explaining low-cost pro-environmental behaviours, the TPB seems more fruitful in explaining behaviour that are characterised by high costs or strong constraints since it includes a wider range of factors (Steg and Vlek, 2009). Yet another perspective highlights the role symbolic, emotional and affective motives play in influencing motivation. Even though this perspective is less explored; many studies suggest that affect and emotion can be strong predictors of behaviour, especially when attitudes are weak or when constraints are present (Vining and Ebreo, 2002, Steg and Vlek, 2009). In an attempt to better explain people's motivation for engaging in pro-environmental behaviour, Lindenberg and Steg (2007) suggested an integrative framework: the goal-framing theory. According to the theory, three high-order goals steer the accessibility of attitudes and influence peoples' evaluation of their behavioural alternatives. Peoples' motivation thus varies depending on what they prefer in different situations. They may prioritise a gain goal, i.e. to improve one's resources, a normative goal, i.e. to act appropriately, or a hedonic goal, i.e. to attain immediate satisfaction (Lindenberg and Steg, 2007). When active, the normative goal often encourages pro-environmental behaviour while the gain and hedonic goal-frames often result in less pro-environmental behaviour.

Research on motivational aspects most often assume that behaviour is influenced by casual factors and is a result of deliberate cognitive processes. However, many everyday behaviours are not deliberate but rather unconscious behaviours carried out habitually without reflection (Jackson, 2005, Verplanken, 2006, Steg and Vlek, 2009, Maréchal, 2010). Everyday behaviours which, over time, have transformed into habits and routines may be difficult to overcome as they are less likely to undergo deliberate evaluation compared to occasional behaviours carried out a few times. Habitual behaviour has been highlighted in literature

on pro-environmental behaviour as many everyday habits are environmentally significant behaviour which make habits important to address when aiming to reduce the environmental impact of everyday behaviours.

In addition to individual motivation and habitual behaviour, pro-environmental behaviour is also influenced by contextual aspects (Ölander and Thøgersen, 1995, Steg and Vlek, 2009, Stern, 2000). As Manning (2009) points out: all behaviour is situational. Even though people might be motivated to behave in a particular way, they are influenced by different contextual aspects and are often locked in unsustainable behaviours (Steg and Vlek, 2009, Jackson and Michaelis, 2003). Contextual aspects commonly refer to all external factors or circumstances that influence behaviour such as situational factors, products and services, and infrastructure (see e.g. Stern, 2000). Although contextual aspects often may hinder pro-environmental behaviours, they could be designed to enable and facilitate pro-environmental behaviours that may also make people more positive towards particular behaviours (Steg and Vlek, 2009, Lockton et al., 2008, Bhamra et al., 2008, Wever et al., 2008). Unfortunately, contextual aspects have not been studied in the same extent as both motivational aspects and habitual behaviour, and are therefore often missing in the theoretical models of human behaviour.

A few integrative models of human behaviour have been proposed to bring together more aspects of relevance for pro-environmental behaviours, e.g. the motivation-ability-opportunity model (Ölander and Thøgersen, 1995) that include e.g. motivational aspects, personal ability, habits, and situational conditions. The research domain has however not yet reached consensus on a comprehensive model for understanding pro-environmental behaviours that have the potential to account for all relevant aspects (Jackson, 2005, Stern, 2000). Furthermore, the models and frameworks with a strong behavioural orientation do not generally take into consideration the dynamic character of behaviour or the cultural environment in which behaviours evolve. Jackson (2005) describes peoples' behaviour not as static but as dynamically changing over time with social trends. Peoples' behaviours do not only change incrementally over time but may sometimes also change radically due to the uptake of new technologies (Rogers, 1995) or societal changes, for instance. A transition in perspectives, from casual factors towards more comprehensive frameworks that take the dynamic and interconnected nature of human behaviour into consideration may thus be needed to further the understanding of pro-environmental behaviour and to explore ways of supporting conservation.

## 2.2 ENERGY CONSERVATION

Studies on energy conservation have been particular plentiful within the research domain of pro-environmental behaviour. The majority of studies have either sought to assess to what extent different factors influence domestic energy consumption or explored ways of supporting householders in reducing their consumption. This

section provides a brief summary of the two lines of research.

### 2.2.1 FACTORS INFLUENCING DOMESTIC ENERGY BEHAVIOUR

Research during the last few decades has explored many of the underlying factors described in section 2.1 in the context of domestic energy consumption. The majority of studies have aimed to assess to what degree these factors influence certain energy behaviours and to validate the relationship between different factors. Other studies have adopted a more qualitative approach to gain deeper insight into additional factors that may explain particular energy behaviours or the lack of energy conservation behaviours.

Research by Gatersleben et al. (2002) suggest that while pro-environmental behaviour is strongly related to attitudinal variables, domestic energy consumption is not. Instead, Gatersleben et al. found domestic energy consumption to be primarily related to income and household size. Similarly, Poortinga et al. (2004) concluded that domestic energy consumption could to a higher degree be explained by considering socio-demographic factors, i.e. income, household size, level of education, and a family, health and safety dimension, in addition to values, environmental concern, and specific environmental beliefs. Abrahamse and Steg (2009) lend additional support to these findings after concluding that energy consumption is mainly determined by socio-demographic variables. However, Abrahamse and Steg suggest that energy consumption and energy behaviour aimed at reducing consumption are influenced by different factors. In contrast to energy consumption, they found energy savings to be mostly associated to psychological factors, i.e. attitude, perceived behavioural control, personal norms, awareness of consequences, and ascription of responsibility (ibid.). They however indicate that there may be other influential factors and suggest that a wider range of factors should be considered to better understand and explain domestic energy consumption and conservation. Many additional factors have also been identified and discussed in other studies on energy conservation, e.g. knowledge level (Niemeyer, 2010, Throne-Holst et al., 2008, Steg, 2008), cognitive mechanisms (Corradi et al., 2013), economic factors (Niemeyer, 2010, Throne-Holst et al., 2008, Steg, 2008), lifestyle factors (Steg, 2008), habits (Maréchal, 2010), social norms (Schultz et al., 2007), availability of artefacts (Steg, 2008), physical and structural environment (Throne-Holst et al., 2008, Maréchal, 2010, Steg, 2008, Niemeyer, 2010), cultural factors (Throne-Holst et al., 2008, Steg, 2008), and legislations and regulations (Throne-Holst et al., 2008). The mentioned factors can influence peoples' will and/or possibility to reduce their energy consumption. They can also function as either drivers or barriers that mediate the outcome of people's energy behaviours. Knowledge can for example empower people to reduce consumption while lack of knowledge may impede action.

### 2.2.2 WAYS OF SUPPORTING DOMESTIC ENERGY CONSERVATION

As described in 2.2.1, peoples' behaviour is influenced by many different factors

which makes influencing behaviour a complex matter (Jackson, 2005). To change behaviour, Abrahamse et al. (2005) suggest that strategies should be directed towards influencing both the particular behaviour and the influencing preconditions. Several strategies to encourage more environmentally attuned behaviours have been proposed in the past along with categorisations of how different types of strategies can influence both behaviours and preconditions. Dwyer et al. (1993) proposed one categorisation of intervention strategies for encouraging environmental-preservation behaviour based on a taxonomy made by Geller et al. (1990) concerning change techniques for traffic safety behaviour. The modified taxonomy made by Dwyer et al. (1993) divides strategies into either antecedent strategies or consequence strategies. Antecedents include strategies that are applied prior to a certain behaviour being carried out and that in different ways activates or enable a more environmentally attuned behaviour, e.g. information, goal-setting, competition, and environmental alteration. In contrast, consequence strategies are applied after a particular behaviour has been carried out to encourage more environmentally attuned behaviours in the future, e.g. feedback, rewards, and penalties.

Many studies during the few last decades have assessed the strategies' potential of influencing householders' energy behaviour and reducing energy consumption. Abrahamse et al. (2005) conclude in a review of intervention studies aimed at household energy conservation that the strategies vary in effectiveness and that the generated outcomes differ. While information and learning as a strategy for change is generally considered to increase people's knowledge, it seems less successful in influencing energy behaviour and habits (Abrahamse et al., 2005, Verplanken, 2006). Commitment and goal-setting have been identified to be potentially successful strategies, and public commitments and sufficiently difficult goals were found to be especially effective (Abrahamse et al., 2005). Incentives and disincentives that manifest in rewards and penalties are other promising strategies but their effectiveness and outcome are highly dependent on the size of the incentive and the specific circumstances in which the incentive comes into play (Gardner and Stern, 2002). Incentives with positive effects that will be realised sooner, rather than later, seem to be preferable over disincentives (Geller, 2002). Past studies also suggest that rewards and penalties only are effective on a short-term basis and that the effects most often cease once the incentive is gone (Dwyer et al., 1993, Abrahamse et al., 2005).

Feedback, i.e. detailed information provided to people about their current behaviour and the consequences of their behaviour (Gardner and Stern, 2002), appears to be an effective strategy to reduce household energy consumption (Abrahamse et al., 2005, Darby, 2006). Darby (2001) provides a typology of different forms of feedback and distinguishes between direct feedback, indirect feedback, inadvertent feedback, utility-controlled feedback, and energy audits. Direct, indirect and inadvertent feedback is identified as most promising for raising awareness and bringing about

reduced consumption (ibid). Besides providing input on the energy consumption of a single household, the consumption can also be related to the consumption of other households. Comparisons may activate a feeling of competition, social comparison, or social pressure that may be especially effective when relevant others are used as a reference (Abrahamse et al., 2005). Thøgersen (2006) also points out that evoking social norms can lead to an internalisation of norms and the development of personal integrated norms that may have a more long term effect on behaviour compared to social norms. However, normative messages only seem to be successful for people that have a high level of consumption and tend to engage in destructive behaviours. Normative messages may have the opposite effect for consumers already engaged in constructive behaviours (Abrahamse et al., 2005, Schultz et al., 2007).

Steg (2008) argues that informational strategies are effective when the behaviour is relatively convenient and not very costly in terms of money, time, effort or social disapproval, and when individuals do not face severe constraints. If people are constrained to certain behaviours, contextual changes may be necessary instead of, or in addition to informational strategies. Contextual changes may even give rise to a reconsideration of people's habits (Steg and Vlek, 2009). Recent research within the design domain discusses several ways of encouraging resource consumption though deliberate re-design of artefacts and contextual preconditions (see e.g. Lilley, 2009, Wever et al., 2008, Lockton et al., 2008). Lidman and Renström (2011), among others, have suggested a categorisation of design strategies for influencing behaviour. The suggested categories comprise strategies to enlighten, spur, steer, force, or match people's behaviour to reduce consumption.

Which strategy that is most effective in a certain situation varies depending on the preconditions and the current barriers that hinder individuals from behaving in an environmentally sound way (Steg and Vlek, 2009). Since one particular situation can involve individuals with different types of barriers and needs, a combination of strategies could be used to increase the potential for changing behaviour and for supporting long term effects (Gardner and Stern, 2002, He and Greenberg, 2009, Steg and Vlek, 2009, Abrahamse et al., 2007). Individual commitment to behave appropriately can for example increase the effect that information or feedback would have resulted in alone (Abrahamse et al., 2005, Dwyer et al., 1993, McCalley and Midden, 2002).

### 2.2.3 DIRECT ENERGY FEEDBACK

Direct feedback as a way of supporting energy conservation has been explored in many contexts and in many different forms. Research suggest that direct feedback have the ability to make consumption more visible, to encourage reflection, to increase peoples' understanding of energy, and subsequently encourage behaviour that reduce consumption (Gardner and Stern, 2002, Grønhøj and Thøgersen, 2011, Hargreaves et al., 2010). Froehlich (2009) identified ten design dimensions

that varies between different feedback systems: frequency, unit, data granularity, availability, presentation medium, location, visual design, recommendations, comparisons, social sharing. Energy feedback can thus, for instance, be provided immediately through real-time data or accumulated over a certain time period, be customised or ambient, be personal or comparative, be provided on a detailed level or as aggregated data, and be passive or interactive.

Literature suggests that the effectiveness of direct feedback varies between different forms of feedback and feedback mediums. After reviewing studies on feedback, Dwyer et al. (1993) concluded that continuous feedback on consumption and cost provided the most useful information and prompted more behavioural changes than less immediate types of feedback. Fischer (2008) concluded, after reviewing original papers and reviews on energy feedback studies, that feedback is most effective when given daily or more often. Similarly, Grønhøj & Thøgersen (2011), Darby (2006) and Abrahamse et al. (2005) conclude that feedback is most effective when provided continuously through interactive technologies and when providing insight into the consequences of specific behaviours. Fischer (2008) also suggests that feedback should be provided over a long period of time, provide appliance-specific data, and be presented in an appealing and interactive way that allow for activities through which the feedback can be explored or experienced. If the individuals are given the opportunity to compare their current consumption with previous consumption as well, the effect of feedback can be reinforced (Fischer, 2008, Froehlich, 2009). Overall, literature suggests that potential energy reductions between 5-12% can be attained when households are provided with feedback on their energy consumption (Fischer, 2008, Darby, 2006).

Even though many studies have indicated positive effects of feedback, few studies have been able to identify any long-term behavioural changes (Abrahamse et al., 2005, Van Dam et al., 2010, Van Dam et al., 2012, Dwyer et al., 1993). Further research that can evaluate effects long term is needed in order to be able to draw inferences regarding the usefulness of feedback to encourage energy conservation in the long run (Abrahamse, et al., 2005; Steg & Vlek, 2009). Moreover, the use and acceptance of these systems have hardly ever been addressed. As the potential for energy savings depend entirely on the users accessing the energy feedback, embracing the information, and changing their behaviour, there is a need to study the adoption of these systems in depth.

# 3. RESEARCH APPROACH

This chapter describes my philosophical assumptions about the nature of reality and outlines the implications they have had for the research described in this thesis. Ontology and epistemology beliefs can be considered to underpin all research and direct the methodological approach and choice of methods (Grix, 2010, Guba and Lincoln, 1994, Crotty, 1998). An explicit clarification about the fundamental theoretical assumptions are therefore essential when describing the research approach and process undertaken (Grix, 2010, Creswell, 2014). Furthermore, following the recommendation of Creswell (2014) a short description of the personal background and context is provided to give insight into the values and pre-understanding that has directed the choice of research focus. Figure 1 provides an overview of the interconnected key components that has informed the methodological approach undertaken during this research. My personal context, theoretical assumptions, methodology, and methods are elaborated on in the subsequent sections.

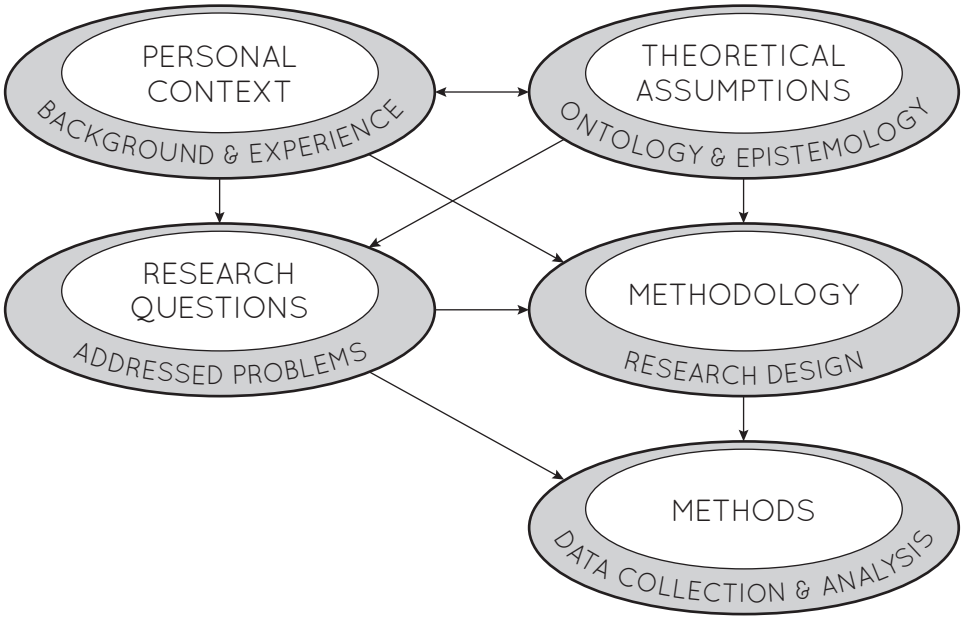



Figure 1. Key components forming the research approach

## 3.1 PERSONAL CONTEXT

My education within the field of product design, including undergraduate and postgraduate studies, was characterised by a user-centred design approach focused on problem solving. Throughout my studies and subsequent experience as a practicing designer, I have acquired a pragmatic view of the design discipline by engaging in different methodologies for developing knowledge and finding suitable solutions to relevant problems. Over the years, my interest in and comprehension of sustainability in regards to the design discipline have both

expanded and diversified. Today, the aspects of design and sustainability are not only interests relevant for my profession, they underpin my philosophy of life and influence what I value and how I think, learn, and act.

