Designing for shared energy responsibility

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Abstract

A significant part of the world's carbon emissions is related to energy use for housing and personal transport, and there are many efforts to make this energy use more sustainable. In the field of Sustainable Human-Computer Interaction, there has been a great interest in exploring how interactive systems can be used to influence people's energy use, often with a focus on providing information and encouraging energy users to change their behaviours. Similar ideas have been implemented in commercial products aiming to raise households' awareness of their energy use. This approach suggests that energy use is a matter of individual choice, and that it is the energy user's responsibility to change energy-related practices such as driving, cooking and heating the home. The effectiveness of the approach has, however, been questioned and it has been proposed to extend the focus beyond the individual – to the communities, corporations and governments that influence people's energy practices.

With my research, I have aimed to contribute to an understanding of how various stakeholders can *share responsibility* for energy use and of how to take shared responsibility into account in design. The research has a starting point in studies of *sustainable mobility* and *energy management in housing cooperatives*. For these two cases, I have used design interventions to explore energy-intensive practices and more sustainable alternatives from the perspectives of both energy users and other stakeholders. In the thesis, I present ways that stakeholders influence, or could influence, energy use in terms of adoption of more sustainable practices and maintenance of these practices over time. Building on these findings, I suggest opportunities for interactive systems to amplify stakeholder initiatives and support shared responsibility for energy use, for example by contributing to transparency and trust between households and more powerful stakeholders. This includes to consider design sensitivities such as tensions between "odd" and "normal" practices, when and how to engage different stakeholders, and designing for other values than resource optimisation.

Sammanfattning

En stor del av världens koldioxidutsläpp kommer från energianvändning kopplad till boende och persontransporter, och mycket resurser läggs på att göra denna energianvändning mer hållbar. Inom forskningsområdet Hållbar människa-datorinteraktion finns många exempel på studier av hur interaktiva system kan användas för att påverka människors energianvändning, ofta med fokus på att tillhandahålla information och att uppmuntra energianvändaren att förändra sitt beteende. Det finns också många kommersiella produkter som bygger på liknande idéer om vikten av att hushåll blir medvetna om sin energianvändning. Ett sådant fokus utgår från att energianvändning är ett val som görs på individuell nivå och att det är individens ansvar att själv förändra sin energianvändning, men från forskningsresultaten är det tveksamt hur effektivt detta är. För att förändra energianvändning i hushåll kan fokus inte bara vara på individuellt ansvar för förändring. Vi behöver även förstå hur beteendemönster kring boende, transporter, mat och konsumtion, som resulterar i energianvändning, påverkas av andra aktörer som företag, politiker och olika samhällsgrupperingar.

Med min forskning har jag haft som mål att bidra till en ökad förståelse för hur olika aktörer kan *dela ansvar* för energianvändning och hur man med design kan stödja ett sådant gemensamt ansvar. Som utgångspunkt för forskningen har jag två studier – den första handlar om *hållbar mobilitet* och den andra handlar om *energiarbete i bostadsrättsföreningar*. I studierna har jag använt designinterventioner för att utforska både beteendemönster kopplade till hög energianvändning och alternativa beteendemönster som är mer hållbara. I avhandlingen presenterar jag olika sätt som dessa aktörer påverkar, eller skulle kunna påverka, hur nya, mer hållbara, beteendemönster kan spridas och behållas över tid. Baserat på detta ger jag förslag på hur interaktiva system kan förstärka befintliga aktiviteter som redan utförs av olika aktörer och stödja gemensamt ansvar för energianvändning, till exempel genom att bidra till transparens och tillit mellan hushåll och aktörer med större makt. Detta inkluderar att i designen av systemen ta hänsyn till aspekter som spänningar mellan “udda” och “normala” beteenden, när och hur olika aktörer kan involveras, och att designa för andra värden än resursoptimering.

Acknowledgements

When I applied for PhD studies five years ago, my motivation was primarily related to the opportunity of working with and learning about sustainability issues, rather than to a strong interest in doing research. And with a background as designer, I had a feeling I already knew how to do research since every new design case requires exploration. Five years later I have indeed learned a lot about sustainability, but definitely also about how to do research and make use of my design skills to contribute to creating new knowledge – a learning experience which many people have contributed to.

First, I want to thank my main supervisor Cristian Bogdan for pushing me to move from the consultant mindset of delivering good projects to thinking about what makes interesting and important research, and for supporting and finding ways of making it possible for me to work on the research I was most passionate about. I am also grateful to my co-supervisors: Mario Romero who has provided both learning opportunities and enthusiasm; Ylva Fernaeus who, between parental leave and other supervision duties, has found the time for valuable discussions and feedback; and Elina Eriksson who always has wise things to say about research, sustainability and life in general. In addition to my supervisors, I appreciate the support I have received from Maria Håkansson, discussant at the 50 percent seminar, and Rob Comber, discussant at the 80 percent seminar, who both took the time to read my work, provide feedback and engage in encouraging and inspiring discussions. I would also like to thank Olle Bälter for conducting the internal review of the thesis.

Although doing a PhD is in some ways a very individual undertaking, I have really enjoyed to explore sustainability issues, energy use and design opportunities together with other researchers. I am grateful to have gotten the opportunity to be part of the project A Car-Free Year, and special thanks to Teo Enlund for managing the project and welcoming me to the team. The car-free year study would not have been the same without my PhD colleague Mia Hesselgren – thank you for sharing both the fun and the difficulties of the study and for all our more general design research discussions. I have also had the opportunity to explore energy use together with researchers from outside of Sweden and from various backgrounds, including Giacomo Poderi, Yilin Huang and Sanja Šćepanović whom I have greatly appreciated working with in the CIVIS project. I would also like to thank Omar Shafqat for introducing me to the local energy research context in Stockholm.

Not all projects explicitly made it to the thesis, but they were nevertheless valuable experiences. Many thanks to Anders Lundström for early on including me in your research, and for the many discussions beyond that study. It has also been a pleasure to work on smart grids research with Cecilia Katzeff (including sharing an office) and our colleagues from RISE Interactive. In addition, all of the projects involved study participants and partners from outside of academia, without whose participation there would not have been any research.

Furthermore, I have benefited from being part of a number of research contexts at KTH. It has been inspiring to hear about other design and sustainability projects in the Green Leap group and valuable to spend time working in the CESC corridor – many thanks to Mattias Höjer for inviting me to CESC and to everyone else for good company and nice coffee breaks. I have also enjoyed the creative company in the Interaction Design Jungle, the sustainability discussions in the MID4S team, and working together with many other current and former colleagues at the MID department. And, although not present in person in Stockholm very often, I am grateful to have shared PhD time with Christiane Grünloh – special thanks for generously passing on your insights from being one step ahead in the process of finalising the thesis.

I moved to Stockholm for the PhD studies but, no matter what some people say, PhD life is not only about research. Many thanks to my friends and family, in Stockholm and visiting, who have made life here a better experience and made it easy to forget about work when needed. There are also occasions when both worlds meet in beautiful ways. In Filip I have been lucky to find not only a programmer helping me to realise design ideas for research, but also someone to share small and big adventures with outside of work.

Hanna Hasselqvist
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Contents

1 Introduction

Energy is an integral part of life and although it is often described as "invisible", and therefore presumably difficult to understand and influence, it provides very concrete values. Energy is used for meeting basic needs as well as for fulfilling desires and realising dreams – we use it for food production, manufacturing of goods, making homes comfortable and moving ourselves around. However, currently the world's energy use comes at a huge environmental cost. Despite increases in renewable energy and nuclear power, coal is still the most common source for electricity production and the transport sector almost solely relies on fossil fuels (International Energy Agency, 2017). To reduce the environmental impact of energy use, there are goals of increasing the efficiency throughout the energy systems, of reducing the demand for energy, and of switching to renewable energy production. At the same time, the use of energy is extremely unevenly distributed around the world, and an important part of social sustainability work is increased access to energy in developing countries.

There is a lot of research on energy use, distribution and production, and for many years energy has also been an important topic for research in the field of Sustainable Human-Computer Interaction (Sustainable HCI). In Sustainable HCI, energy can be an explicit concern, such as in studies of how interactive technologies can support reduced or shifted energy use in homes (e.g. Dillahunt & Mankoff, 2014; Strengers, 2011a; Yang, Pisharoty, Montazeri, Whitehouse, & Newman, 2016), or more implicit, such as in studies of eco-feedback for transport (Froehlich et al., 2009) or of support for reflections on food waste (Ganglbauer, Fitzpatrick, & Güldenpfennig, 2015). Much research in Sustainable HCI have focussed on increasing people's awareness and knowledge of their own (and other's) energy use, with the aim of encouraging a more sustainable use of energy (Brynjarsdottir et al., 2012). This approach has, however, been criticised for focussing too much on persuading individuals to make the "right" choices, which has turned out to be very difficult and often comes with a simplified view of sustainability that promotes only incremental change (ibid). In order to influence energy use, it is important to understand the practices behind energy use: "…*since energy demand is an outcome of what people do, any radical change depends on reconfiguring the practices that comprise everyday life*" (Shove, Watson, & Spurling, 2015, p.2). For Sustainable HCI, understanding practices requires consideration of many other elements of practices than interactive systems (Pierce, Strengers, Sengers, & Bødker, 2013). It also requires consideration of new types of interactions and engagements. Changing the way energy is used cannot be considered only a responsibility of "energy users", since there are many other stakeholders, such as governments and companies, that may have greater possibilities to influence energy-intensive practices (Shove, 2010). There are, however, few studies in HCI actively engaging with or designing for such stakeholders.

To understand which stakeholders may influence energy-intensive practices and how they could share responsibility for energy use, it is necessary to first try to understand configurations of these practices. There is a growing body of work in HCI concerned with energy-intensive practices, and in my PhD research I have built on this work in explorations of practices related to sustainable mobility and domestic energy use. In addition, the papers included in this thesis contribute to an understanding of how various stakeholders are, or could be, engaged in changing energy-intensive practices and how this can be considered in design of interactive systems and other types of interventions.

1.1 Objective and research questions

The objective of my PhD research has been to contribute to transitions towards sustainable use of energy by exploring two cases: (1) energy use in homes, with a focus on energy management practices in housing cooperatives, and (2) sustainable mobility, with a focus on car-free transport practices. In terms of sustainability, I have mainly addressed environmental aspects of energy use, with the aim of reducing negative environmental impact of energy use in a Swedish or Western context. The ambition has specifically been to explore this from a design perspective and to contribute to the sustainability discourse in HCI as well as in a broader design field. The contributions address the following research questions:

RQ1: In what ways do stakeholders influence, and could share responsibility for, resource use in energy-intensive practices?

RQ2: What design sensitivities are important to consider when aiming to support the types of stakeholder influence and opportunities for shared energy responsibility identified in RQ1?

1.2 Papers included in the thesis

The contributions of this thesis are published in five papers. Below is a summary of each paper and its specific contributions, as well as a description of my contributions to the different papers.

Paper I: Challenging the car norm: Opportunities for ICT to support sustainable transportation practices

Hasselqvist, H., Hesselgren, M. and Bogdan, C. (2016). In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*, 1300–1311.

This paper is based on the outcomes of a project called "A car-free year", where we explored what more sustainable transportation practices may look like and how these can be supported by various stakeholders. In many contexts, the car has become an important part of numerous practices, at the expense of both local air quality and the global climate. To see how car-dependent practices change if the car is removed from the equation, we studied three families in Stockholm who replaced their cars with light electric vehicles (electric bikes, box bikes, scooters and four-wheeled motorcycles) during one year. In the paper, we present the findings from the car-free year analysed from a practice perspective. Furthermore, we discuss a number of opportunities for designers of interactive technologies to support car-free living. Concrete transport-related suggestions include supporting "odd" types of vehicles, such as electric bikes and box bikes; providing services for transporting stuff away;

facilitating helping between users of different transport modes; and designing travel planning tools not only to optimise time and cost but also to highlight positive values of sustainable mobility. Furthermore, the analysis resulted in more general design sensitivities for work aiming to support transitions towards sustainable practices: considering tensions between "odd" and "normal" practices, understanding which actors beyond the individual that can influence important elements of sustainable practices, and designing for other values than resource optimisation.

The car-free year project was a collaboration between KTH Royal Institute of Technology and the non-profit organisation Sustainable Innovation, and many people were involved in setting up and carrying out the project. Mia Hesselgren and I were in charge of the research activities; we planned and carried out the interviews and observations, as well as analysed the material. I had the main responsibility for writing this paper, which was written together with Mia, and for developing the HCI aspects of the background and analysis. Cristian Bogdan contributed with comments on the paper and suggestions for how to articulate more general design implications.

Paper II: Give car-free life a try: Designing seeds for changed practices

Hesselgren, M. and Hasselqvist, H. (2016). In *Proceedings of DRS2016: Design + Research + Society - Future-Focused Thinking*.

This paper is another result of the car-free year study (presented in paper I). We found that an important aspect of the car-free year was the support the project provided to the participating families – both in terms of addressing practicalities and in terms of dealing with being different. Many practices were affected when the families removed their cars, and in this paper we focus on three types of practices with different temporal occurrences: daily commuting, regular transport to evening activities, and occasional weekend or holiday trips. Furthermore, we identify stakeholders that may influence transport practices, such as workplaces, bike service shops and public authorities. We discuss how they together could make it easier for people to try out new transport practices, for example by providing services that combine rental of light electric vehicles with maintenance of the vehicles and advice on how to use them. To support transitions towards sustainable practices, we also suggest that design needs to understand and intervene at *tipping-points* in life when people's practices are disrupted, for example by a move to a new place or the breakdown of an old car.

The paper is based on Mia Hesselgren's and my analysis of the car-free year study. We planned and structured the paper together, and I contributed to the writing which Mia had the main responsibility for.

Paper III: Bridging citizen and stakeholder perspectives of sustainable mobility through practice-oriented design

Hasselqvist, H. and Hesselgren, M. Accepted for publication in *Sustainability: Science, Practice and Policy (SSPP)*.

Based on the analysis of practices in the car-free year study presented in Paper I and Paper II, we created concepts for sustainable mobility to visualise important elements of car-free transport practices and to support discussions of transitions towards such practices. The concepts were co-created together with a design firm and the families participating in the car-free year study. In this paper we present the concepts, which are divided into four themes: trying out new mobility practices, cycling infrastructure, child-friendly public transport, and transporting stuff. We used the concepts, together with a video and descriptions from the car-free year study, in mobility discussions with private and public sector stakeholders. The discussions were analysed with a focus on the interests and responsibilities of different stakeholders. We found greater interest in practices related to commuting compared to leisure related practices, although leisure related practices may be even more important to address to reduce car-dependency. Furthermore, we identified clashing responsibilities of different stakeholders that may limit their influence towards more sustainable mobility. In the paper, we also discuss how practice-oriented design can support stakeholder discussions as well as support stakeholders in learning about mobility practices.

The sustainable mobility concepts were created in collaboration with the design firm Propeller in Stockholm. Mia Hesselgren and I both participated in all the concept discussions with stakeholders, and we analysed the stakeholder discussions and structured the paper together. I had the main responsibility for writing the paper and Mia was in charge of the methods description and discussion of practice-oriented design.

Paper IV: Linking data to action: Designing for amateur energy management

Hasselqvist, H., Bogdan, C. and Kis, F. (2016). In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems (DIS '16)*, 473–483.

This paper presents results from our work with housing cooperatives in Stockholm, where we identified amateur energy managers in housing cooperatives as interesting actors with a potentially high influence on energy use in apartment buildings. In Swedish housing cooperatives, the buildings are owned by the residents, with a board selected among the residents to be in charge of management of the buildings. This includes responsibilities related to energy use, but the board members might not know much about energy issues. In our study, we identified challenges and concerns of amateur energy managers in housing cooperatives and based on these we designed an energy app that aims to support amateur energy management work and sharing of experiences between housing cooperatives. The app allows housing cooperatives to see their own and other cooperatives' energy use data and register actions they have taken to reduce energy use. From the design work, including feedback from six housing cooperatives testing the app, we identified important design aspects to consider when aiming to support amateur energy management: supporting amateur energy managers in implementing energy reduction actions, working with long time perspectives that reflect the many years it may take to implement energy actions in housing cooperatives, and sparking energy interest among housing cooperative members.

The work behind the paper was done within a larger EU project where the housing cooperative study was only one of many parts. I planned and carried out the study on housing cooperative energy management and designed the energy app, which Filip Kis developed into a functioning web application and integrated into the technical platform of the EU project. I analysed the interview data and other material, and wrote the main part of the paper. Cristian Bogdan was in charge of the amateur perspective in the paper and contributed to the overall writing, and Filip described the technical aspects of the app development.