From my point of view, the need for sustainable development is not only limited to ensure the prosperity for future generations of the human species, but for all species alike and the world we all share. I believe that each and every one of us, as individuals and citizens, as employees or employers, or as designers and researchers, has the responsibility to do what we can to contribute to sustainable development. Achieving sustainable development can be considered the ultimate design challenge and the most relevant design problem to solve. Unfortunately, there are few right and wrong answers when it comes to sustainability decisions in the design discipline. Sustainability issues are integrated in all aspects of society and three main domains are commonly referred to: Economical sustainability, Environmental sustainability, and Social sustainability (Thorpe, 2007). The work presented in this thesis is mainly focused on contributing to environmental sustainability by addressing energy consumption and studying energy conservation as a means to decrease society's environmental impact. The research topic takes its starting point in my personal values and views on sustainability and energy conservation - that reduced consumption is not only preferable but also crucial to limit society's environmental footprint. The research and research questions posed have been based on what I find to be relevant aspects to consider in order to increase our understanding of people's energy consumption and to facilitate the development of solutions that may enable change.

## 3.2 THEORETICAL ASSUMPTIONS

My philosophical beliefs acknowledge an objective world that exists independently of our presence (cf. the post positivist worldview (Creswell, 2014)). From my perspective, the world can however be affected by human influence and we are also influenced and restricted by the world and its physical limitations. Different people may experience different realities, as our experience of the world is dependent on our specific context, i.e. our worldview is influenced by personal, cultural, historical, and social contexts, for example. People's understanding of the world and the meaning they make of their reality can thus be considered socially constructed within the context they live (cf. the constructivist worldview (Guba and Lincoln, 1994, Creswell, 2014, Crotty, 1998)). Furthermore, I argue that the mental model people have of their reality can be considered to correspond more or less to the physical world they seek to represent (cf. the pragmatic worldview (Johnson and Onwuegbuzie, 2004)).

My epistemological beliefs concerning knowledge and truth logically follow my ontological assumptions. I believe that our knowledge about the world is influenced by the context we live in and the social constructions currently employed. Our knowledge can thus not be considered objectively true or static,

but is forever changing with society (cf. the constructivist worldview (Grix, 2010)). With regards to people's energy behaviour, there is not one truth that can explain every person's individual behaviour but rather multiple truths and realities that can provide deeper knowledge of the complexity of the situation. Knowledge of measured environmental effects, for instance, is not sufficient to understand specific sustainability challenges; we also need to acquire knowledge of the social processes that govern different situations in order to be able to understand how the effects came about. From this point of view, I value practical and applicable knowledge that can be used as a tool to create change and improve the world we live in (cf. the pragmatic worldview (Johnson and Onwuegbuzie, 2004)). To manage change, we not only need knowledge about what is, but also about what preferable alternatives are available and how those might be supported.

In my opinion, we cannot study a phenomena completely objectively as we as researchers influence, and are influenced by, both the research process and the interaction with informants during the process (cf. the constructivist worldview (Creswell, 2014)). My understanding and personal constructs related to the topic has constantly evolved during this research and consequently influenced my interpretation of the data. Even though I have tried to remain as objective as possible throughout the process of gathering and analysing data, I nonetheless acknowledge that other studies might result in other interpretations of the problem depending on the context and constructs in those specific settings.

## 3.3 METHODOLOGY

The research presented in this thesis seek to build ideographic knowledge of behavioural phenomenon, i.e. an understanding of individual energy behaviours, and seek probable explanations for those behaviours (cf. the constructivist and post positivist worldviews (Guba and Lincoln, 1994)). Furthermore, the research aims to discuss a specific design solution and its potential in facilitating change. The methodological approach is influenced by pragmatic design thinking, i.e. seeking the most suitable way of addressing the posed research questions (cf. the pragmatic worldview (Creswell, 2014, Johnson and Onwuegbuzie, 2004)). A mixed methods approach, incorporating both qualitative and quantitative approaches (Creswell and Clark, 2011, Johnson and Onwuegbuzie, 2004), have therefore been adopted during this research to triangulate data collection and data analysis to facilitate the interpretation and conclusion drawing. The research presented in this thesis includes two studies, here referred to as Study One and Study Two, which were designed to address the previously described research questions. The design can be referred to as a multiphase design (Creswell and Clark, 2011) with the two studies carried out sequentially. The knowledge gained through Study One informed the design of the energy feedback system evaluated in Study Two. The overall design of the research and the two studies are outlined in Figure 2 and further elaborated on in section 3.4. Methods.

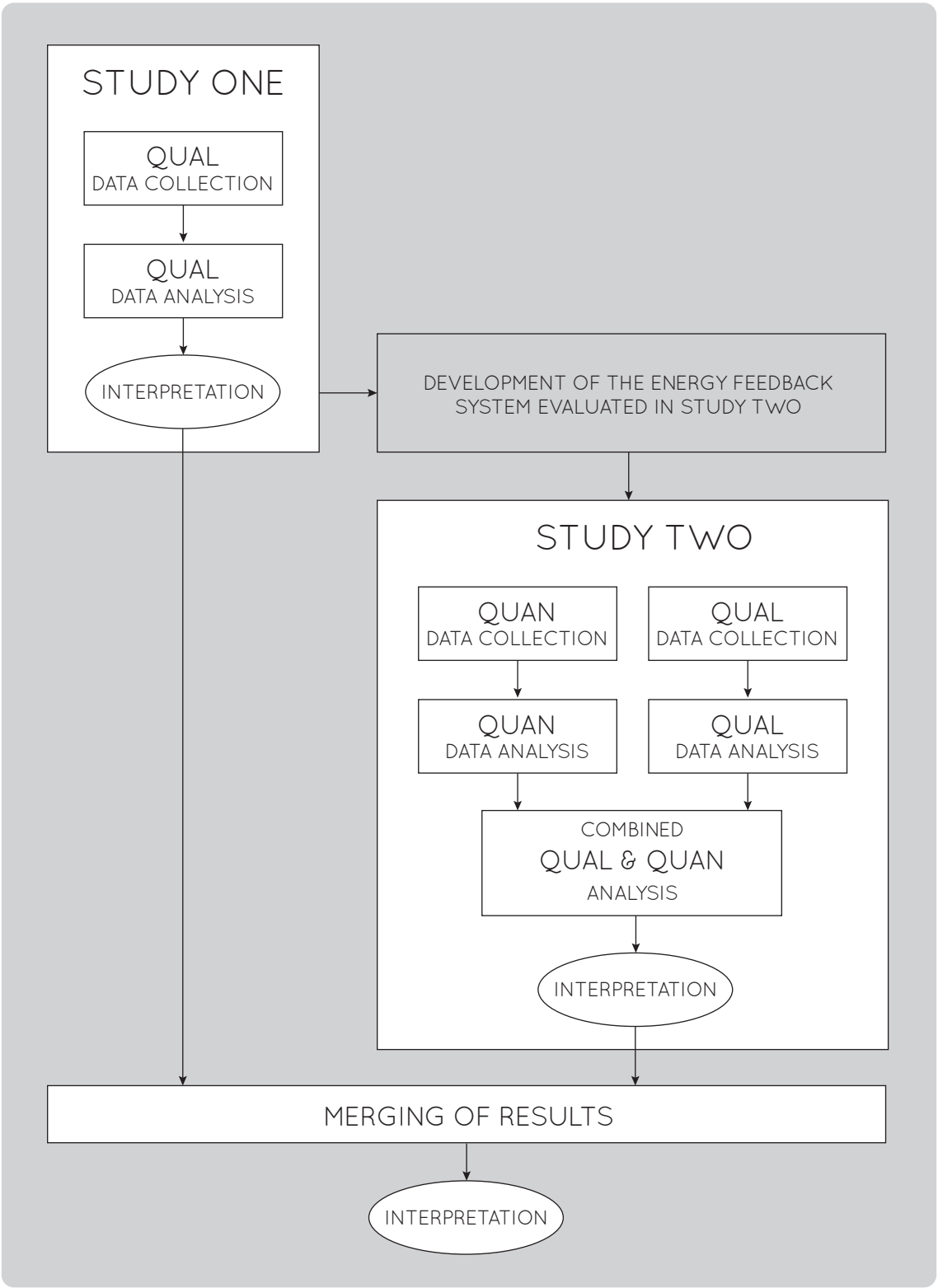



Figure 2. Research design

## 3.4 METHODS

Study One was an explorative interview study that addressed people's everyday preconditions, possibilities, and limitations for engaging in energy conservation. Study Two was undertaken to evaluate the use and benefits of the energy feedback system Eliq Online. The study was conducted as a field trial and data was collected via three online surveys along with continuous monitoring of the households' electricity consumption and their use of the system during the trial. Additionally, electricity consumption data was also collected for a large control sample. The aim of the two studies and methods used are clarified in Figure 3 (see next spread). Chapters 4 and 5 describe the studies in more detail.

The analysis process included iterative stages of drawing conclusions and the collected data were also contrasted to previous research in the field as well as relevant theory on behaviour and energy consumption. The design of the two studies and the relatively small sample sizes directed the analysis of the data and advocated a primary focus on an ideographic analysis process, i.e. analysing energy consumption in relation to particular cases. The data from Study One was analysed through a thematic analysis in which emphasis was put on individual experiences and common patterns between individuals. The diverse data collected during Study Two required an analysis approach mixing qualitative and quantitative methods. Parts of the survey data were interpreted qualitatively, on an individual or group basis, to provide meaning and explanation to the more quantitative analysis. Several statistical analyses were carried out to evaluate absolute changes in electricity consumption, behaviour, and influencing factors, as well as potential correlations between changes and the participants' use of the evaluated feedback system. An additional statistical analysis were performed to assess the participants relative change in electricity consumption compared to a control sample of households with matching consumption patterns during the baseline period. The conclusions from the two studies were finally merged to form an overall interpretation of the results.

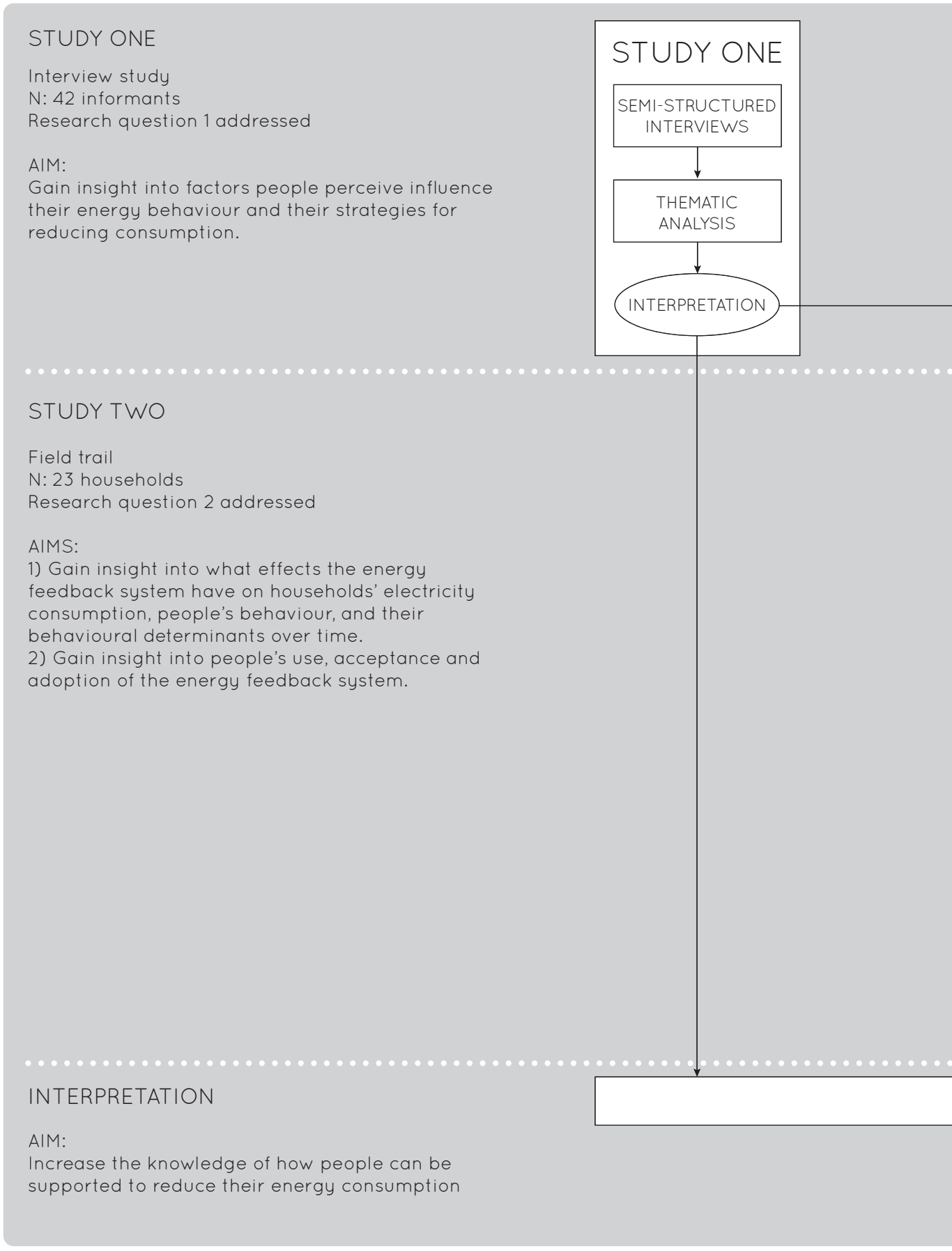
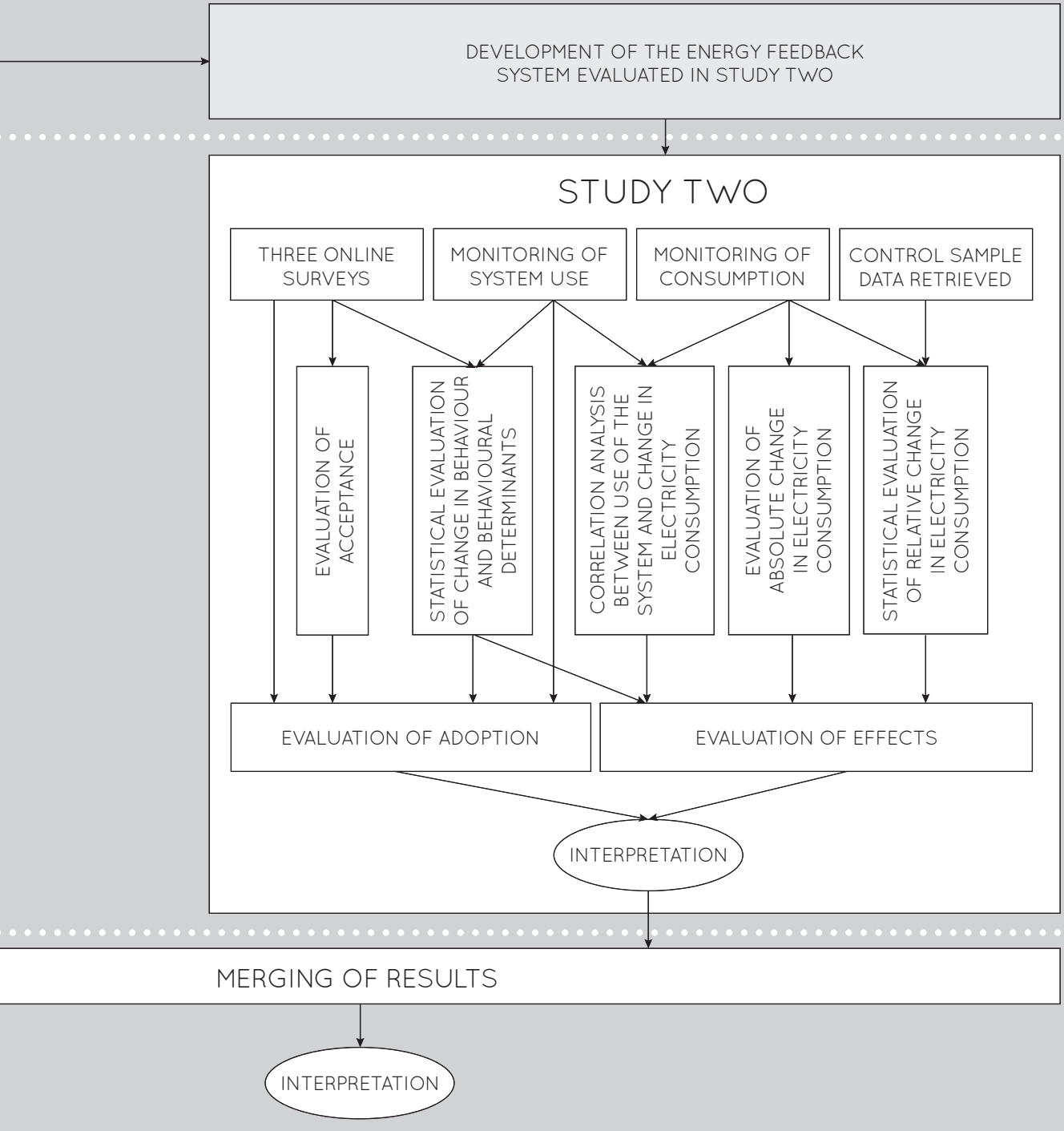



Figure 3. Overview of covered studies and methods used


DEVELOPMENT OF THE ENERGY FEEDBACK SYSTEM EVALUATED IN STUDY TWO
STUDY TWO
THREE ONLINE SURVEYS
MONITORING OF SYSTEM USE
MONITORING OF CONSUMPTION
CONTROL SAMPLE DATA RETRIEVED
EVALUATION OF ACCEPTANCE
STATISTICAL EVALUATION OF CHANGE IN BEHAVIOUR AND BEHAVIOURAL DETERMINANTS
CORRELATION ANALYSIS BETWEEN USE OF THE SYSTEM AND CHANGE IN ELECTRICITY CONSUMPTION
EVALUATION OF ABSOLUTE CHANGE IN ELECTRICITY CONSUMPTION
STATISTICAL EVALUATION OF RELATIVE CHANGE IN ELECTRICITY CONSUMPTION
EVALUATION OF ADOPTION
EVALUATION OF EFFECTS
INTERPRETATION
MERGING OF RESULTS
INTERPRETATION

# 4. STUDY ONE: EXPLORING DOMESTIC ENERGY BEHAVIOUR

The first study was undertaken as an interview study to explore people's everyday preconditions and possibilities for reducing their domestic energy consumption to add to the existing literature. Factors people perceive to influence their domestic energy behaviour and people's current strategies for reducing their consumption were explored to further the understanding of how people can be supported in reducing their consumption. Paper A addresses in particular how everyday goals influence domestic energy behaviour and what strategies people use to manage conflicts between energy saving goals and competing goals.

## 4.1 PROCEDURE

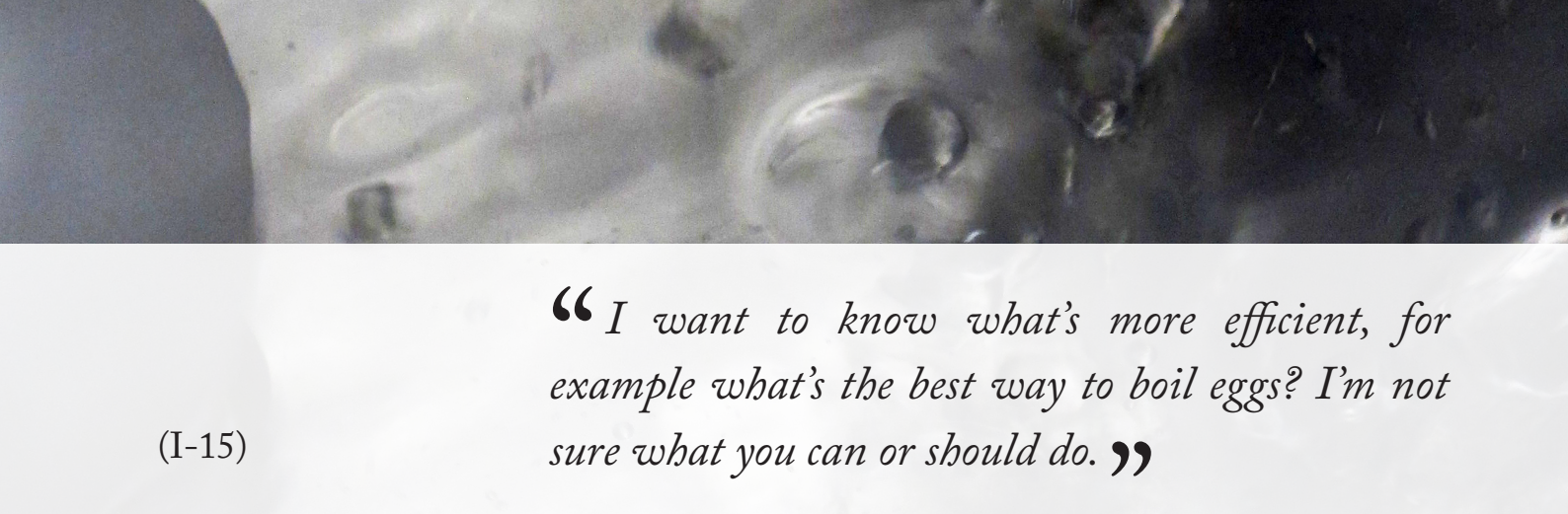
The interview study was carried out in a university setting with 42 individuals from different households in Gothenburg and nearby communities. The recruitment process was undertaken in two steps; people were first approached in public shopping malls and enquired about their willingness to take part in the study, secondly, an advertisement was put in the local newspaper along with a subsequent radio announcement. A semi-structured interview guide was used during the interviews. Apart from demographic characteristics, the informants' preconditions, attitudes towards technology, and use of appliances were discussed in relation to energy related behaviours and energy conservation. The interview data was analysed using an iterative thematic coding process as described by Miles and Huberman (1994). The collected data was analysed and condensed through a two-step coding procedure, in which different themes and patterns were explored. Excerpts from the interviews have been translated from Swedish to English by the author.

## 4.2 RESULTS

The results of the study initially address the different factors that the informants (Is) considered to influence their domestic energy consumption, and secondly the various strategies they have adopted for reducing consumption.

### 4.2.1 FACTORS INFLUENCING DOMESTIC ENERGY BEHAVIOUR

The factors can be described from a systemic perspective and categorised in three main groups. The first category includes factors related to the individual performing the behaviour such as motivational aspects and personal characteristics. The second category highlights many influential factors related to the energy demanding activities the informants engaged in. The third category describes more general preconditions and factors related to societal aspects that the informants also felt influenced their energy behaviour.



*"I want to know what's more efficient, for example what's the best way to boil eggs? I'm not sure what you can or should do."*

(I-15)

Factors related to the individual performing the behaviour that was touched upon during the interviews included beliefs, personal norms, knowledge, skills, and financial education, see Figure 4.

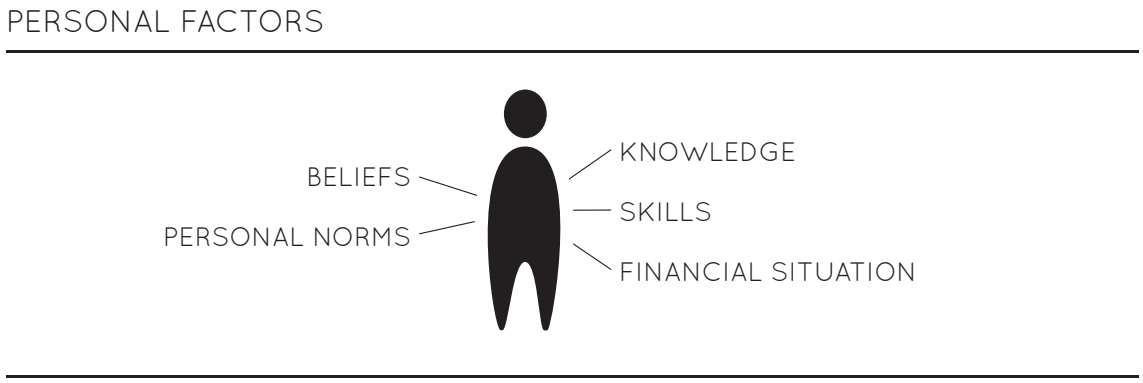


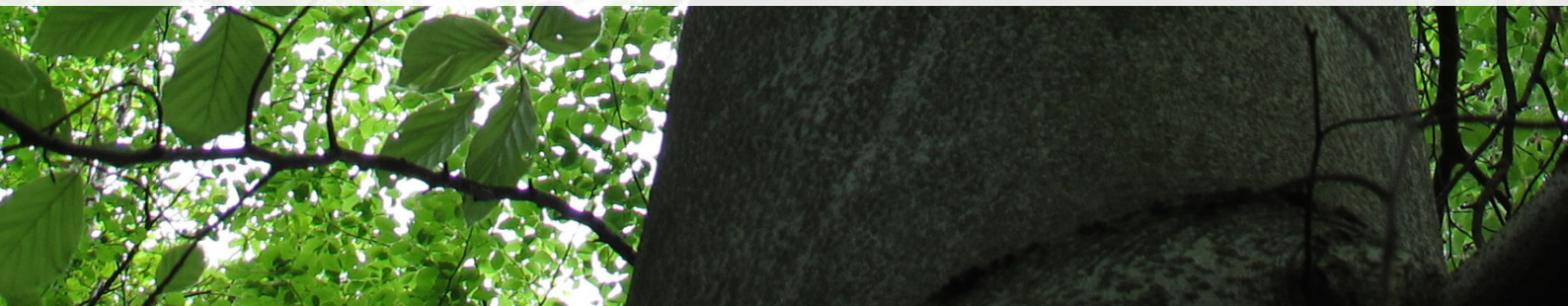

Figure 4. Personal factors influencing domestic energy behaviour

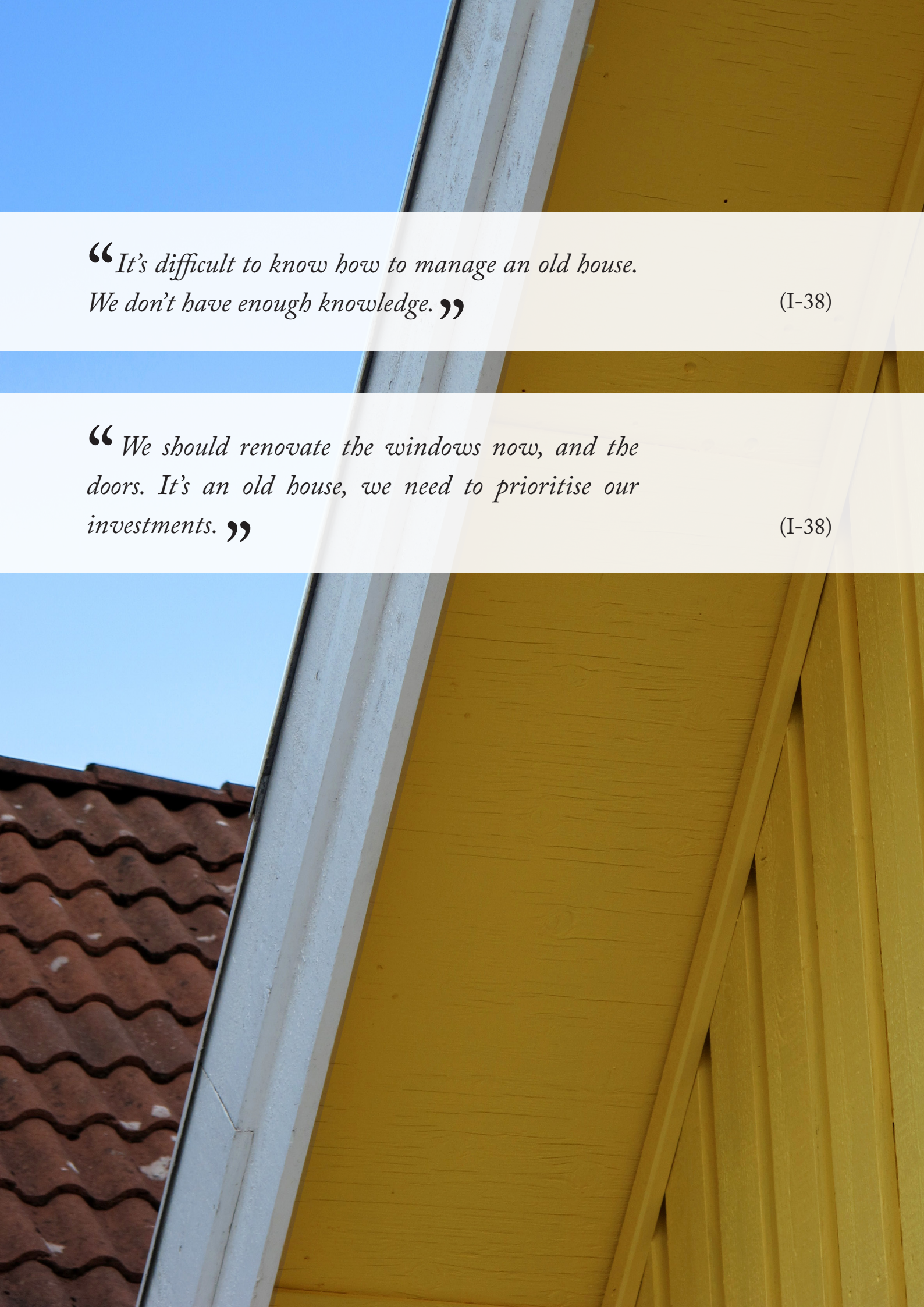
The informants' beliefs regarding the consequences of their behaviour and the outcome expectancies of energy saving measures influenced their disposition towards using energy. Some informants had strong beliefs regarding their appliances and heating systems that made them unwilling or uninterested in energy saving measures: "*The energy consumption of appliances is insignificant in comparison to the electric heating system. So there's no point in turning them off, the electricity turns into heat anyways.*" (I-18). Others were uncertain of the effects of their energy behaviour but nonetheless tried to reduce consumption: "*I don't know if it matters what we actually do, but I think so. If there is any environmental advantage of doing it, I'll gladly do it.*" (I-9). The majority had the belief that their behaviour and energy saving measures in particular could make a difference if everyone else also did their part which motivated them to act: "*Every little bit helps, our share will contribute to a larger whole.*" (I-35). Others however did nothing as they considered their behaviour to play an insignificant role in a global perspective: "*We need to start considering these things, but Sweden is a drop in the sea, Sweden is too small. What use would what we do be?*" (I-22). Perceived self-efficacy was another aspect that differed between the informants and shaped their view of their possibility to reduce their consumption. People who expressed low self-efficacy did not engage in energy saving measures to the same degree as people who expressed high self-efficacy: "*I think I'm already a light consumer so I don't think I can reduce my consumption any further*" (I-31).