Paper V: Designing for diverse stakeholder engagement in resource-intensive practices

Hasselqvist, H., Eriksson, E. (2018). In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction (NordiCHI '18)*, 426-438.

The work with housing cooperatives continued beyond the study presented in Paper IV, and through the long-term engagement our understanding of practices related to housing cooperative energy management increased. We found that many stakeholders, such as municipal energy advisors, building management companies and energy companies, influenced housing cooperative energy management practices and that the opportunities of addressing and designing for only housing cooperatives were limited. In this paper, we present the results from meetings with these stakeholders that already engage with housing cooperatives in various ways, for example by offering energy advice, providing building management and building maintenance services, and trying out new types of energy services and support. We identified a number of design opportunities to support these specific activities and reflect on how the aim of supporting stakeholder engagement affects design considerations compared to when designing only for housing cooperatives. Finally, since Sustainable HCI researchers have called for more studies that target people in other roles than individual consumers, we discuss how a focus on supporting more diverse stakeholder engagement can be considered generally in Sustainable HCI in terms of: which stakeholders and practices to include, temporal aspects of engagement, and opportunities for supporting shared responsibility for resource use.

For this paper, I planned and held the stakeholder meetings, analysed the outcomes and related it to other work in Sustainable HCI. I wrote the main part of the paper and Elina Eriksson contributed to the overall writing and to refining the arguments.

1.3 Additional publications

In addition to the papers included in the thesis, I have contributed to a number of other peer-reviewed publications related to the topics of energy use, sustainability and design:

Huang, Y., Hasselqvist, H., Poderi, G., Scepanovic, S., Kis, F., Bogdan, C., Warnier, M. and Brazier, F. (2017). YouPower: An Open Source Platform for Community-Oriented Smart Grid User Engagement. *14th IEEE International Conference on Networking, Sensing and Control*.

Hesselgren, M., Hasselqvist, H. and Sopjani, L. (2017). Design strategies for exploring and bridging: Intersections of everyday life and decision-making for sustainability. In *Conference proceedings of the Design Management Academy: Research Perspectives on Creative Intersections*.

Hasselqvist, H., Bogdan, C., Romero, M. and Shafqat, O. (2015). Supporting Energy Management as a Cooperative Amateur Activity. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '15)*, 1483–1488.

Hesselgren, M., Hasselqvist, H. and Eriksson, E. (2015). A car-free year: providing vehicles for change. *Nordes 2015: Design ecologies*.

Romero, M., Hasselqvist, H. and Svensson, G. (2014). Supercomputers Keeping People Warm in the Winter. *ICT for Sustainability 2014 (ICT4S '14)*.

Hasselqvist, H., Bogdan, C., Jeon, A. and Kankainen, A. (2014). Tackling the "unknown sustainability" with service design methods: two case studies. In *Proceedings of XXIV Annual RESER Conference 2014*, 544–559.

1.1 Thesis outline

This thesis is a compilation thesis where the papers, which can be found in the second part of the thesis, are the main contributions of my PhD research. The first part of the thesis summarises and synthesises the results of the different papers and provides a more holistic picture of my research, in relation to the research field I aim to contribute to, than the papers alone. This part of the thesis is structured as follows: *Chapter 2* provides a background to my research through a summary of general aspects of sustainability I find important, an introduction to the research field Sustainable HCI, and an overview of previous research addressing energy-intensive practices and ICT. In *Chapter 3*, I briefly describe the theoretical framework practice theory, with a focus on details and views of practice theory that are important for understanding how I have applied practice theory in my studies. In *Chapter 4*, I present my research approach and how I have combined design-oriented research with a practice theory perspective. *Chapter 5* is a summary of the main contributions of my research, which answers the research questions presented in section 1.1. *In Chapter 6*, I discuss the results and my research approach, including what was not done as part of the research and suggestions for future research. Finally, in *Chapter 7* I revisit the research questions and present the conclusions of the thesis.

2 Background: Sustainability, HCI and energy-intensive practices

Contributing to sustainability has been a fundamental motivation for my research, and I start this chapter by briefly introducing aspects of sustainability that I find relevant. This is followed by an overview of research within field of Sustainable HCI and more details on research specifically addressing energy-intensive practices and ICT, with a focus on practices related to mobility and domestic energy use.

2.1 Sustainability and energy use

Central to most notions of sustainability is the idea of environmental constraints – there are limited resources on the planet and limits to how much the ecological systems can change if the planet is to remain in a stable, and for humans favourable, state. Steffen et al. (2015) have explored these limits, framed as *planetary boundaries*, and identified a "safe operating space" in which the risks for humanity are low. Climate change is a core boundary that has already been exceeded and we are consequently operating outside of the safe space. The world's energy use has a direct effect on climate change, with 80% of the global energy use currently depending on fossil fuels (International Energy Agency, 2017).

Adding to the planetary boundaries, Raworth (2012) suggests the concept of "a safe and just space for humanity" where people's basic needs are met without exceeding the planetary boundaries. Raworth stresses that both planetary boundaries and human needs are normative concepts rather than definite limits; it is negotiable what is acceptable risk for the planet and what are acceptable lower limits of well-being. This is negotiated locally as well as globally, and a recent example of a global agreement on both environmental risks and social development is the United Nations' Sustainable Development Goals (SDGs)[1].

However, in a changing world, sustainability continuously has to be renegotiated. Robinson (2004) suggests that sustainability should be perceived as a process, rather than a measurable goal, and distinguishes between two main approaches to sustainability: one promotes sustainable development in terms of technology and efficiency measures, and the other is a more radical approach that challenges growth and current lifestyles. Much technology-centred energy research is close to the first approach, by for example exploring how to optimise energy use and to increase production and use of renewable energy. It is however very questionable if efficiency measures alone are enough to sufficiently reduce the environmental impact from resource use (Haberl, Fischer-Kowalski, Krausmann, Martinez-Alier, & Winiwarter, 2011). In addition, an efficiency-approach can have rebound effects, when reduced costs due to optimisations of technology or processes result in a growth of technology use and an overall increase in energy use (Hilty, 2012).

2.2 Sustainable HCI

Sustainability has been an explicit concern in HCI for many years, through communities such as Sustainable HCI, HCI for development (HCI4D), and, more recently, Computing within Limits. In Sustainable HCI, two main research directions can be distinguished: "sustainability *in* design" and "sustainability *through* design" (Mankoff et al., 2007).

"Sustainability in design" is concerned with the direct environmental effects of the production, use and disposal of technology, and how HCI and interaction design may add to or mitigate negative effects. Although direct effects may seem like a concern mainly for the design of hardware, the design of software also matters for aspects such as use of physical materials and longevity or obsolescence of hardware (Blevis, 2007; Remy & Huang, 2015). In addition, interaction design affects the energy use of digital infrastructures, for example when efforts to improve user experiences and to create new

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1 https://sustainabledevelopment.un.org/sdgs

engaging services result in increased energy needs for data storage (Preist, Schien, & Blevis, 2016).

My research belongs to the other direction of Sustainable HCI, "sustainability through design", which is concerned with how interactive systems can be used to support sustainable lifestyles and thus indirectly have *positive* effects on the environment. There is a large body of work in HCI exploring this, much of which has had a focus on promoting resource efficient behaviours by providing feedback on resource use (Brynjarsdottir et al., 2012). However, Brynjarsdottir et al., among others, question the effectiveness of such persuasive technologies in changing how people use resources. Suggestions for increasing the impact of sustainable HCI research include: exploring and understanding resource-intensive practices (Strengers, 2011a), and moving from a focus on individual consumers to other intervention levels (Dourish, 2010), for example by engaging directly with decision-makers (Prost, Mattheiss, & Tscheligi, 2015). Linking back to the negative environmental impact from energy use and materials in interactive systems, it is also suggested to remember that technology is not always an appropriate approach and interactive systems may in some cases even do "more harm than good" (Baumer & Silberman, 2011).

2.3 Energy-intensive practices and ICT

Energy use for housing and transport constitute more than half of the world's energy use (International Energy Agency, 2017), which significantly contributes to carbon emissions and climate change. From a Swedish household perspective, about 20% of a household's carbon emissions are housing related and about 30% are transport related[2] (Naturvårdsverket, 2017). There are numerous practices that contribute to this energy use, but all practices are of course not equally energy intensive. Travelling by car is usually more energy intensive than using public transport, and in Swedish homes more energy is used for heating than for lighting. It can, however, be difficult for households to connect energy use to practices or use such connections to change energy use. Strengers (2011a) found that people who receive energy feedback do not necessarily identify the practices with the highest impact on energy use and

2 Based on a consumption perspective, i.e. including both domestic and international emissions from Swedish consumption, measured in CO2 equivalents.

change those, but instead take what they perceive as green actions, such as turning off appliances or changing to more efficient lighting. Furthermore, design research aiming to promote sustainable behaviours also often fail to identify and address resource-intensive practices (Coskun, Zimmerman, & Erbug, 2015).