The informants' personal norms and attitudes towards using energy were other aspects described to influence energy behaviour. Some considered energy conservation as a matter of course and some even felt uneasy when using more energy than required: "*It's natural for us to do it. It's not about saving, it's about acting in a sound way*" (I-10); "*It feels wasteful, unpleasant to squander.*" (I-14). While many had a clear personal norm not to waste energy, others did not give their energy

(I-33) *“It’s deeply rooted within me, you don’t waste.”*

*“It’s a question of upbringing, to be economic. It’s a general attitude to not use more resources than necessary.”* (I-37)





*“It’s difficult to know how to manage an old house. We don’t have enough knowledge.”* (I-38)

*“We should renovate the windows now, and the doors. It’s an old house, we need to prioritise our investments.”* (I-38)

consumption too much thought: "*I use the appliances I need, I don't reflect on it that much.*" (I-41); "*I'm in the air transport business, and I have a bigger perspective on things.*" (I-40).

Even though many of the informants' were positive towards energy conservation due to their beliefs and norms, their personal characteristics such as knowledge level, skills, and financial resources sometimes limited their efforts to reduce consumption. Only a few of the informants considered themselves knowledgeable regarding their energy use and the amount of energy required by different appliances. The majority however expressed that they did not know which activities contributed the most to their consumption, nor which appliances that used the most energy: "I *would like to know about standby power, will I save anything by turning it off completely or will I not? And how about dimmers, do they reduce the consumption?*" (I-13); "*I'm unsure about what consumes energy, for instance, an extension cord?*" (I-31). As long as the informants were unsure, they did not know how to act to reduce their consumption and consequently often did nothing. However, when they acquired more knowledge, many chose to change their behaviour, e.g. unplugging chargers for portable devices: "*I learnt that this summer, so nowadays I always unplug leads.*" (I-28).

In addition to the lack of general knowledge on energy consumption, many of the informants also lacked specific task knowledge on how to go about a certain activity which made them hesitant: "*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). Even though some expressed that they did know what should be done, they did not feel knowledgeable or skilled enough to carry out the task themselves; "I *know I should change to new insulating tape around the windows, but I don't have enough knowledge to do it.*" (I-3); "*It's nothing we can do ourselves, we need experts, a builder or craftsman.*" (I-9).

Financial resources were yet another aspect that was expressed to influence the informants' behaviour related to energy consumption. Even though many investments in new appliances or energy efficient solutions would in time reduce the financial cost of energy consumption, initial high investment costs and long term payoff periods hindered some households from making energy efficient investments: "*We want to switch to more efficient appliances, but it's costly and the payoff is long term. If we had the resources we would have installed it later on.*" (I-42); "*Today we burn pellets in our old oil boiler. It is not as efficient as using a pellet furnace so I would like to switch to that. But it would require an investment.*" (I-33).

Factors that were discussed in relation to the energy demanding activities the informants engaged in included everyday goals, artefacts, habits, use context, and social context, see Figure 5 on the next page.

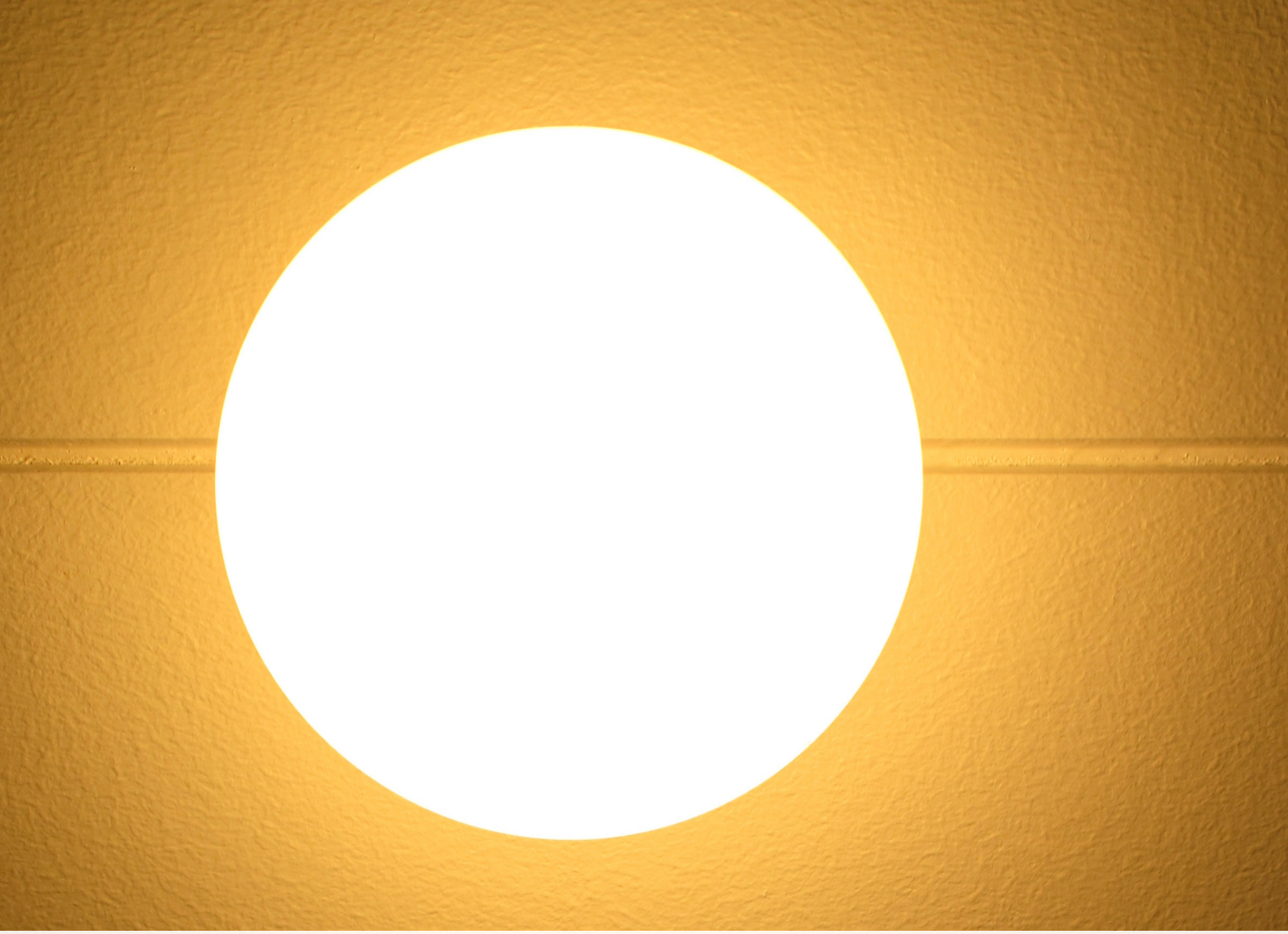

Figure 5. Activity related factors influencing domestic energy behaviour

During the interviews, the informants talked about their energy consumption in relation to their everyday activities. The informants engaged in many different activities to satisfy their everyday basic needs, or fulfil desires related to their lifestyle, that involved the use of energy-consuming artefacts. They often related their energy behaviour to everyday goals, not overarching life goals or goals related to specific actions, but to goals that, when met, fulfilled their needs or desires during everyday activities. Many informants explicitly described a goal of reducing their environmental impact, and specifically reducing their energy consumption. This goal was sometimes strengthened by other goals such as reducing financial costs and reducing safety risks related to electric appliances. However, the informants often experienced conflicts between the goal of reducing consumption and other concurrent, competing priorities that made energy conservation difficult to manage. Reducing energy consumption was often associated with behaviour perceived to be hard work, difficult to carry out, time consuming, or by other means negatively affecting the informant's lifestyle, well-being or home environment. Most informants' foremost goal was to live "a good life" and sub-goals relating to aspects such as effort, time, well-being and safety were therefore often implicitly referred to during the interview as reasons to why energy conservation were not prioritised in all situations. Many informants especially described that it would require a lot of engagement and work to reduce their energy consumption. Several informants talked about reducing effort in relation to standby consumption and particularly related to their television set. They expressed that it was both physically annoying to have to walk up to the TV to turn it off and cognitively burdening to deal with the appliances: "*When it comes to standby power, the TV channel box discourage me to turn 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). Moreover, with regards to managing appliances in everyday life, the findings suggest that the goal of reducing effort may be reinforced by the number of appliances and the frequency of use: "*It is convenient to not do anything, there are many appliances to manage if you are to shut them all off.*" (I-37). Another informant pointed out that the frequent use of his mobile phone influenced the use of the charger: "*It*

*consumes a lot which makes me have to recharge it every night. So the charger is always plugged in next to my bedside table.*" (I-22). Time was yet another important factor mentioned by several informants. They did not want to waste their time managing appliances or waiting for slow appliances to perform. Appliances used frequently were especially highlighted: "*I try, but it's easy to forget, it depends on what appliance it is, but I don't want to restart the computer every time, it takes forever.*" (I-1). One informant elaborated on her behaviour when doing the laundry: "*My top priority is to make it convenient and easy, so I use a tumbler dryer. I don't have the time to do it differently.*" (I-23).

The artefacts themselves, independent of activities or goals, were also an aspect perceived to influence the informants' energy consumption. Some stated that they had a tendency to acquire many different electrical appliances due to, for instance, interests, enjoyment, or encouragements from the family, which often spurred energy-demanding activities and contributed to an increase in energy consumption. Furthermore, the design of the appliances was highlighted as another important aspect. Appliances which functionality did not correspond to the informants' needs often created frustration and resulted in undesirable and wasteful energy behaviour; "*The design of the dishwasher is faulty. Sometimes you have to run it even though its only filled with cups, it should be better designed.*" (I-15); "*I always have small loads of laundry and as I have only a few items to wash, the washing machine in never fully loaded.*" (I-31). Most also considered the functionality and usability of many electrical appliances defective in supporting efficient use of them: "*For some products it's hard to know how to use them correctly, it can be hard to know how to turn them off. I wish for appliances that are easier to turn off, standby is tricky, automatic solutions are better.*" (I-6); "*I don't know when an appliance is in standby mode or completely off, it depends on how the product is designed. (…) In regards to the telly, I don't know how to turn it off, I don't think it has an off-button.*" (I-30).

Daily habits were highlighted as another factor influencing the informants' energy consumption during different activities. Many of the informants mentioned resource efficient habits such as turning of the lights, unplugging chargers, running the washing machine fully loaded, and taking short showers. Others described habits that normally resulted in increased resource consumption such as always using standby energy modes or leaving the TV on when engaging in other activities. Many felt that it was difficult to engage in energy saving behaviour during daily activities if they did not already have a habit of doing so: "*It doesn't come naturally. It takes time to develop it into a habit.*" (I-21) or if they had a habit of not doing so: "*You pull yourself together for a while but then you fall back into a bad habit again.*" (I-19). Some also related the nature of their habits to the products they used during specific activities: "*It depends on the product, turning of standby is very demanding, and it's a habit not to.*" (I-12), or to previous experience: "*It's an attitude from days past, you weren't supposed to turn it off completely because it used to be dangerous to do so.*" (I-30).



*“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 for changing the old appliances. But for me to use the energy meter it requires me to creep under the frezzer to read the meter.”* (I-6)

*“I turn off the lights, but the others don’t. It’s an abstract thing for the children to relate lighting to money.”* (I-33)

The context in which energy demanding activities took place were mentioned to influence both habits and the household energy consumption. One informant described how a move to a new home, where the cost of energy consumption was no longer included in the monthly rent but paid separately, had influenced their consumption behaviour: "*When we moved to the new house from our former apartment we had to save, now it's turned into a habit.*" (I-23). Inefficient energy consumption lock-ins related to the use context also limited many informants opportunity to reduce their consumption by simple measures, such as inefficient heating systems and old houses requiring considerable renovations. Furthermore, several were cautious of introducing energy efficient measures that would influence their home and living space negatively. For instance, one informant (I-9) was hesitant of buying a heat pump as she considered it distasteful, too loud, and problematic to handle due to water leakage issues.

The majority of the informants also discussed interpersonal relations and the social context in which energy related activities take place. Many had noted a discrepancy between how they sought to behave and how others in their household chose to behave, which caused frustration, lead to disputes, and made reductions difficult to achieve. Not only did the prioritisation made by spouses sometimes differ, but parents also frequently experienced a conflict between their children's behaviour and their own: "*I chase the kids, they always leave the telly on, and we have a continuous fight over the lighting at home, do we keep it on or off? It's usually on.*" (I-22). In contrary to creating frustration, the discrepancy sometimes led to new habits if one of the persons accepted changed behaviour patterns: "*When it comes to standby and electronic equipment I got a new habit from my former partner. He was concerned with not turning the TV and the stereo off completely. I think that's the reason why I nowadays don't consider turning off standby.*" (I-8).

General preconditions and factors related to societal aspects that the informants also felt influenced their behaviour covered social norms, climate, market, physical and structural environment, legislations and regulations, and societal players, see Figure 6.

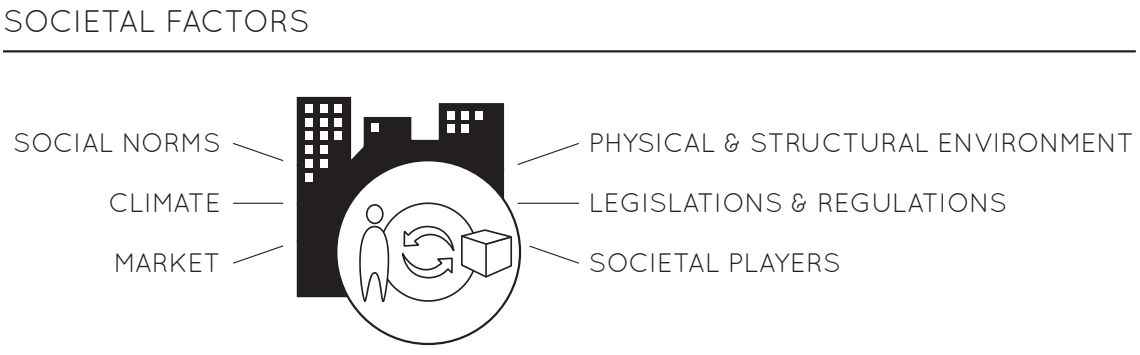



Figure 6. Societal factors influencing domestic energy behaviour

Some informants discussed social influence from a societal perspective in addition to the social context and social influence experienced during activities. Other peoples' view of their own responsibility in a societal setting was highlighted as an aspect influencing the informants' behaviour, either positively or negatively: "*We don't concern ourselves with what other people do. Everyone is ignoring it (referring to energy conservation), we can't be bothered either.*" (I-27). Social norms were also mentioned to limit certain energy efficient behaviours: "*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, it's a different norm there.*" (I-36).

Contextual aspects from a societal point of view were discussed in regards to climate and the physical and structural environment. Several informants talked about climate related aspects in regards to their own comfort and pleasure. Some would rather keep their home lit, warm, and cosy than reduce their consumption: "*In a dark and cold country it's not all wrong for people to be able to see and keep warm.*" (I-1); "*Electricity is not the worst villain when it comes to environmental issues, we can do other things to reduce our environmental footprint. We have other priorities. I have the right to electricity indulgence, it's so cold and dark in Sweden.*" (I-36). Instead, they prioritised everyday luxury activities like taking a long shower, turning up the heating, or keeping the lights on when leaving the home. Others discussed climate related aspects in regards to possible investments: "*Solar heating would be interesting if only it would yield more during the winter season.*" (I-24). In regards to the physical environment, the informants discussed different infrastructural limitations that reduced their action space and made it difficult for them to make radical systemic changes. Several mentioned their frustration over regulations that required them to hire qualified electricians and prevent them from making adjustments themselves. Several informants also considered themselves locked-in to inefficient energy systems due to the infrastructure and energy system already in existence where they lived: "*We would like to connect to the district heating system, but Göteborg Energi (the local energy distributor) did not want to expand their grid to include us.*" (I-38). Many also discussed the current possibilities for small-scale energy production for private households. Even though most of them were positive towards the concept, they considered the current circumstances too demanding in regards to the effort and financial resources required: "*You have to take it quite far, make it your hobby, to be able to invest and make bigger changes like becoming energy self-sufficient.*" (I-7).

The current energy system and in particular the current tariff structure were discussed by all the informants. At the time of the study, time-based pricing was yet not available in Sweden and several informants were waiting for the introduction of a new tariff structure that would motivate them to shift part of their energy consumption to off-peak periods: "*If it was cheaper during night time, we would use more energy then. That would enable us to save a little, it would create an incentive.*" (I-24); "*When the cost starts varying with time we will run the appliances demanding*

*a lot of energy at night. Now the cost is the same to us, so it doesn't matter when we run them.*" (I-39). Apart from the tariff structure, the actual price of energy also influenced the informants' behaviour. Some found it expensive which created an incentive for energy efficiency measures while others found is too cheap to create an incentive: "*I find electricity rather cheap, it's so convenient, it's worth it considering what we gain from it.*" (I-37). The energy price was also mentioned as a factor of frustration. The majority of informants found themselves confused whenever they had to make decisions regarding their energy contract or when paying the energy bill as they did not understand the way the price was communicated nor how the price was determined: "*I want to know more about the electricity price setting: how it is calculated, where the money goes, about the electricity grid, and what determines the price. Now the energy companies are so big and you don't have a clue, you just have to go with it.*" (I-27). The lack of knowledge and understanding for the system left some of the informants disinterested in energy issues and less keen on engaging in energy efficiency measures: "*It's difficult to understand the numbers, I can't be bothered.*" (I-12).

In addition to the energy system, the society and its players were also discussed as important factors influencing the preconditions, norms, and culture related to energy consumption. Some informants considered many parts of society irresponsible, wasteful, and not interested in pursuing opportunities to reduce consumption: "*A system perspective is missing, there is no collective force.*" (I-32); "*Everyone must contribute, private, public, and corporate sectors (…) A one man race will not cut it.*" (I-20); "T*he consumer society mass hysteria needs to change, developers need to take responsibility, not just go on and on.*" (I-31). The lack of a joint force made some informants feel less inclined to make an effort themselves since they felt that their contribution wouldn't matter if the rest of society did not do their part.

Many informants discussed the market and particularly aspects such as market forces, access to energy efficient technologies and unbiased information. Many of the informants were unable to or reluctant to make energy conservation investments due to the low availability of energy efficient technologies such as commercial photovoltaics, the quality and performance of certain technologies, and the lack of suppliers willing to support consumers in their choice of technology: "*We wanted to build an energy efficient house but it was too troublesome. None of the suppliers were willing to use the systems, the same goes for renovations, it's difficult to make that choice, it's completely impossible.*" (I-18). Furthermore, the majority of the informants considered it difficult to find information on energy efficient product alternatives or specific information regarding certain products: "*I want information about products, heating systems, and their energy consumption. I usually ask the retailer but they do not always know.*" (I-3). Ignorant and unreliable sales personnel were another aspect brought forward by several informants: "*The TV sales person recommended me not to turn it off, but I have been thinking about if*

*that can be correct, I have found a button that doesn't really show, but I'm too afraid to try using it.*" (I-28).

### 4.2.2 STRATEGIES FOR INFLUENCING PRECONDITIONS AND REDUCING DOMESTIC ENERGY CONSUMPTION

Many informants talked about different strategies they employed to reduce their domestic energy consumption due to either environmental, financial, or safety reasons. As the informants' preconditions and level of motivation varied, the type and number of strategies also varied between the informants. The strategies targeted the different factors the informants perceived influenced their consumption, i.e. the personal factors, the activity related factors and the societal factors discussed in 4.2.1. The strategies can be described on three levels: the informants' overall strategies to influence their preconditions (strategic level), the tactical approaches that were used in specific situations (tactical level), and the execution of the tactical approach through specific actions (action level). The informants described few strategies for engaging in actions aimed at changing personal and societal factors, but many different strategies were employed to influence factors related to their everyday activities.

KNOWLEDGE LEVEL
PERSONAL FACTOR

| STRATEGIES | TACTICS | ACTIONS |
|---|---|---|
| INCREASE KNOWLEDGE | REQUEST DETAILED DATA | use wattmeters<br>use energy displays<br>ask energy provider |
| | ANALYSE PATTERNS | analyse energy bills<br>compile data<br>compare data |
| | GET ADVICE | ask friends<br>get an energy-performance certificate |

Figure 7. Tactics and actions for increasing knowledge

The majority of informants had strategies for increasing their knowledge to enable themselves to reduce their consumption in the long run, see Figure 7. Some sought to get a better understanding of their energy consumption through tactical approaches such as analysing consumption and activity patterns, getting expert advice on possible measures, or requesting in-depth data from the energy provider. On an action level, they analysed energy bills, compiled and compared long-term data in Excel, applied for an energy-performance certificate done, asked friends for advice and recommendations, used energy feedback displays to analyse their consumption, or used wattmeters to assess energy intensive appliances. Most of the actions discussed were however not always effective or appreciated by the informants. For example, many felt frustrated when they did not understand how to analyse available information, when given low quality advice irrelevant to their

situation, or when forced to creep under the freezer in order to assess its energy consumption with a wattmeter. Furthermore, even though many informants perceived an increased awareness and understanding of their consumption, the support available often did not increase their knowledge on how to actually go about reducing consumption.

EVERYDAY GOALS
ACTIVITY RELATED FACTOR

| STRATEGIES | TACTICS | ACTIONS |
|---|---|---|
| INCREASE AWARENESS | HELP EACH OTHER OUT | remind family members<br>share responsibility |
| INCREASE CONVENIENCE<br>REDUCE EFFORT | USE ASSISTIVE EQUIPMENT | use alarms<br>use feedback displays<br>use timers<br>use on-off switches |
| REDUCE TIME NEEDED | FOCUS ON HIGH-IMPACT MEASURES | evaluate impact level of alternative measures |

Figure 8. Strategies, tactics and activities for managing conflicts between the goal of energy conservation and competing goals

Various strategies for limiting or overcoming conflicts arising between the goal of reducing energy consumption on the one hand, and other competing goals on the other hand were discussed by many informants. The strategies the informants discussed varied depending on the type of conflict they experienced and their current preconditions, see Figure 8. Most common were strategies to make energy saving measures more convenient, less effortful, and less time consuming, or strategies to make themselves more aware of potential actions. On a tactical level the strategies were represented by different approaches such as helping family members, using assistive equipment that would either facilitate or highlight possible energy saving measures, or focusing on measures that could reduce consumption significantly. Actions that followed included developing routines for reminding each other within the family, sharing the responsibility of energy efficiency measures, using products with alarms or similar features as reminders for possible measures, using feedback displays or services to increase awareness or to reduce time spent analysing consumption data, and using e.g. timers and on-off switches to make reductions more convenient and less time consuming during everyday life. Even though many of the informants described strategies to manage competing goals, the majority still most often prioritised other goals than energy conservation.

Strategies for investing in appliances that enabled the informants in reducing their consumption were also common, see Figure 9. Two tactical approaches were discussed by several informants, i.e. investing in appliances with high energy efficiency or investing in products that would support efficient energy use. The informants however clarified that these tactics were not valid for all appliances,

ARTEFACTS
ACTIVITY RELATED FACTOR

| STRATEGIES | TACTICS | ACTIONS |
|---|---|---|
| MAKE INVESTMENTS | INVEST IN ENERGY EFFICIENT APPLIANCES | assess energy efficiency<br>talk to sales personnel<br>talk to electricians |
| | INVEST IN APPLIANCES ENABLING EFFICIENT USE | prioritising eco-features<br>prioritising eco-modes |
| CURTAIL USE | LIMIT NO. OF APPLIANCES | buy less appliances |
| | LIMIT USE OF ENERGY INTENSIVE APPLIANCES | limit use of e.g. vacuum-cleaner, oven, microwave oven<br>turn of lights<br>unplug appliances |
| CHANGE USE STYLE | USE DIFFERENTLY | use timers, sensors, and on-off switches etc.<br>fill out washing machine<br>use spot-heating |
| | USE LESS ENERGY | use eco-programmes<br>decrease temperature |
| MAINTAIN APPLIANCES | OPTIMISE CONDITIONS | clean behind refrigerator<br>defrost freezer |

Figure 9. Strategies, tactics and activities for reducing energy consumption resulting from the use of artefacts

for example, most informants only considered these aspects for white goods, TVs, and light bulbs. The energy efficiency of these products was however overlooked sometimes, as other aspects such as aesthetics, performance, price and usability were deemed more important. The first tactic included actions such as assessing the energy efficiency of different appliances, talking to for instance sales staff or electricians to evaluate different investment alternatives, and subsequently buying the appliance. The second tactic included similar actions, such as prioritising features that enable or support energy efficient use such as appropriate off buttons, or buying appliances with eco and energy saving programmes or appliances without a standby option. Many informants found these actions difficult due to aspects such as lack of information, disengaged and ignorant personnel, and the perceived absence of appliances with energy saving features.

Apart from investing in new appliances, many of the informants also applied three main strategies to reduce energy consumption of the artefacts they used during everyday activities: curtailing use, i.e reducing consumption by limiting use, changing use style, and maintaining the appliances in good condition, see Figure 9. For these strategies, the informants elaborated on several tactical approaches such as limiting the number of appliances, limiting the use of energy intensive appliances, and modifying the use of certain appliances. On the action level most of the informants did many things to reduce their energy consumption while using with different appliances. For example, they curtailed their use by turning off lights, unplugging appliances, adjusting the thermostat, limiting the use of energy

intensive appliances, and turning appliances off when not at home for extended periods of time. Some also described different ways of how they had changed their use style to reduce consumption when using appliances: taking advantage of eco-programmes, avoiding standby modes, fully loading the washing machine when doing laundry, using warm water mindfully, airing rooms efficiently, and using spot-heating in relevant rooms. Several informants also mentioned using for example timers, sensors, and on-off switches to reduce unnecessary consumption. A couple of informants also highlighted the possibility of reducing consumption by engaging in maintenance activities to optimise conditions such as cleaning behind or under the refrigerator or defrosting the freezer. The informants were however not always satisfied with the design of the products and many thought that the design often hindered energy efficient use instead of facilitating it. A number of informants considered long-term investments in new appliances to be easier and of more interest than changing how they use current appliances, provided that they had the knowledge, personal interest, and financial circumstances to be able to invest. In contrast, other informants who lacked the ability to invest in new appliances often tried to reduce consumption by behaving in a less energy-demanding manner when using artefacts in their everyday life. Many informants however found it tiresome to try to reduce wasteful energy consumption on a daily basis as it required constant attention and often forced them to forgo their own comfort.

CONTEXT
ACTIVITY RELATED FACTOR

| STRATEGIES | TACTICS | ACTIONS |
|---|---|---|
| IMPROVE CONTEXTUAL PRECONDITIONS | IMPROVE HEATING SYSTEM | change heating system<br>complement heating system |
| | RENOVATE HOUSE | improve insulation<br>change to efficient lighting<br>discuss actions with friends<br>compare solutions |
| | BUILD NEW HOUSE | ask sales personnel and housing suppliers for advice |

Figure 10. Tactics and actions for improving contextual preconditions

The majority of informants mentioned a general strategy to improve their contextual preconditions to allow for overall energy reductions, see Figure 10. They discussed tactical approaches such as changing to a more efficient heating system, renovating the house, or building a new house with energy efficient technologies and material. The most commonly mentioned actions included asking for advice or assistance from sales personnel and housing suppliers, comparing alternative solutions, improving the efficiency of the heating and ventilation system, installing an air heat pump, improving the insulation, and changing to more efficient lighting solutions. Many informants found these actions difficult as they

often experienced resistance from the responsible personnel and few received any help when asking for more energy efficient alternatives. Instead, when looking for trustworthy information to base investment decisions on, discussing energy efficiency investments with friends or neighbours was considered to be a better choice avoid having to spend time and effort evaluating alternatives.

SOCIAL CONTEXT
ACTIVITY RELATED FACTOR

| STRATEGIES | TACTICS | ACTIONS |
|---|---|---|
| INFLUENCE PEOPLE WITHIN THE SOCIAL CONTEXT | REDUCE CONFLICTS | setting a good example<br>energy mindful upbringing<br>prompting family members |

Figure 11. Actions for reducing conflicts within the social context

Another common approach was to try to influence other people to reduce energy consumption. Two strategies could be distinguished from the interviews: influencing people in the use context, i.e. family members, and influencing friends and other people in society. The main tactic for the first, more common, approach was to reduce conflicts between family members, see Figure 11. The informants engaged in several activities such as setting a good example for their children by behaving mindfully, discussing energy related topics with their children already at an early age, and prompting their adolescents to behave appropriately. The tactic for the second strategy was to spur positive norms that could lead to reduced energy consumption in the long run, see Figure 12. The actions taken to follow through the second tactic included discussing their energy consumption with other families, comparing consumption levels, and giving advice on energy efficiency measures. The perceived effectiveness of the two strategies and their corresponding actions varied between the informants and depended on how receptive the other people were. Some people gladly welcomed the discussions and recommendations or conformed to given instructions while others simply ignored them.

SOCIAL NORMS
SOCIETAL FACTOR

| STRATEGIES | TACTICS | ACTIONS |
|---|---|---|
| INFLUENCE FRIENDS AND PEOPLE IN SOCIETY | SPUR ENERGY CONSERVATION NORMS | discuss energy topics<br>compare consumption levels<br>give advices<br>engage neighbours<br>inform housing cooperative |

Figure 12. Actions for spurring energy conservation norms in society

## 4.3 CONCLUSIONS OF STUDY ONE

The findings show that the informants considered many different factors to influence their energy behaviour and their possibilities to reduce their consumption. The factors were not only related to them on a personal level or to the activities they engaged in, but also to more general preconditions and societal factors they experience to be outside of their control. Several strategies were identified through which the informants sought to influence their preconditions as a way to reduce their energy consumption. Energy feedback displays were, for example, used by some of the informants to increase knowledge and thus facilitate actions to reduce their consumption. The informants did not have strategies for how to address all of the preconditions discussed, nor did all informants generally adopt strategies to reduce their energy consumption. The degree to which the informants engaged in a particular strategy thus varied between informants and different strategies. Furthermore, the findings suggest that the informants often experienced difficulties when wanting to engage in energy saving measures, such as a lack of support from societal players and measures limited to inconvenient and arduous options. Conflicts between competing everyday goals were identified to be a common reason for not engaging in energy conservation.