Among energy-related design research, a majority of the work focus on energy use in buildings, and particularly domestic electricity use (Coskun et al., 2015; Pierce & Paulos, 2012a). This includes how to make people aware of, and learn about, their energy use (e.g. Broms et al., 2010; Schwartz et al., 2013); how to motivate and support people to reduce their energy use (e.g. Dillahunt & Mankoff, 2014; Strengers, 2011a; Yang, Pisharoty, Montazeri, Whitehouse, & Newman, 2016), and how to support people in shifting electricity use to non-peak times or to times when renewable electricity production is high (e.g. Costanza et al., 2014; Sugarman & Lank, 2015). This research has, however, identified many challenges to changing energy-related practices with the help of interactive systems. At the core of these challenges is the perception of many practices in the home as non-negotiable (Strengers, 2011a). When people feel that current practices are too important to change, providing energy feedback may cause a lot of frustration and make people feel "helpless" (Prost et al., 2015). As an alternative to trying to influence practices, technology is often explored as a means for directly increasing energy efficiency and reducing energy waste in homes, for example through smart thermostats and energy systems controlled by occupancy prediction (Koehler, Ziebart, Mankoff, & Dey, 2013; Yang & Newman, 2012).

There are examples of research going beyond feedback or efficiency approaches by investigating alternatives to energy-intensive practices, such as design supporting person heating (e.g. use of hot water bottles) rather than space heating of entire rooms (Kuijer & Jong, 2012) and design that challenges the idea of thermal comfort being a result of constant heating and static temperatures (Clear, Friday, Hazas, & Lord, 2014). Other examples that are different from most Sustainable HCI work is research that considers the perspective of both energy users and energy professionals in practices such as facilities management and energy auditing (e.g. Finnigan, Clear, Farr-Wharton, Ladha, & Comber, 2017; Mauriello, Norooz, & Froehlich, 2015).

Research on mobility with an explicit energy and sustainability perspective has received less attention in HCI than building-related energy use. There is, however, research addressing feedback on environmental impact of transport choices (Froehlich et al., 2009) and design explorations of how the energy use of electric cars can be presented to reduce range anxiety (Lundström, 2016). There is also research that connects mobility and energy use in homes, such as investigations of how locally produced solar power can be used to power electric cars (Bourgeois et al., 2015) and of how electric cars can be used as batteries to help households reduce the use of electricity from the grid during peak hours (Brush, Krumm, Gupta, & Patel, 2015).

Whether or not ICT is used for sustainability purposes, interactive systems are already integrated in, and have influenced, many mobility practices. ICT allows for travel planning on the go, provides opportunities for work or other activities while commuting, and can support people in coordinating trips or use of vehicles. While ICT often is expected to reduce the environmental impact of travelling, for example by replacing the need for travelling with online meetings, ICT may at the same time contribute to an increased amount or distance of trips through optimisation of the transport system (Cohen-Blankshtain & Rotem-Mindali, 2016).

Overall, much Sustainable HCI research related to energy use has focused on providing information and persuading individuals to use resources differently. Such approaches have been criticised for framing sustainability as a matter of individual choice and neglecting responsibilities of other stakeholders (Dourish, 2010; Evans, 2011; Shove, 2010; Strengers, 2011b). Shove stresses the need for sustainability research to *"shift the focus away from individual choice and to be explicit about the extent to which state and other actors configure the fabric and the texture of daily life"* (Shove, 2010 p.1281).

Despite the criticism of a focus on individual resource users within Sustainable HCI, Sustainable HCI research at large has not yet significantly changed to include other stakeholders (Remy & Huang, 2018). One reason may be that engaging different types of stakeholders in HCI and sustainability research comes with many challenges. Such challenges include to identify and approach the right stakeholders for each research project and to understand stakeholders' priorities, which may clash with sustainability goals (Remy, Bates, Thomas, & Broadbent, 2018).

To address the complexity of energy-intensive practices and other sustainability issues, Sustainable HCI research has to find ways of engaging with stakeholders and of understanding different stakeholders' involvement in and influence on energy-intensive practices. Contributing to an increased understanding of stakeholder influence has been central in my research and therefore I have involved stakeholders such as politicians, companies and local community groups in my studies.

3 Practice theory

For research addressing sustainability aspects of energy use and other types of consumption, drawing from practice theory is suggested as one way of moving away from the criticised focus on individual responsibility for resource use (Kennedy, Cohen, & Krogman, 2015; Shove et al., 2015; Warde, 2005). In this chapter I briefly introduce the theoretical framework of practice theory, and in the following chapter I will describe how I have applied practice theory in my own work.

There are many different versions of practice theory, but most share a perspective of practices as human activities that are embodied and mediated by natural and artificial objects (Schatzki, 2001). The human is neither seen as intentionally shaping action, nor as passively taking action based on social structures and norms (Reckwitz, 2002). Instead, Reckwitz describes humans as *carriers* of practices who reproduce practices through bodily and mental performances that share particular knowledge, understandings and emotions. Shove, Pantzar and Watson (2012) concretize the concept of practices by suggesting that practices are constituted by elements that can be divided into *material*, *meaning* and *competence*: *material* elements include products, infrastructures, and the bodies of those performing practices; *meaning* has to do with mental aspects of a practice including emotions, motivation and shared ideas such as norms; and *competence* refers to knowledge and skills needed to perform a practices. These elements are linked in practices (e.g. the practice of cycling requires a bike and skills for using the bike) and elements can be shared between practices (e.g. a car can be used for numerous practices such as commuting or going on holidays).

Central to practices is that they are reproduced over time by different people in different places (Reckwitz, 2002). This requires a shared understanding of what a practice entails. However, practices as such *coordinated entities* are created through unique *performances* of practices that may differ between each other (Warde, 2005). For the practice of cycling, for example, different types of bikes are used and various emotions can be part of the practice. Furthermore, practices change over time and some die out. For sustainability research, it may be useful to study both configurations of sustainable and unsustainable practices and how these practices form, transform and disappear. Practices can, however, not be deliberately designed – what can be influenced is only the availability and circulation of elements of desired practices (Shove & Walker, 2010). Such change can be approached in different ways. Spurling and McMeekin (2015) describe three types of interventions to change practices: (1) recrafting practices to address the resource-intensity of current practices, for example by replacing materials to less resource-intensive ones; (2) substituting unsustainable practices with more sustainable alternatives by discouraging the former and promoting the latter; and (3) changing how practices interlock by questioning taken-for-granted needs and intervening in numerous practices.

There is no one way to apply practice theory to research and practice theory comes with a number of challenges. One challenge with studying practices is that practices are difficult to separate from each other and to draw exact boundaries of (Røpke, 2009). Practices are linked to each other in *bundles* or *complexes* based on co-location and co-existence, and some practices are part of other higher-level practices (Shove et al., 2012). This makes it difficult to specify and analyse all practices included in "car-free practices" or "energy management practices". At the same time, these complexes of practices are necessary to engage with to study opportunities for more radical change, such as changing how practices interlock. Another challenge is that a practices as coordinated entities only can be studied indirectly – for example through observations of unique performances of practices and studies of material artefacts used in practices – and it is therefore important to make use of several sources for a study to capture variations in practices (Kuijer, 2014).

4 Research approach and process

In my PhD work I have combined a design-oriented research approach, in which design interventions have played an important role, with a practice theory perspective. More specifically, I have used design methods as a means for exploring current and potential future practices related to energy use. This includes taking practices both as a unit of analysis and as a unit of design, i.e. doing practice-oriented design (Kuijer, De Jong, & Van Eijk, 2013). One reason for me to take a practice-oriented design approach was to move away from the questioned focus on designing for individual behaviour change (e.g. Brynjarsdottir et al., 2012; Strengers, 2014). Another reason was to take a step back from perceiving interactive systems as solutions to sustainability issues in themselves. With that purpose, I used practice theory as a tool for properly acknowledging other elements of energy-related practices and possibly situating interactive systems among those.