# 5. STUDY TWO: FIELD TRIAL ASSESSING DOMESTIC ENERGY FEEDBACK

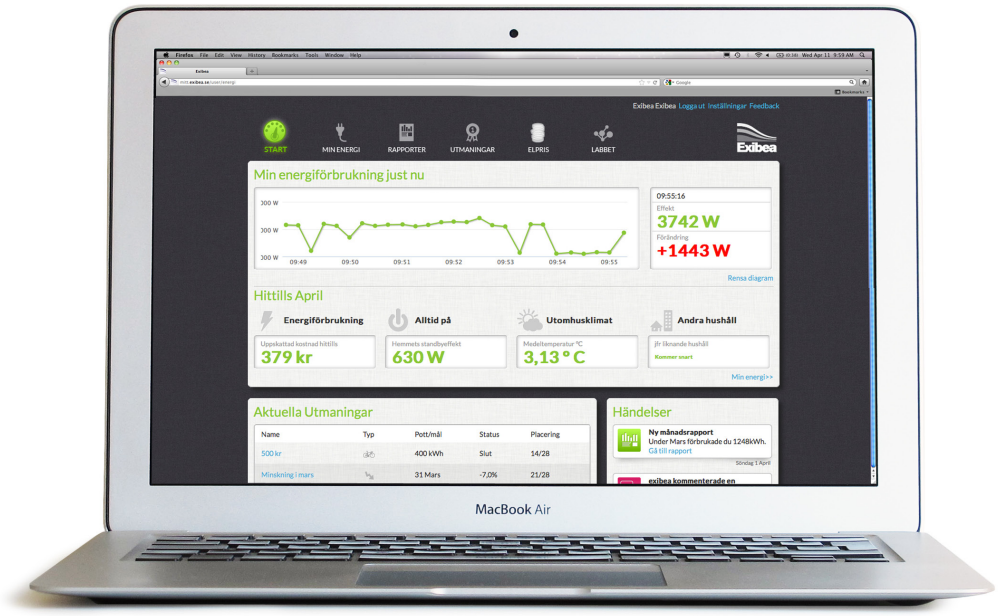
The second study aimed to evaluate the effectiveness and adoption of a particular energy feedback system with potential to support domestic energy conservation by increasing awareness and knowledge, and inspire discussions and energy conservation measures. The study was carried out in collaboration with an industry partner, Exibea AB, and the first version of their energy feedback system Eliq Online was used for the field trial. Exibea developed the system in 2011 through collaboration with the research team at Design & Human Factors, Chalmers University of Technology, and BOID, an external design agency. This chapter summarises the main findings of the study while Paper B describe the effects of the energy feedback on the participants electricity consumption, behaviour, and influencing factors and Paper C discusses the households' use and adoption of the system in more detail.

## 5.1 THE ENERGY FEEDBACK SYSTEM ELIQ ONLINE

The energy feedback system consisted of three main parts. An add-on energy meter was used to gather the electricity consumption data of participating households directly from their main electricity meters. An energy hub in each household stored the energy data and transmitted it successively to an online database. The energy data was accessible to the users through a web portal that could be accessed via any web-based user interface.

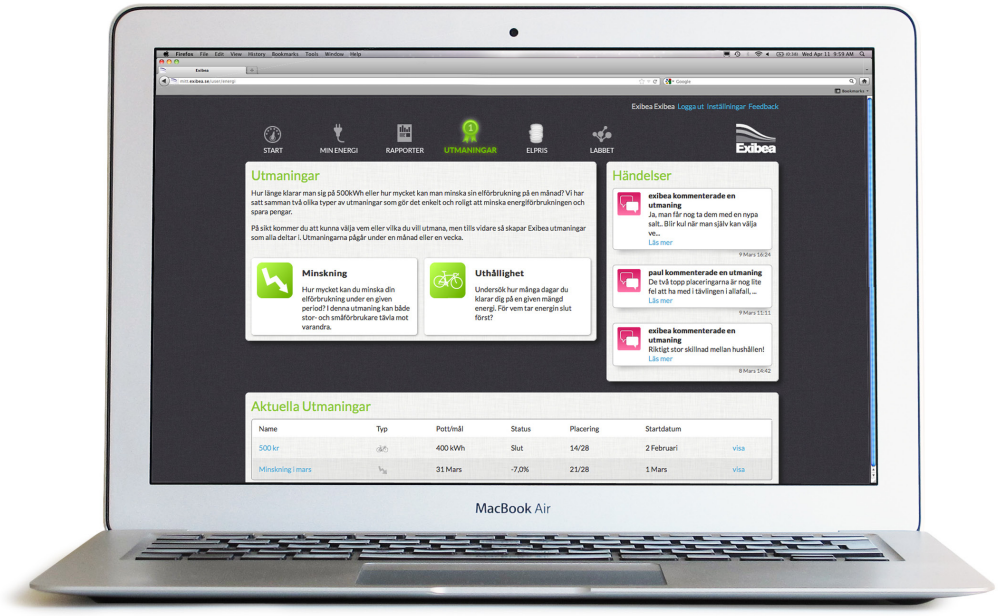
The web portal included several different functions that visualised the data and provided the households with energy related information, see Figure 13. The home screen provided each household with real-time feedback on their electricity consumption as well as comparative figures of the consumption with regards to cost, standby consumption, and outdoor climate. The real-time feedback was provided as aggregated data on a household level and the data was updated every 6 seconds. The home screen also included a news feed and the household's current status in on-going energy challenges. Another section of the web portal, My Energy, offered a historical overview of the household's consumption on an annual, monthly, and daily basis, in order to enable historical comparisons. The section Reports provided summaries of the household's monthly consumption, along with key comparative figures. Two types of challenges that enabled normative comparisons between households were offered in the section Energy Challenges. The first challenge was to make a greater reduction in the household electricity consumption compared to the other households, and the second challenge was to outlast the other households by managing as long as possible on a limited

Figure 13. (See opposite page) The web portal interface showing the home screen, My Energy, and Energy Challenges from top to bottom (text in Swedish)




MacBook Air


MacBook Air




MacBook Air

amount of electricity. The next section, Electricity deal, provided an overview of available deals from Swedish electricity suppliers and recommended the best deal based on the household's individual consumption patterns. In The Lab, a set of interactive evaluation tools were available to analyse how a household's electricity consumption could be expected to vary based on different parameters, such as indoor temperature, heating system, and number of household members. In addition, all users had the option of discussing and giving each other advice on energy conservation measures with individuals in other households by posting comments to the different energy challenges or on the web forum.

## 5.2 PROCEDURE

The study was designed with a twelve month baseline period prior to the test, a six month test period during which the energy feedback systems were installed in the households, and a six month follow-up period, see Figure 14. Twenty-three households in Gothenburg and nearby communities participated in the study and attention was paid to including households with both low and high prior engagement for energy conservation as well as households with both low and high prior interest in online social media. In addition, a sample of comparable households in the region was used as control.

Several types of data were collected during the study i.e. the household electricity

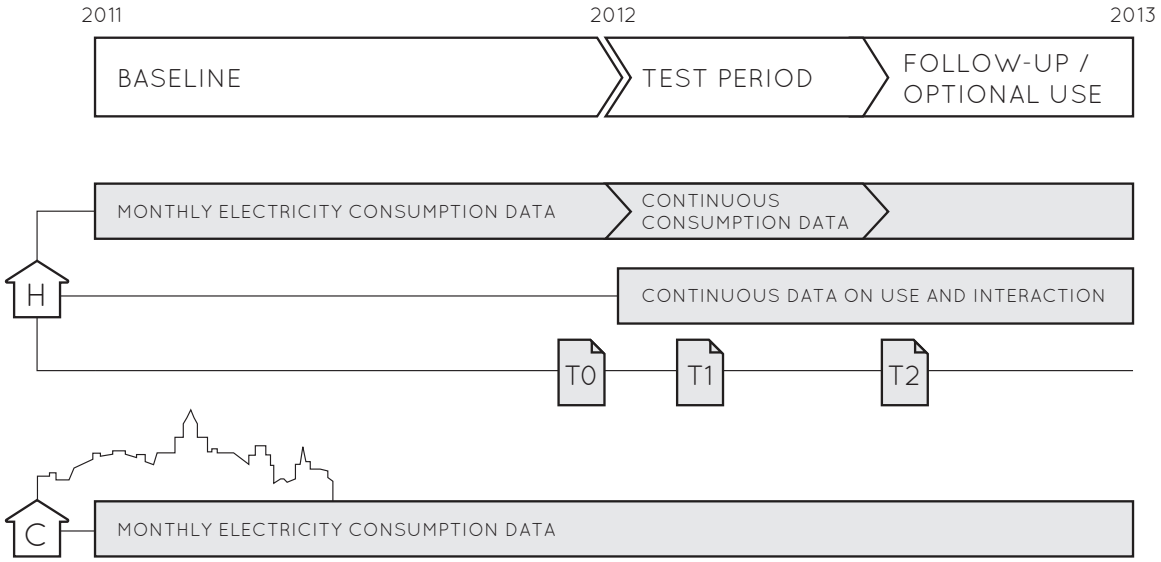



Figure 14. Study design

consumption, use of the web portal, and self-reported changes in behaviour and influencing factors, see Figure 13. The monthly electricity consumption for the households during 2011 and 2012 were collected, either via self-report or through the system database. The electricity distributor in Gothenburg provided data on the monthly household electricity consumption for the control group (43,237 households during 2011 and 43,789 households during 2012). The households' activity on the web portal was automatically registered by the system throughout the six month test period. Three online surveys were distributed to the households;

prior to the test period (T0), two months after the start of the test period (T1), and at the end of the six month test period (T2). The first survey collected data on the demographic characteristics of the households, their attitudes towards energy conservation, perceived self-efficacy, and energy related behaviours while the two following surveys checked for any changes since the beginning of the study. The two latter surveys also collected data on the general perception of the households energy related behaviour, their perceived changes in influencing factors, and their use of the web portal. Furthermore, the third survey measured the households' acceptance of and attitudes towards the web portal.

Electricity savings were calculated in two ways. First, the average consumption during the test and follow-up periods were compared with the corresponding consumption during the same period the previous year for the group of test households:

$$\text{Difference in consumption} = \frac{(\text{Average consumption during 2012} - \text{Average consumption during 2011})}{(\text{Average consumption during 2011})} * 100$$

Second, stratified Wilcoxon (Van-Elteren, Cochran-Mantel-Haenszel) tests were conducted to test if any difference could be found between the test households' change in electricity consumption and the change in consumption of a group of matching households from the control group. The tests were conducted using the absolute accumulated energy consumption for different time periods of 2012 (first half of 2012, second half of 2012, whole year 2012) and a group of 10 households from the control sample were matched to each of the 15 test households. The matching was performed on the data from 2011 by selecting households from the control sample with the 10 lowest Euclidean distances to the respective test household. In order to avoid including the test household in the control group, the best match was rejected for all 15 test households. Table 2-4 provides mean electricity consumption data for the test households (H) and the group of matching control households (C) for 2012 as well as the first and second half of 2012.

| | H2 | H5 | H7 | H8 | H9 | H10 | H12 | H14 | H15 | H16 | H17 | H19 | H20 | H21 | H22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | 1669 | 1843 | 1055 | 1791 | 445 | 814 | 960 | 1100 | 1596 | 675 | 1681 | 1377 | 1159 | 385 | 2739 |
| C | 1396 | 1709 | 1288 | 1747 | 629 | 919 | 1102 | 863 | 1309 | 1215 | 1755 | 1325 | 1438 | 870 | 3471 |

Table 2. Mean total electricity consumption in 2012 (kWh) for each test household (H) and matching control group (C)

| | H2 | H5 | H7 | H8 | H9 | H10 | H12 | H14 | H15 | H16 | H17 | H19 | H20 | H21 | H22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | 1958 | 1944 | 1219 | 1969 | 464 | 869 | 1030 | 1071 | 1769 | 744 | 1817 | 1528 | 1355 | 443 | 2986 |
| C | 1303 | 1785 | 1453 | 1904 | 845 | 944 | 1311 | 464 | 1290 | 1815 | 2076 | 1479 | 1676 | 1319 | 4732 |

Table 3. Mean electricity consumption for January to June 2012 (kWh) for each test household (H) and matching control group (C)

| | H2 | H5 | H7 | H8 | H9 | H10 | H12 | H14 | H15 | H16 | H17 | H19 | H20 | H21 | H22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H | 1379 | 1742 | 891 | 1614 | 426 | 759 | 889 | 1129 | 1424 | 605 | 1545 | 1226 | 963 | 326 | 2492 |
| C | 1489 | 1632 | 1123 | 1591 | 414 | 895 | 893 | 1262 | 1328 | 616 | 1434 | 1170 | 1200 | 421 | 2211 |

Table 4. Mean electricity consumption for July to December 2012 (kWh) for each test household (H) and matching control group (C)

The null hypothesis claimed that there would be no difference between the test and the control households, and the alternative hypothesis claimed that they would differ. Row mean scores derived from ranks were used to test the hypotheses with a stratified Wilcoxon test according to the statistic:

$$W = \frac{\sum_{j=1}^{J} \sqrt{\frac{n_{0j} n_{1j}}{n_{0j} + n_{1j}}} \left( \frac{1}{n_{0j}} \sum_{k=1}^{n_{oj}} R_{0jk} - \frac{1}{n_{1j}} \sum_{k=1}^{n_{1j}} R_{1jk} \right)}{\sqrt{\sum_{j=1}^{J} \frac{1}{n_{0j} + n_{1j} - 1} \sum_{i=0}^{1} \sum_{k=1}^{n_{ij}} (R_{ijk} - \overline{R}_{\cdot j \cdot})^2}}$$

where $R_{ijk}$ is the rank of the observation $X_{ijk}$ within strata j, i=0 denotes the control and i=1 the test group, j=1,.., 15 denotes the strata, k=1,..,$n_{ij}$ denotes the subjects within the $i^{th}$ treatment group (control or test group) in the $j^{th}$ strata and $\overline{R}_{\cdot j \cdot}$ is the average rank of all observations in strata j. The test over the full year was conducted with a significance level of $p < 0.05$ while the test over the first and the second half of 2012 applied a significance level of $p < 0.025$ following a Bonferroni alpha correction. The stratified Wilcoxon tests were conducted by the Mathematics and Statistics Consultants group at Chalmers University of Technology.

Effects on behaviour and influencing factors were analysed using the Spearman's Rank Order correlation test, and a significance level of $p < 0.05$ was used to evaluate the results. The analysis sought to evaluate potential correlations between the use of the web portal and changes in behaviour on the one hand, and between the use of the web portal and influencing factors on the other. Both tests were performed on a short-term, i.e., comparing T0 and T1, and medium-term basis, i.e. comparing T0 and T2. The attitudes towards, and acceptance of, the web portal was analysed in relation to their use of the system by applying a qualitative approach that assessed different constructs influencing acceptance.

## 5.3 RESULTS

The results initially address the use of the energy feedback system based on data from all 23 households. Changes in energy consumption are then examined for the 15 households that provided energy data for the full 24 months. Lastly, the effects on behaviour and influencing factors, along with the households' acceptance and adoption of the system, is discussed based on data from the 19 households that completed the three surveys.

### 5.3.1 THE HOUSEHOLDS' USE OF ELIQ ONLINE

Use of the system was found to vary considerably between households. Most households used the web portal initially but decreased or even ceased using it after the first couple of months. The households that used the web portal regularly were those highly motivated to conserve energy before the study and wanted to explore ways of reducing their consumption. However, not all individuals were interested or motivated enough to engage with the web portal despite their initial positive attitude towards energy savings and/or energy feedback. Six households, all initially highly motivated to conserve energy, were identified to having used the web portal more frequently and more regularly compared to the other households.