In this chapter, I introduce the two approaches *design-oriented research* and *practice-oriented design* together with how they relate to and have been applied in my research. This is followed by a description of my research process, which outlines the specific research activities and their relation to the papers included in the thesis. Finally, I provide details on the research setting for the two cases I have worked on.

4.1 Design-oriented research

Using design methods and design of artefacts to create new knowledge can broadly be described as design-oriented research. In contrast to most design practice outside of research, design-oriented research does not have immediate "problem solving" as its primary goal (Fallman, 2003). Consequently, the value of artefacts in design-oriented research is not mainly as products that solve a problem, but rather as means for exploring problems and creating knowledge (ibid.). Thus, in my research the goal has not been to create commercial products for housing cooperative energy management or sustainable mobility. However, the knowledge outcomes of the research could be used in design processes, commercial or not, that aim to address those issues.

Creating knowledge through design can be done in various ways that have different perspectives on the roles of artefacts and users. Koskinen et al. (2011) use the term "constructive design research" to describe design research that has the construction of artefacts as a central component in knowledge creation. They further divide constructive design research into three types: (1) lab research that take the design out of its context, for example with the purpose of evaluating specific aspects of a design; (2) field research that explore design in "natural settings"; and (3) showroom research that use design to question what is taken for granted and aim for reflection and dialogue. My research, which explored energy management and mobility practices in real life settings, is mainly related to design research in the field. However, design was also used to question current practices and support reflection on more sustainable alternatives, and thus the studies include aspects of showroom research. The showroom approach is also known as "critical design", and a central concern of this approach is to design artefacts that are provocative enough to trigger reflection on current norms and on how these are manifested in more conventional design (Bardzell, Bardzell, Forlizzi, Zimmerman, & Antanitis, 2012).

For design research in the field, methods such as co-design and action research are common for engaging participants in research and design processes (Koskinen et al., 2011). Action research explicitly aims for collaboration between researchers and other project participants throughout an iterative process of *problem diagnosis*, *action intervention* and *reflective learning* (Avison, Lau, Myers, & Nielsen, 1999). This does not necessarily include any design work, but the focus on collaborative intervention and change has served as inspiration for design research traditions where design interventions are a core part of the process (Bannon & Ehn, 2012). Participant engagement and co-design has been important also in my work; the car-free families and housing cooperative representatives were involved in discussions of the study setup and in the concept and prototype design, and they expressed interest in the results and in contributing to the research. Such active engagement can blur traditional roles of participants and researchers, and it may be valuable to consider, and reflect on, participants as "investigators" and researchers as "participants" when exploring technology in the field (Brown, Reeves, & Sherwood, 2011).

Design research in the field and action research have in common that the immediate outcomes of the research are closely linked to the specific context of the interventions. Hence, it is difficult to generalise these outcomes. For action research, it has been suggested that focus should be on transferability of knowledge rather than generalisability (Hayes, 2011). Similarly to action research, design research results of a specific case do not have to be generally applicable to be relevant, they can still provide valuable knowledge and inspiration for future design and research (Koskinen et al., 2011). To facilitate transferability of the knowledge outcomes of my research, I have contextualised the results I present in my papers and I also provide a description of my research setting later in this chapter.

Artefacts created as part of the research process can support the creation and presentation of knowledge in different ways. In my cases, the most important artefacts we worked with were design concepts for more sustainable mobility and prototypes for an energy app supporting housing cooperative energy management. These artefacts are central parts of the research results since they illustrate key insights from the studies and work as a complement to descriptions of *design sensitivities*, which are important design aspects to consider when the insights are applied to other cases with similar design goals.

In addition, the artefacts were used to support discussions with various stakeholders to further increase the understanding of different practices and responsibilities for energy use. The car-free concepts were for example discussed with politicians, mobility experts, employers and the public, and the energy app prototypes were used to discuss housing cooperative practices both with housing cooperatives and with other stakeholders involved in the practices. However, Gaver et al. (2015) show that when design research artefacts are deployed for longer times, study participants may not only consider the artefacts as *research tools* but also as *products* that are expected to provide direct benefits for the users. While my research intention was to create artefacts as research tools, for the energy management case I also strived to design the energy app to be immediately useful for housing cooperatives in order to encourage long-term participation in the study.

4.2 Practice-oriented design

In my work, practice theory has been used both as an analytical lens for understanding current energy-related practices and as a unit for design supporting alternative mobility practices and future energy management practices in housing cooperatives. Taking practices as a unit of analysis is an approach applied to various types of research, and particularly research with a sustainability focus. For Sustainable HCI, studying practices has been suggested as an alternative to a focus on individual behaviours to better understand the complexity of resource use (Brynjarsdottir et al., 2012). This follows a general HCI interest in investigating practices, as opposed to a more traditional interaction-centred approach (Kuutti & Bannon, 2014).

In addition to analysing practices, practice-oriented design has been proposed as a design process where current practices are deconstructed with the purpose of reconfiguring the elements and exploring design opportunities supporting the formation of new practices (Scott, Bakker, & Quist, 2012). Deconstructing practices includes analysis of the materials, meanings and competences of a practice, and how these elements are linked, to identify opportunities for intervention. Practices are then reconstructed by adding and removing elements, into "practice prototypes" that can be tested by people in their everyday life. Thus, practices are used also as a unit of design. This process can be facilitated by creating "crises of routines", where people's routines are deliberately disrupted as part of the study setup to trigger new formations of practices (Kuijer et al., 2013).

In my research, creating crises of routines was central in the car-free year study; the removal of the car disrupted the participating families' mobility practices and we were interested in which practices would replace previously car-dependent practices. By studying families with cars, instead of families who were used to living without cars, we could follow how the families reconstructed their practices into new ones.

For the housing cooperative case, crises of routines were less important in the study setup. The aim was not to disrupt any specific resource-intensive practices, but rather to understand how currently marginal energy management practices may be linked more closely to other housing cooperative management practices and practices of professionals working with housing cooperatives. These practices are different from the everyday practices typically explored in sustainability research since many housing cooperative representatives only engage sporadically in energy management work and much housing cooperative management are performed by professionals. Furthermore, rather than aiming to understand alternatives to energy-intensive practices, as we did in the mobility case, the housing cooperative focus was mainly on energy management practices mitigating the impact of energy-intensive practices.

A first step of practice-oriented design is to define a target practice and investigate its environmental impact (Kuijer, 2014). However, many mobility practices, as well as housing cooperative energy management practices, are closely linked in complexes or bundles of practices and it is difficult to separate different practices within "car-free practices" or "energy management practices". The aim in my studies was not to identify one specific practice to analyse and change, nor to define and analyse all practices related to personal mobility or energy use in housing cooperatives. Instead we were interested in these broader complexes of practices and the links between them. To make the analysis and design work manageable, some practices were analysed in greater detail than others and for the design work we selected the practices and linkages that we found most interesting. In addition to focussing on practices with a high impact (or potential impact) on energy use, we focused on practices, or elements of practices, that the participants clearly associated with negative or positive experiences.

4.3 Research process

Although the research setup differs between the cases, they both include long-term studies with similar activities. This section briefly introduces the activities (see Figure 1 for an overview), and more details can be found in the respective papers.

For the mobility case, we started with an intervention – the car-free year – where three Stockholm families with children replaced their cars with light electric vehicles such as electric bikes, box bikes and scooters for one year. The

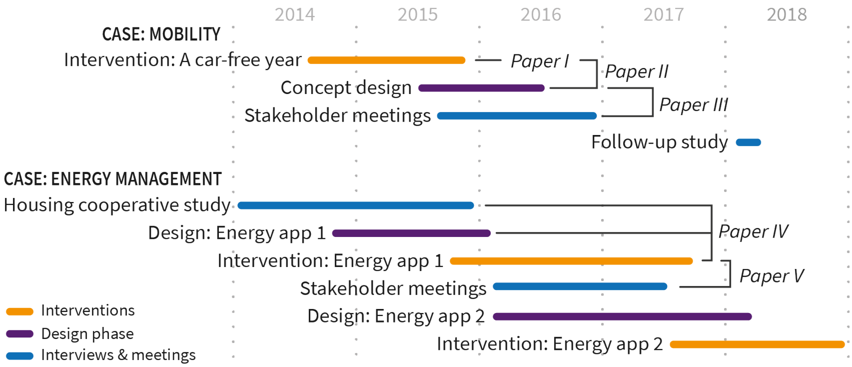

Figure 1: Research process overview.

families were allowed a maximum of 24 car trips (where one trip could last at most one day) with taxi or a borrowed or rented car, at their own expense, for situations that they did not know how to solve without a car. During the car-free year we visited the families for monthly interviews and observations in their homes. We provided them with a diary to document and reflect on their experiences between the meetings and a 24-car-trips card where they registered any car trips. To further support reflections on travel practices the families used an app and an online tool to track and visualise their trips (see Figure 2 for images of the materials used to support reflections). Based on the interview material and observations, we analysed the families' car-free practices and their experiences of going from owning cars to establishing new transport practices. Specifically, we identified various elements of car-free mobility practices and positive and negative experiences associated with the new practices.