### 5.3.2 THE EFFECTS ON ELECTRICITY CONSUMPTION

Changes in the household electricity consumption for the group of 15 households that provided complete energy data were evaluated for the medium-term, i.e. comparing the six month test period 2012 with the corresponding period 2011, and for the long-term, i.e. comparing the full year 2012 with 2011. The individual change in absolute consumption differed between the 15 households. The seven households that reduced their consumption in the medium-term attained an average reduction of 8.7% (corresponds to 5,081 kWh in total savings) while the remaining group of eight households increased their average consumption by 10.0% (corresponds to a total increase of 4,811 kWh). Five households managed to reduce their consumption by an average 8.0% when looking at the long-term change (corresponds to 4,442 kWh in total savings) during 2012 compared to 2011, and the remaining ten households increased their average consumption by 11.8% (corresponds to a total increase of 17,651 kWh). In general, households that used the web portal regularly managed to reduce their consumption to a greater extent than the others, see Figure 15. A Spearman's Rank Order correlation test found a statistically significant positive correlation between the use-frequency and attained energy savings in the medium-term ($r_s(13)$=-0.626*, $p$=0.012) and the long-term measures ($r_s(13)$ =-0.567*, $p$=.028). The results thus indicate that the use of the energy feedback system may have contributed to the observed decrease in household electricity consumption.

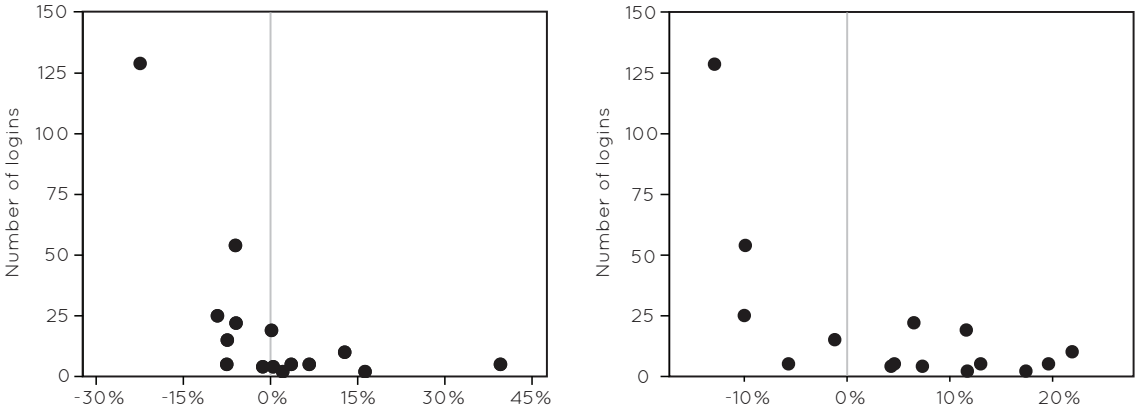



Figure 15. Average change in electricity consumption in relation to number of logins when comparing a) the test period 2012 to baseline data, and b) the full year 2012 to baseline data

*“I have worked with energy conservation a long time. We have reduced our consumption 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)

The households as a group did only marginally manage to reduce their consumption in absolute numbers in the medium-term (average decrease 0.2%) and increased their consumption in the long-term (average increase 6.1%). Even though the group did not reduce their consumption in absolute numbers, the results indicate that as a group they managed to reduce their consumption relatively compared to other households with similar consumption patterns during the baseline year. A stratified Wilcoxon test found a significant difference ($W$= 6, $p$=0.0143*) between the medium-term average change in electricity consumption for the group of 15 households compared to that of a group of matching control households. As the control households and test households displayed similar consumption patterns during 2011, the results thus suggest that the introduction of the energy feedback system in 2012 supported the test households in reducing their consumption in the medium-term. When looking at the long-term changes in average consumption, 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 15 households and the matching control households. This indicates that the households as a group managed to decrease their consumption initially, but was not able to maintain the decrease in consumption in the long run. The effects of the energy feedback system on consumption, relative to similar households, thus seem to be rather short-lived after temporary use of the system. Nonetheless, indications that a prolonged use of the web portal may result in sustained effects were seen. Access to the web portal was extended at the end of the test period for those households wanting to continue using the web portal during an additional six months. Two households did continue using the system regularly during the follow-up period and managed to reduce their average electricity consumption by an average of 9.9% during the full year (corresponding to a total decrease of 1,906 kWh).

Not everyone felt that they were able to reduce their consumption even if they would have liked to. Many mentioned aspects such as lack of task knowledge, structural preconditions, and financial means as hindering energy conservation. In addition, some experienced difficulties in decreasing consumption when the number of household members increased or when more time than before was spent at home. Another participant explained that cutbacks he had previously accomplished made further reductions difficult.

### 5.3.3 THE EFFECTS ON BEHAVIOUR AND INFLUENCING FACTORS

Some of the 19 households that completed the surveys expressed that the energy feedback system had contributed to changes in everyday energy behaviour and/or changes in influencing factors. However, no significant correlations was found between the use of the web portal and energy related behaviour, environmental attitudes, self-efficacy, motivation, knowledge, and intentions for engaging in curtailment or investment behaviours, see Paper B for more details. There may be many possible reasons for the low effect. Some households mentioned that they had not been able to report positive changes since their level of motivation or

knowledge was high already at the start of the study. Others felt that the lack of detailed data by the feedback system meant that they had not been able to learn more about how to go about reducing their consumption. Several also explicitly mentioned their family situation and lifestyle as a cause for not engaging in energy conserving behaviour. Moreover, a Spearman's Rank Order correlation test found a significant positive correlation ($r_s(17)=0.595^*$, $p=0.007$) in the medium-term between the households' use-frequency and increased agreement with the statement: "*A reduction in our energy consumption would reduce our quality of life*". The results indicate a possible shift in opinion amongst the households that used the web portal frequently; they found it more difficult to continue reducing their consumption over time without compromising their quality of life. This implies that the households that frequently used the web portal and managed to reduce their consumption initiated acceptable behavioural changes during the test period but did not feel that they were able to instigate any additional measures later on.

### 5.3.4 ACCEPTANCE AND ADOPTION OF ELIQ ONLINE

The households' general impression of Eliq Online was mostly positive and many of the households were affirmative towards using the web portal or similar energy feedback systems in the future. The majority considered the web portal to be an appropriate tool for providing energy feedback and many felt that the system suited their needs when trying to lower their consumption. In regards to ease of use, households with high use-frequency found the web portal easy to use and also considered it easy to understand the information provided online while others expressed the opposite. Understanding the information and how to act based on the provided feedback was expressed as particularly problematic. The households that used the web portal frequently felt that it did not offer them enough control and found, due to frequent experiences of the systems shortcomings, the web portal less reliable and less trustworthy than the other households. Nevertheless, the group generally found the web portal useful and capable of helping them save energy more efficiently, although it did not to any higher extent make energy conservation measures more convenient to carry out.

Few of the households that had used the web portal initially continued using the portal during the six month test period and only two households were motivated to continue using the portal long term. Several impediments were observed that limited the use of the web portal, lowered the users' acceptance, and hindered adoption. These included technical and practical barriers, lifestyle barriers, and motivational barriers, see Paper C for details. Households with high initial motivation for energy conservation expressed more technical and practical barriers while households with low motivation mentioned lifestyle barriers and motivational barriers to a greater degree. The technical and practical barriers included aspects such as the design of the interface, functionality, and usability issues, while the most commonly mentioned lifestyle related barriers were lack of time and prioritising other activities. Furthermore, some households were just not

*“ I actually consider the web portal fantastic. Unfortunately, we have not used it to the extent that it deserves to, due to time limitations and lack of motivation. I also try to avoid computers during my spare time. However, I have become generally more aware about my decisions when it comes to energy consumption. ”*

(H11)

interested in lowering their consumption or considered the information provided online to be uninteresting and unhelpful.

Another aspect that inhibited long-term adoption of the system for some households was a mismatch between the household domestic activities and the type of information channel through which the feedback was provided. Many households considered it undesirable to use a computer during their spare time to access the web portal and even though the portal was also available through other channels such as mobile phones and tablets, the households were still reluctant to access the web portal. The results indicate that, even though the portable devices might have been accessible, the use of the devices were not necessarily part of current or desired domestic activities and routines.

## 5.4 CONCLUSIONS OF STUDY TWO

The findings suggest that the online energy feedback system assessed in the study can reduce the domestic energy consumption in households under certain conditions. Significant positive correlation between the use of the system and reductions in energy use, on both medium and long-term measures, indicate that the feedback was effective as long as the households used the system. A significant difference was also found between the medium-term average changes in electricity consumption compared to the control sample. For the households that did use the system frequently and managed to reduce their consumption; average reductions of 8.7% and 8.0% were noted for the medium-term (six months) and long-term (12 months) respectively.

People interested in increasing their knowledge and awareness of their energy consumption, assessing potential investments and behavioural changes, and receiving information to use as a basis for discussion have the potential to benefit notably from this type of tool. However, as indicated by the findings, energy feedback systems are not for everyone. Few of the households adopted the system into their domestic activities due to barriers related to technical and practical aspects, lifestyle choices, and motivational factors. The feedback was not provided through a channel that fitted the technology usage habits of all households. In order to facilitate use, and increase adoption of the system, the web portal should be further adjusted to fit the users' needs and technology usage habits. It would also be beneficial to explore other channels for providing the feedback.

The overall findings suggest that access to online energy feedback does not per se make people utilise the information, although, if motivated people would use such a feedback system frequently and embrace the information provided, it can increase their awareness and support them in reducing their energy consumption. However, it is worth noting that even though feedback can enlighten and provide incentives for energy conservation it cannot in itself change the contextual circumstances that govern people's energy consumption.

# 6. DISCUSSION AND IMPLICATIONS

This chapter seeks to put the results of the studies and the research approach in relation to other relevant research to discuss the contribution and validity of the research. Key findings are reviewed in comparison to that of other studies and overall implications of the findings are discussed. The research approach is reviewed in relation to the methodology and the specific methods applied.

## 6.1 DISCUSSION OF KEY FINDINGS

The findings are discussed first in relation to the two posed research questions, as they coincide with the two studies covered in this thesis, and finally in regards to the overall contribution of knowledge on opportunities for supporting energy conservation.

### 6.1.1 PEOPLE'S PRECONDITIONS AND STRATEGIES FOR REDUCING ENERGY CONSUMPTION

The results from Study One highlight a number of factors people perceive influence their energy behaviour and affect the conservation strategies they employ. Many of the factors have been commonly discussed in energy conservation literature, while other less so. When comparing the factors identified in Study One to the factors commonly discussed in literature, such as attitude, knowledge, norms, habits, availability of artefacts, legislations and regulations, and the physical and structural environment, see Section 2.2.1, it can be noted that some aspects have been articulated from an individuals' point of view rather than from an external point of view to increase the emphasis on the preconditions and limitations of the individual. The informants did for example not mention their cognitive capabilities explicitly but many did talk about the artefacts they used and the difficulties they sometimes experienced when trying to understand how to use them correctly. However, the findings from Study One also highlight some new aspects, e.g. everyday goals, artefacts, the use context, and the market, as conservation literature in general, and energy conservation literature in particular, have not addressed these factors to great extent (Stern, 2000, Steg, 2008, Steg and Vlek, 2009). This section will therefore provide a brief discussion on some of the identified factors related to everyday activities and societal aspects that has not yet been brought forth to the same degree as the previously mentioned factors. Additionally, examples of people's strategies for managing energy conservation will be discussed in relation to the limited literature available.

The findings suggest that the conflicts people experience between multiple and competing everyday goals often make them less willing to prioritise energy conservation in many situations. Implicit goals to reduce effort, reduce time misspent, and increase well-being were identified as often conflicting with the informants' explicit goal of reducing energy consumption. These findings are in line with conclusions by Richetin et al. (2012) that identified similar goals,

e.g. maintaining an easy life, seeking immediate pleasure, and prioritising time for other activities, and by Wallenborn et al. (2011) that found that households prioritise convenient activities that provide immediate pleasure over activities that reduce their energy consumption. Gatersleben (2001) and Crosbie and Baker (2010) similarly discussed that people do not mind minor measures to reduce energy consumption as long as they do not need to make changes that could compromise their comfort, freedom, and pleasure. People's potential strategies for managing these competing goals have however not been discussed to great extent in literature. The informants' strategies identified in the study often aimed to reduce the conflicts between goals, for instance by reducing the effort or time needed, so that the goal of energy conservation was experienced as less burdensome. In line with this, Kaplan (2000) argue that desirable choices must be available for people in order for them to engage in lower energy consuming activities that do not counteract their perceived own interests. Findings by Guerin et al. (2000) also indicate that people can have strategies that eliminate conflicts by fulfilling multiple goals, e.g. performing major weatherproofing to both reduce energy consumption and to improve comfort.

The results highlight the role of artefacts and the influence of their design, functionality and usability with regards to energy behaviour. The design of artefacts has implications for peoples' understanding of the particular product, use of the product, and the use of energy during everyday activities. Furthermore, the way in which a product satisfies people's needs seem central as it can determine if the interaction results in efficient or wasteful energy behaviour. Thornander and Karlsson (2011) similarly suggest that energy wastage can be attributed to people's understanding of the product they use and to how they use it in daily life, partly as a consequence of the product functionality and design. The informants in Study One described several different strategies for reducing their energy consumption in relation to the artefacts they use; many had attempted to curtail or change their use of the appliances, maintained the major appliances in good condition, or invested in more efficient appliances. Successful strategies varied between the households and were limited by e.g. the informants' knowledge, time and effort required, or their everyday goals as discussed above. The findings of Niemeyer (2010), which identified curtailment, adjustments of use, low-cost investments, and maintenance behaviours to be strategies people engage in, are in line with these results. The results from Study One also indicate that investment decisions regarding a product can be highly dependent on the design and functionality of the product which thus influence the product's overall potential in contributing to decreasing energy consumption, for instance poor light quality of LED lights limits adoption. Few informants prioritised energy-efficiency over other aspects such as aesthetics, functionality, and price which corresponds to findings by Crosbie and Baker (2010).

The contextual circumstances in which an artefact is used, both in terms of the immediate use context and the social context, was also identified to be of importance for energy conservation. The results indicate the condition of the house and technological lock-ins to be important factors in accordance with previous conclusions made by Niemeyer (2010). The informants mentioned several strategies for improving their particular circumstances but did not however, want to engage in actions that would affect their living space negatively, even though it may have decreased their consumption. Renovating, weatherproofing, installing efficient lighting, and improving the heating system were common strategies that correspond to those found by Niemeyer (2010). Moreover, the results from Study One regarding strategies for managing discrepancies and conflicts between family members are in line with results described by Goldsmith and Goldsmith (2011) for example both deliberate strategies such as instructions and formal teaching processes, and informal strategies such as spontaneous conversations. Similarly, Kleinschafer and Morrison (2014) also describes how families, due to differences of opinion, set up rules and use sanctions to regulate and regularise other household members behaviour. The findings indicate that the energy of informants engaged in social influence strategies dwindled with time if others were too irresponsive and disinterested in making an effort.

Two aspects that have been given little attention in literature are the roles different societal players have and the role the market play in individual energy consumption. The results from Study One suggest that some informants considered many players in society irresponsible and they felt that a joint force was lacking which made them frustrated and unmotivated. Furthermore, the results suggest that people interested in investing in new appliances grow frustrated with the low availability of energy efficient technology on the market and the lack of information and guidance regarding different alternatives. These results support previous assumptions by Steg (2008), Niemeyer (2010) and Hargreaves et al. (2010) that propose low availability or poorly designed appliances to hinder investments and adoption of new energy efficient technologies. The informants did however not mention any direct strategies for influencing societal players nor for influencing the market. As it may be difficult for an individual to influence these factors Faiers et al. (2007) argues that it is the responsibility of the players on the market to provide appropriate technologies and solutions that can facilitate energy conservation for individuals in different contexts.