These results were summarised in a workbook (see Figure 3) and used as input for the design of concepts for more sustainable mobility, which was done in collaboration with a design firm and the families. During and after the concept development, the concepts were discussed in meetings with mobility stakeholders from the public, private and third sector: local government representatives from the City of Stockholm, a national politician from the Ministry of Environment and Energy, a sustainable mobility project manager from a large company, and mobility experts from the Swedish Transport Administration and an NGO with focus on promoting sustainable mobility.

Figure 2: Materials used during interviews with the car-free families. Left: a day view of the diary. Top right: the upper part of the 24-car-trips card. Bottom right: Visualisation of travel patterns colour coded by transport mode.

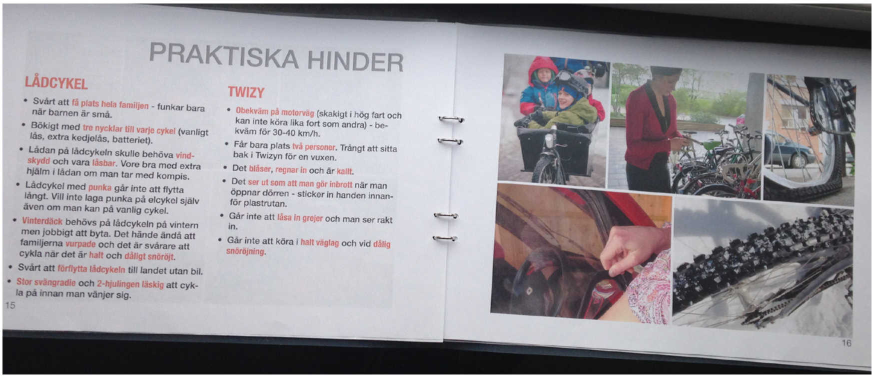

Figure 3: Workbook mapping elements of car-free practices that was used for generating design concepts for sustainable mobility.

The meetings were later analysed with a focus on the stakeholders' possibilities to influence car-free mobility practices. Finally, more than two years after the families' ended their car-free year, we revisited the families in their homes for a follow-up interview. We interviewed the families about their current mobility practices, changes in practices after the car-free year and their thoughts on the car-free year when looking back at it.

For the case exploring energy management, we started with a study of current housing cooperative energy practices, which included participation in local energy meetings for housing cooperatives, creation of scenarios of ICT support for community energy work, and interviews with housing cooperative representatives. Based on the insights we designed an energy app (Energy app 1, see Figure 4), in collaboration with housing cooperatives, that we tested with a small group of housing cooperatives in Stockholm. We also used the app to discuss energy management practices with other stakeholders involved in energy-related work with housing cooperatives. These stakeholders included building management companies, a building maintenance consultancy, a national housing cooperative organisation, a local energy initiative, municipal energy advisors and an energy provider. The stakeholders' engagement in housing cooperative energy management was analysed and opportunities for interactive systems to support this work were identified. In parallel with the stakeholder meetings, we redesigned the energy app (Energy app 2, see Figure 5) with the intention of testing it with a larger number of housing cooperatives all over Sweden.

In addition to the research process of each case I have worked on, there was a higher-level research focus, across the cases, that evolved throughout my PhD work. Both cases included in my thesis originated in projects where the goal was to explore how design and technology could contribute to reducing energy use and environmental impact of energy use. A first focus was to explore and understand energy use in apartment buildings and for mobility. Understanding the environmental impact of different types of energy use, and the potential impact of changing this use, was important for deciding which types of energy use to address, particularly in the housing cooperative case where the impact of different types of energy use was less obvious. To understand the potential for changing energy use, and reducing its environmental impact, a next step was to investigate the reasons behind the energy use. At this point practice theory was used as a lens for understanding both activities related to high use of energy and alternative activities that could replace more energy-intensive practices or mitigate the impact of current energy practices (e.g. through energy management). Finally, I wanted to understand

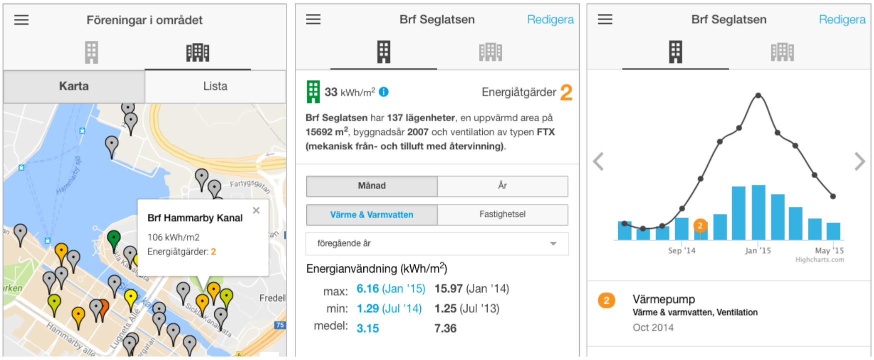

Figure 4: Screenshots of an early design of the housing cooperative energy app (Energy app 1).

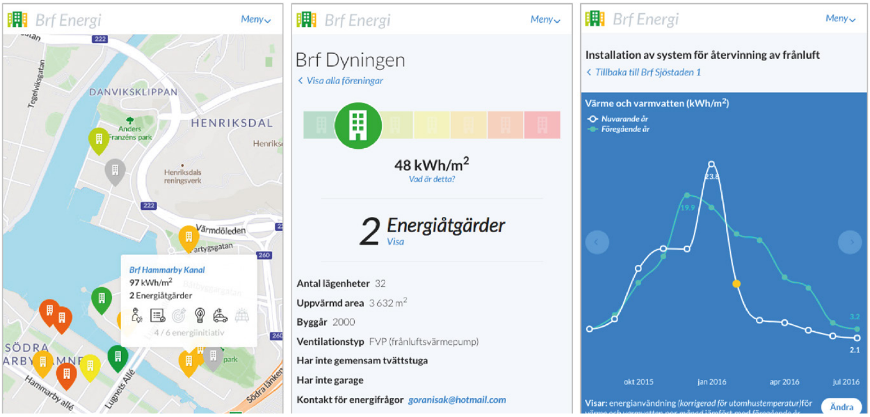

Figure 5: Screenshots of the most recent design of the housing cooperative energy app (Energy app 2).

more about how different stakeholders influence practices and possibly can share responsibility for energy use. This included investigating practices and activities that influenced the housing cooperatives' and the car-free families' energy use but that were performed by other stakeholders, such as building management work performed by professionals and mobility initiatives carried out by private and public sector decision makers. Throughout the different stages of this process I identified design opportunities (as well as challenges and limitations) for interactive systems to support sustainable practices and I formulated specific design sensitivities for designers that aim to contribute to transforming practices into more sustainable ones.

4.4 Research setting

The cases I have worked on are set in Sweden, with the main part of the studies carried out with study participants in Stockholm. There are of course many contextual factors affecting energy use, and in this section I describe particularities of the research setting, related to transport practices and energy management in housing cooperatives, that I believe are important for understanding the results of my studies.

One important factor that affects both transport practices and how energy is used in homes is the local climate and its seasonal changes. In Stockholm, the winters are usually rather cold, and sometimes snowy, with an average of -3°C (27°F) in Stockholm in January[3], and the summers are mild, with an average of 16°C (61°F) in July[4]. The number of daylight hours also changes with the seasons: in Stockholm from 6 hours the shortest day in December to 18 hours the longest day in June[5]. Consequently, considerably more heating and lighting is needed in the winters and local travelling becomes more energy intensive with fewer people biking in the winter. More context-specific details on energy use in homes, particularly for the case of housing cooperatives, and transport are elaborated on below.

4.4.1 Transport in Stockholm

Stockholm has a good public transport system and public transport is the dominant mode of transport for commute trips (see Figure 6)[6]. However, people's commuting choices change with the seasons: fewer people bike in the winter and instead even more rely on public transport and cars. On average, slightly more than 20% of the commute trips are made by car in Stockholm, which can be compared to about 60% of all commute trips in Sweden (Trafikanalys, 2015) and almost 90% in the United States (Federal Highway Administration, 2010). Nevertheless, Stockholm suffers from congestion and local air pollution, and the city aims to both reduce the total number

3 Data from the Swedish Meteorological and Hydrological Institute (SMHI), http://www.smhi.se/klimatdata/meteorologi/temperatur/normal-medeltemperatur-for-januari-1.3976

4 Data from SMHI, http://www.smhi.se/klimatdata/meteorologi/temperatur/normal-medeltemperatur-for-juli-1.3991

5 Data from SMHI, https://www.smhi.se/kunskapsbanken/meteorologi/dagslangdens-forandring-under-aret-1.7185

6 Data from the City of Stockholm, http://miljobarometern.stockholm.se/trafik/resvanor/

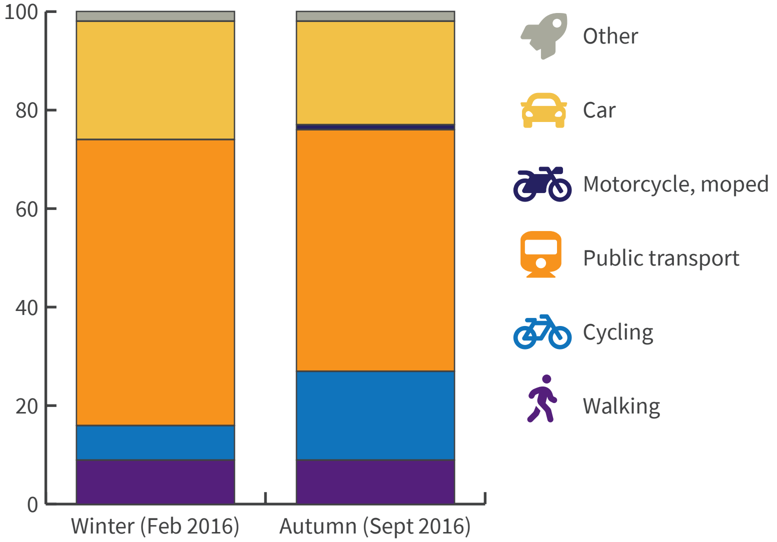

Figure 6: Distribution between transport modes during different seasons.

of car trips and increase the share of fossil-free trips. This will, however, be challenging, with a steadily increasing population as well as an increase in car use for commute trips from 20% of the winter trips in 2013 to 24% in 2016[7].

The use of different transport modes varies between different groups of people. In the Stockholm region, low-income households travel less by car and by bike, and more by public transport, compared to households with higher incomes, and men and people above the age of 40 are using cars the most (Trafikförvaltningen Stockholms Läns Landsting, 2016). However, about half of the car trips in Sweden are shorter than 7.5 kilometres, and for the Stockholm region it is estimated that more than 100 000 (about 30%) of those who drive to work could make the same trip in less than 30 minutes by bike (Johansson et al., 2017).

7 Data from the City of Stockholm, http://miljobarometern.stockholm.se/trafik/resvanor/fardmedelsfordelning-host/?start=2007&end=2016

4.4.2 Swedish housing cooperatives and their energy use

Household energy use has a share of 22% of the total energy use in Sweden (Statens Energimyndighet, 2015). In my work, I have focused on energy use in apartment buildings owned by housing cooperatives. This is the most common form of housing in the Stockholm region, with 36% of the households living in housing cooperative apartments, and overall in Sweden about 20% of the households live in apartments owned by housing cooperatives[8]. In Sweden, housing cooperatives (bostadsrättsföreningar) are a legal entity for building ownership, where the residents buy the right to live in an apartment and at the same time become members of the cooperative. The size of a housing cooperative can vary from a minimum of three member households up to hundreds of households. It is the cooperative that owns and manages the buildings of the cooperative, and the members pay a monthly fee that covers shared costs such as daily and long-term maintenance, loans for the buildings, and energy use for heating, hot water and facilities electricity. Buying an apartment comes at a high cost in many cities – the average price for an apartment in Stockholm is currently about 6400 euros (69000 SEK) per square metre[9]. Consequently, people typically need loans for buying an apartment, which are an addition to any shared loans of the cooperative.

The housing cooperative format of building ownership dates back to the late 19th century, although it has evolved over the years (Ruonavaara, 2005). Today, the legal obligations include to annually produce a report on the cooperative's finances and to invite the members to an annual meeting[10]. During the meeting, a board is elected among the cooperative's members, and it is the board members who are in charge of the finances and maintenance of the cooperative – often with no or only a small economic compensation.

When it comes to energy use, the main part (about 70%) of Swedish energy use in households is for heating and hot water, which in apartment buildings mostly is provided by district heating (Statens Energimyndighet,

8 Data from Statistics Sweden, http://www.statistikdatabasen.scb.se/sq/36685 and http://www.statistikdatabasen.scb.se/sq/36684

9 Data from Svensk Mäklarstatistik, based on 12 months data from August 2017 to August 2018, https://www.maklarstatistik.se/omrade/riket/stockholms-lan/stockholm/#/bostadsratter

10 Bostadsrättslagen, https://lagen.nu/1991:614

2015). Energy costs are a significant post in the housing cooperative budget, and the cost for heating and hot water is typically split between households based on apartment size rather than on actual energy use. This cost, as well as the underlying energy use, may be difficult for individual apartments to influence, since it largely depends on the buildings' energy efficiency and how well energy systems are maintained. Shared efforts, that address building-level issues, therefore become important for housing cooperatives that aim to reduce their energy use.

5 Contributions

This chapter summarises and provides synergies between the research contributions of the papers included in the thesis. The contributions provide answers to the research questions:

RQ1: In what ways do stakeholders influence, and could share responsibility for, resource use in energy-intensive practices?

RQ2: What design sensitivities are important to consider when aiming to support the types of stakeholder influence and opportunities for shared energy responsibility identified in RQ1?

The results are divided into three sections. First, in section 5.1, I describe insights into the practices I have studied, to provide an understanding of important elements of these practices and how they are linked, and I present the design concepts that were created based on these insights. In section 5.2, I focus on the influence of different stakeholders on mobility and energy management practices and the stakeholders' current and potential responsibilities related to energy use (RQ1). Finally, in section 5.3, I present design sensitivities for interventions aiming to support shared responsibility in transformations of energy-intensive practices and in formations of alternative practices (RQ2). These are informed by the design work presented in section 5.1 and linked to the types of influence and responsibilities identified in the exploration of RQ1.

5.1 Energy-intensive practices and more sustainable alternatives

For the case of mobility, we studied car-free mobility practices that the three participating families formed during the study. The families reflected on their new practices in relation to their previous, or other people's current, more energy-intensive practices involving cars. For the housing cooperative case, energy management practices were studied as part of general housing cooperative management practices. This section introduces a number of practices related to car-free mobility and housing cooperative (energy) management. After describing the practices related to each case, design concepts for supporting more sustainable practices are presented. Further details on the mobility case can be found in Paper I, II and III, and details on the housing cooperative case in Paper IV and V. In addition to the results published in the papers, I have added results from recent follow-up interviews with the families participating in the car-free year study. The interviews were carried out more than two years after the car-free year ended, and I include a selection of the interview results to provide a picture of how the families' practices changed, or resisted change, in the years after the study.

5.1.1 Car-free mobility practices

Not owning a car affected many of the families' practices. They had to adjust their routines for how to get to work, school and after-school activities, how to do grocery shopping and how to meet with family and friends. They also had to find new ways of engaging in more occasional activities, such as going to summer houses, going on holidays and renovating at home. Many practices involved people outside of the families and in certain contexts the families faced strong car norms; most colleagues of the parents and friends of the children had access to cars. These norms were particularly apparent in some situations, such as when going to sports team activities or when visiting family in the countryside.

The removal of the car and the access to new vehicles (see Figure 7) was an important change of elements in the families' practices. But this change was not only about the material aspects of practices in the form of new vehicles – new knowledge and skills were central to the car-free transport practices. As part of the study, the participants had access to experts who helped the families learn how to use the new vehicles safely and comfortably in different weather conditions, and they got help with practicalities such as changing to winter tyres on the bikes and repairing flat tyres. The families also searched for information on their own; they found tips on cycling regulations in a

Figure 7: The three families in the car-free year project and their light electric vehicles: a bike, a four-wheeled motorcycle, a scooter, and box bikes.