In summary, the results support previous literature indicating that more factors than merely psychological aspects may influence people's energy behaviour and their approach to, and engagement in, energy conservation. Positive attitudes and motivation seem relatively unimportant if people are strongly constrained by technology or external circumstances and will most likely not result in energy conservation measures in these situations (cf. Steg, 2008). In contrast, when contextual aspects strongly facilitate conservation, people may not need

to be highly motivated if energy conservation were to be naturally integrated in everyday technologies and activities (cf. Steg, 2008). Psychological aspects may however still be of importance for situations in which people are only mildly constrained or when energy conservation is neither facilitated nor hindered (cf. Gifford, 2011). The results from Study One suggest that people employ strategies for influencing factors directly associated with the activities they engage in to a greater extent than personal or societal factors. This could indicate a discrepancy between their perceived action space and their actual action space for energy conservation measures. It may also suggest that people engage in actions they perceive to be easy or believe to be effective. The most common strategies such as turning of lights or not leaving appliances on standby, may reduce consumption, but might not be the most effective strategies for significantly reducing consumption and may also prevent people from pursuing their other everyday goals. Similarly, Niemeyer (2010) also found that people overlook important strategies that might have had a more significant impact than the strategies employed. This suggest that it can be difficult to understand which strategies they can employ and which may be more effective in reducing the household overall energy consumption.

### 6.1.2 EFFECTS AND ADOPTION OF ENERGY FEEDBACK SYSTEMS

The results from Study Two indicate a reduction in energy consumption for the households that used Eliq Online frequently during the six month test period, which is in line with results observed for other feedback systems (Abrahamse et al., 2005, Darby, 2006, Fischer, 2008, Ueno et al., 2006a, Grønhøj and Thøgersen, 2011). Additionally, the results show significant reductions for the group of test households compared to the control group in the medium-term, i.e. during the period the households had access to the system. The findings also indicate that the system have the potential to motivate and support conservation activities that curtail or change the use of appliances (cf. Ueno et al., 2006a, Hargreaves et al., 2010, Grønhøj and Thøgersen, 2011), learning activities that increased awareness and knowledge (cf. Grønhøj and Thøgersen, 2011, Hargreaves et al., 2010, Wallenborn et al., 2011), and social influence processes through which the household members are given the opportunity to encourage other members of the household to reduce their energy consumption (cf. Kleinschafer and Morrison, 2014, Ueno et al., 2006a, Hargreaves et al., 2010, Grønhøj and Thøgersen, 2011). The energy feedback system thus empowered many to create new or follow through on previously formulated strategies and tactics for reducing consumption, e.g. checking the status of their consumption, analysing patterns and causes, teaching their children appropriate behaviour, and using the system to becoming aware of their actual energy consumption. Additional reflections regarding the results can be found in Paper B and Paper C.

Even though the results indicate positive effects in the medium term, the findings do not show any significant effects on energy consumption for the six month follow-up period. These findings support previous results by Van Dam et al.

(2010) and indicate that it may be hard to reach sustained conservation effects with these type of systems. Recent literature discuss a general overconfidence in energy feedback (Nilsson et al., 2014, Brynjarsdottir et al., 2012, Hargreaves et al., 2010, Strengers, 2011a) and several aspects can be identified to potentially limit the effect of energy feedback systems. First, the design of the system itself may give rise to technical and practical limitations that can make them difficult to use or hard to understand (Nilsson et al., 2014, Van Dam et al., 2010, Strengers, 2011a). Second, there are certain preconditions that an energy feedback system cannot affect, such as individual's cognitive and physical capabilities, financial means, or other contextual and societal aspects that may inhibit energy conservation measures. Similarly, Hargreaves et al. (2010) found that people felt unsupported by the broader social and policy context when making decisions or trying to engage in conservation activities. Third, even though energy feedback systems can reduce consumption through inspiring acceptable changes, it may be more difficult to change non-negotiable activities as they might compromise quality of life or everyday goals. This aspect is also brought up by Hargreaves et al. (2010) who discusses the conflicts people experience when encouraged to reduce the use of necessity appliances or the consumption associated with having a warm and cosy home. Fourth, as both Strengers (2011b) and Wallenborn et al. (2011) have discussed previously, feedback may encourage householders to reduce wasteful consumption associated with existing negotiable practices, but it may not support the development of new practices and conservation activities. Furthermore, Strengers (2011a) argues that feedback could potentially legitimise existing practices and sustain consumption instead of questioning what level of consumption is necessary. Fifth, and finally, the potential effect of energy feedback systems is limited by the actual use of the system as it can be argued that no changes in consumption can be anticipated if the feedback systems are not utilised and the feedback information not accessed. The observed decline in use over time (cf. Ueno et al., 2006a, Hargreaves et al., 2010) suggests that people do not find energy feedback interesting or worthwhile in the long run. In addition, energy feedback systems seem to only attract and support a limited target group that is already motivated to reduce their energy consumption (cf. Gardner and Stern, 2002, Fischer, 2008, Wallenborn et al., 2011). In summary, energy feedback will only be beneficial for those who use the system, embrace the feedback, are willing to reconsider their energy consumption and related behaviour, and have the possibility to change their situation.

Energy feedback, it would appear, is only as successful as the personal, activity related, and the societal factors allow it to be. Hargreaves et al. (2010) therefore argues that it is vital to ensure that all preconditions support changes in domestic energy consumption patterns if the potential of feedback systems is to be realised. Without supportive preconditions, people will be left frustrated and demotivated instead of empowered. Furthermore, to improve the effectiveness and adoption of energy feedback, it is vital to provide the feedback in an attractive and interesting

form that suits peoples' everyday activities and routines, as well as their use of different media in everyday life. Grønhøj and Thøgersen (2011) propose that feedback should be provided in such a way that it is perceived as positive support, i.e. providing relief rather than an additional obligation in everyday life.

### 6.1.3 EXPLORING WAYS OF SUPPORTING ENERGY CONSERVATION

As discussed in the previous sections, it is vital to consider not only personal factors but also activity related and other societal factors that may be relevant for individuals' energy behaviour when aiming to support domestic energy conservation. Encouraging reduced energy consumption by providing information or feedback alone may thus not result in a general decline in domestic energy consumption even though it can be successful for a specific target group. Several authors highlight the importance of considering behaviour in light of social and cultural circumstances in which behaviour is formed as part of everyday practices and activities (Lopes et al., 2012, Gram-Hanssen, 2007, Faiers et al., 2007, Niemeyer, 2010, Karlsson, 1996, Jensen, 2008). Gram-Hanssen (2007) for example, do not portray people as rational decision makers but rather as carriers of practices evolved over time with the cultural norms, social organisations and technology available in society. Others also emphasise that activities and practices undertaken by individuals are often rooted in totally different rationales than environmental considerations, e.g. creating a home (Aune, 2007), satisfying needs (Karlsson, 1996), and creating meaning (Jensen, 2008, Karlsson, 1996), and that people often differ in the way they behave (Aune, 2007, Manning, 2009, Sütterlin et al., 2011). In order to understand how to support energy conservation successfully we must therefore form a holistic understanding of how people behave with regards to energy that acknowledge the cultural and social practices that drive consumption, the diverse characteristics and preconditions of individuals, as well as the role technology plays in everyday activities. Furthermore, as the behaviour and practices evolve with society it is important to broaden the scope from placing the sole responsibility on the individual to placing a shared responsibility on all societal players that govern future domestic practices and consumption behaviours. Such a systemic perspective requires many players to join forces in facilitating domestic energy conservation, e.g. policy makers, urban developers, construction companies, housing suppliers, and product manufacturers. Energy conservation must thus be supported on many levels, stretching from implementing new policies and regulations (Almeida et al., 2011, Dolan et al., 2012, Faiers et al., 2007, Jensen, 2008) to developing new technologies that enable both society and individuals to move towards new ways of living (Gram-Hanssen, 2008, Strengers, 2011a).

For designers specifically, these perspectives provide a variety of opportunities to explore when aiming to support domestic energy conservation through the design of products, services, and systems. Artefacts and conditions that facilitate energy conservation can be designed to enable people to engage in desirable activities and practices that allow them to satisfy their needs and to reach their everyday

goals without consuming large amounts of energy. Facilitating convenient and energy efficient interaction with artefacts can help people reduce consumption while using the artefacts in a desirable way that make sense to them whether or not they have a current goal for reducing energy consumption. Alterations through redesign of artefacts may have the potential to dissolve old habits and establish new desired behaviours and practices that require less energy (cf. Elias et al., 2009). Providing new types of artefacts can also potentially move society towards less resource intensive lifestyles as it has the potential of reconfiguring the current constitutions that govern practices and activities today (cf. Kuijer and Jong, 2012).

There are also several opportunities for supporting those that have an interest in reducing their consumption, both by facilitating current conservation strategies and for enabling and spurring new strategies. For instance, strategies to increase convenience and reduce effort when engaging in energy conservation measures can be supported by improving the design, functionality and usability of artefacts or by making energy efficient interaction intuitive or the most convenient option (Lockton et al., 2008, Elias et al., 2009). People eager to learn more about their energy consumption and increase their task knowledge regarding certain measures could e.g. be provided with relevant information and feedback, or tools that enable them to keep track of and analyse their consumption patterns and behavioural alternatives. Strategies for curtailing energy consumption or changing the use of specific artefacts might be facilitated by integrating feedback on behavioural performance in specific appliances, which according to Wood and Newborough (2003) may empower people to more easily adjust the use of them. Strategies to improve the conditions within the use context by making investments and carrying out renovations, for example, could be supported by explicitly providing relevant information on products and packaging, or by ensuring that appropriate information material is provided to and utilised by retailers and suppliers. People seeking to stimulate discussion and reduce conflicts with other family members could be supported by tools that offer suitable feedback to be used as a basis for discussion, or ways of educating children regarding energy conservation.

In order to support energy conservation through redesign or introduction of new products and services it is vital to facilitate the ease with which people in society can adopt the technologies. To succeed in developing artefacts that are accepted and adopted it is necessary to consider current activities, practices, and expectations and based on this understanding provide lifestyle benefits that allow for satisfying user experiences rather than lifestyle disadvantages. Lifestyle benefits are, according to Crosbie and Baker (2010), a stronger motivational factor than environmental or monetary gain and may thus to a greater extent make people prioritise certain artefacts and activities. Rogers (1995) describes several aspects that influence the process of adoption such as the characteristics of the innovation, the channels used for communication, the social system in which the innovation is introduced, and

the time period from first introduction until adoption or rejection. To facilitate adoption of products one could thus, for example, improve their perceived relative advantage, increase the ease of use, improve the compatibility with the social system, and allow sufficient time for people to form positive attitudes towards the products that may lead the individual deciding whether to adopt or reject the products. Furthermore, Jensen (2008) argues that it is important to give low-consuming technologies a form and style of normality and simplicity. Instead of emphasising the environmental benefits, other qualities of the products or how the products should be used could be highlighted to form the basis of the selling argument. Aune (2007) similarly suggests that an understanding of people's domestication processes can provide new input on how products can be designed to match the style and practice of home making which in turn may facilitate the adoption of energy-efficient technology.

## 6.2 DISCUSSION OF RESEARCH APPROACH

The mixed methods approach undertaken was aimed to address the posed research questions in the most suitable way in regards to the specific questions, current knowledge, available resources, and previous research within the field. This section provides reflections regarding these aspects in relation to the two conducted studies.

Conducting Study One as an interview study instead of, for example, using a survey to collect the data meant that it was possible to gain more insight into the informants' relation to energy conservation and their reasons for engaging or not engaging in conservation measures. The informants were not restricted to predefined alternative answers or questions and were allowed to freely elaborate on aspects they considered relevant. However, carrying out the interviews with individuals in an university setting without mediating objects, i.e. objects that stimulate discussion, did probably limit the informants' narratives. If more resources had been available, it would have been preferable to conduct exploratory interviews in the informants' homes and involve other family members as well. The final sample of 42 informants may seem redundant compared to other similar studies, which have reached sample saturation with fewer participants. But as this study sought to explore factors that might influence people's approach to energy conservation, the sample was increased to include a larger variety of people from different areas and backgrounds with diverse demographic characteristics.

Study Two was conducted as a field trial to gain insight into real life circumstances and to evaluate the effectiveness and adoption of the system in everyday life setting. The different types of data were collected to complement previous work on energy feedback systems by including data that is often missing in other studies, i.e. data on the household use and acceptance of the systems and longitudinal data to enable evaluation of long-term effects. Available resources did not allow for in-depth interviews to assess effects and changes in behaviour throughout the study,

instead online surveys were chosen to complement and triangulate the quantitative data on the household electricity consumption and use of the web portal. The survey questions were constructed in the same manner as many previous studies to enable future comparisons between studies. The study would have benefitted from including family interviews in a home setting to more holistically explore how their approach to energy conservation might have changed over time in order to identify underlying reasons that might have enabled the change. During the recruitment process, care was put into recruiting a sample with varying degrees of prior engagement in energy conservation since previous studies often include only highly motivated participants. The sample size was however limited due to the number of available measuring devices provided by Exibea. Due to the small sample size of 23 households, non-parametric statistics were applied during the analysis. To further triangulate and increase the validity of the data, a control sample was used to contrast the electricity consumption of the test households to the consumption of similar households.

One particular overall challenge experienced throughout the research work is the multidisciplinary aspect of the research topic. In order to further improve the overall understanding of energy conservation and contribute to the existing paradigms exploring the topic, several different approaches to explaining behaviour have been taken into consideration during the research. Initially, the research was influenced to a high degree by environmental psychology, which partly set the research focus and influenced the choice of methods for the two studies. As more insight into the topic was gained, it was essential to expand the narrow notion of behaviour and address also the notion of everyday activities and practices. Energy behaviour has thus been discussed in a wider perspective when interpreting the results in order to acknowledge other views and contribute to a more holistic understanding.

# 7. CONCLUSIONS

The findings discussed in this thesis highlight the importance of acknowledging not only psychological factors, but also other personal factors along with activity related and societal factors when discussing people's approaches towards energy conservation. These factors set the preconditions for possible and desirable conservation measures and can often explain people's lack of engagement for reducing energy consumption. Societal factors or contextual preconditions may hinder action even if the individual is highly knowledgeable and motivated. In contrast, competing everyday goals may make people prioritise energy intensive activities even if they are not physically restrained from reducing consumption. People thus engage in energy conservation measures to the extent that makes sense to them depending on their preconditions. To understand people's approach to energy conservation a systems perspective is therefore needed that takes into account the interconnectedness of the different factors.

Understanding people's energy behaviour and approach to energy conservation is vital when aiming to support them in reducing their consumption. As this research have indicated, energy feedback is one important option for supporting those that seek to increase their knowledge and explore effective ways of reducing their consumption, but feedback alone may not be enough to influence the activity related factors or societal preconditions that govern how or why people consume energy. There are however many other opportunities for designers, as well as other players to find ways of supporting society to move towards decreased consumption, by developing products, services, and systems that enable, support, and encourage people to use them energy efficiently while increasing their quality of life. However, when doing so it is essential to acknowledge the complexity of human behaviour and consider various preconditions and the different factors that may sometimes hinder change or drive individual behaviour in unexpected directions.

To further increase the understanding of how to support energy conservation, it would be advantageous if future research continue exploring how people's preconditions, related to personal factors, activity related factors and societal factors, influence their approach to energy conservation. It would be very valuable to gain insight into how people prioritise between different activities and goals related to energy consumption in order to identify explicit windows of opportunities for design. Additionally, exploring to what degree different artefacts can lower consumption would also be beneficial as it may help to identify appropriate ways for different players to support energy conservation.

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