Facebook group for cargo bikes and used transport planning tools such as Google Maps and local public transport apps for learning about new routes.

For all families, the car-free year resulted in more cycling as well as in new forms of cycling. The families with box bikes could transport both people and stuff in the boxes, and the batteries enabled longer bike trips and heavy loads. The increase in cycling had many practical aspects, such as charging batteries, dealing with flat tyres, and managing new equipment for cycling in different kinds of weather. In addition, the cycling practices had important emotional aspects. Much of the transport infrastructure was not adapted for cyclists, and particularly not for the bigger bikes the families used, which left them with feelings of uncertainty or of being "odd". However, cycling also brought many positive experiences, and the families highlighted values such as getting exercise, being outdoors, and taking a more scenic route to work.

Another change for the families was how the different family members were involved in transport-related practices. Before the car-free year, the parents often drove the children to after-school activities by car. During the car-free year the children instead travelled themselves by public transport or got a ride with other families. Further changes included replacement of some types of trips with services, such as online shopping of groceries with home delivery. This made the children less involved in shopping practices, and the parents spent less time on grocery shopping.

Overall, the families reported that managing without cars became natural after a while and they formed new routines for many situations where they previously had used cars. Immediately after the car-free year, one family, who sold their car during the car-free year, considered buying a new car but instead joined a car sharing service. The other families did not think that they would want to continue to own cars and instead imagined renting cars more often to solve challenging situations such as visits to summer houses.

Mobility practices after the car-free year

When we revisited the families two years after the end of the car-free year, many of their mobility practices had changed. The family who initially joined a car sharing service now owned a car that they bought when their oldest son was about to get a driver license and needed to practice driving. They used the car mainly for driving to sports activities, going on trips outside of the city and doing grocery shopping. Compared to before the car-free year, they believed that they used the car less and they prioritized to use it for activities such as getting out in nature rather than going to shopping centres.

One of the other families also joined a car sharing service after the project finished. They, however, found the service stressful and expensive since they mainly needed a car for longer trips, such as when going to their summer house or when visiting friends outside of the city. Eventually, the family leased a car. They appreciated that it offered them the same access to a car as if they would own one but with less responsibilities and hassle. Similar to the previous family, they experienced that they used the car less compared to before the car-free year. For example, instead of a parent driving the children to sports activities, the children continued to travel by themselves to these activities or they got rides with other families.

Finally, the third family continued to not own a car after the car-free year and they reported having no plans on buying one. One of the parents used a pay-per-minute car sharing service occasionally, for example when running late for picking up the children from school, and the family had borrowed or rented a car for longer trips a few times. Apart from the use of the car sharing service, the family had similar mobility practices as during the car-free year and expressed that this worked very well for them.

5.1.2 Design concepts for supporting car-free mobility

The concepts that were developed as part of the car-free year study included design of products, services, infrastructure and policy. In this section I present the concepts that are most closely linked to ICT and interaction design. Additional concepts are presented and discussed in Paper III.

One key component of the families' car-free practices was the light electric vehicles provided by the project together with knowledge of how to use them in different weathers and situations. Making these elements, i.e. both new vehicles and related knowledge, more easily accessible is therefore important for supporting car-free practices. One of our design concepts (see Figure 8) shows how employers could provide services related to sustainable mobility, such as leasing contracts that allow their employees to try alternatives to the car without having to make a big investment in a new, unfamiliar type of vehicle. To further encourage for example cycling, employers can have

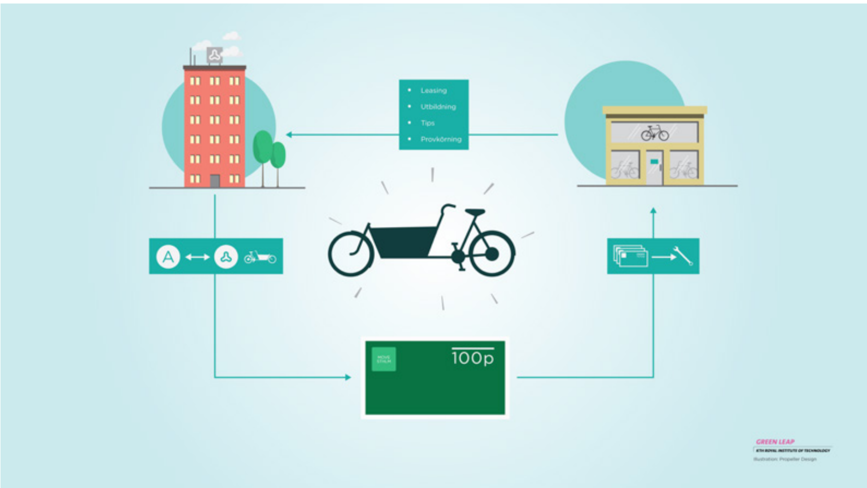

Figure 8: Concept of leasing contracts for box bikes connected to bike services.

agreements with bike service companies that fix the bike if it gets a flat tyre and help with changing to winter tyres at the right time of the year. ICT could support practicalities around leasing and servicing of the vehicles, and also the important element of knowledge of how to use the vehicles. The families in the project appreciated getting advice on bike equipment and clothing from bike experts, and they also used an online community for finding additional information. Employers could provide or make use of existing online communities to facilitate knowledge sharing between colleagues or access to expert advice. Such online communities may also address issues of "feeling odd" when using vehicles outside of the norms by linking up people at the workplace who are engaged in the practice (Bartle, Avineri, & Chatterjee, 2013).

ICT could further support a system of services related to sustainable mobility by linking services to government subsidies. In another concept (see Figure 9) we illustrate this as "reversed congestion charges" that reward cyclists with digital points. The points become a new part of the practices that can be used for purposes that support sustainable mobility, such as paying for having a flat tyre repaired. In return for the points, the city receives crowdsourced cycling data and healthier citizens.

Digital services could also be used to connect physical infrastructure to travel information. The car-free families often used travel planning tools to

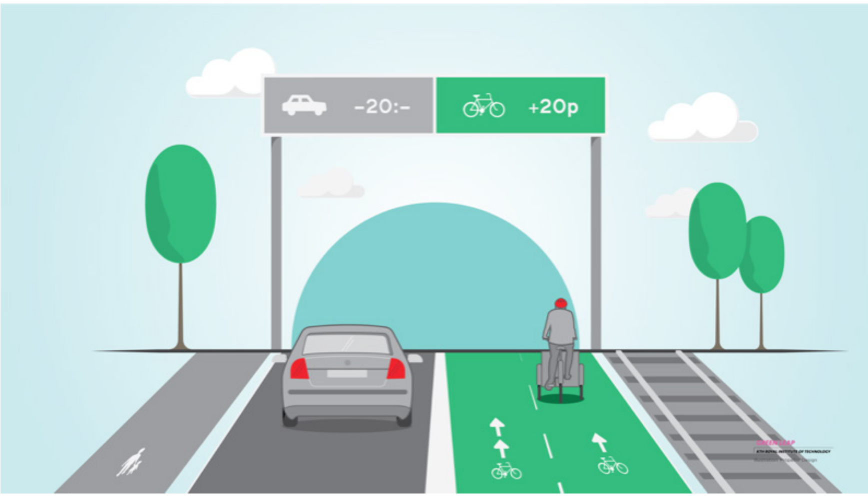

Figure 9: Concept of reversed congestion charges in the form of points for people travelling by bike.

Figure 10: Concept of highlighting scenic routes for bikes both in the physical environment and in a digital tool.

find information about travel times of different routes, and based on their experiences we saw opportunities in providing additional types of information. This includes information about bike routes suitable for wide box bikes, bike paths suitable for children, and where to find scenic routes. The opportunity to take a more scenic route to work, compared to when commuting by public transport or by car, was one type of positive experience the families realised came with cycling. One of our concepts highlights this value of cycling both in the infrastructure, in the form of road signs, and in information in travel planning tools (see Figure 10). Conventional travel planning tools often focus on optimising a route based on time or costs. While more sustainable modes of transport such as bikes and public transport sometimes are both faster and cheaper than going by car, this is not always the case. Highlighting other benefits of sustainable transport might therefore contribute to circulating more abstract values of these practices, such as positive experiences connected to cycling.

Another way ICT was already used to facilitate mobility practices, was for coordinating ride sharing in sports teams. While this makes it easier for families without cars to organise transport, it only allows families with cars to help with taking children to the activities. In that sense, the design and use of the ride-sharing tool reinforces the norm of using cars for sports activities.

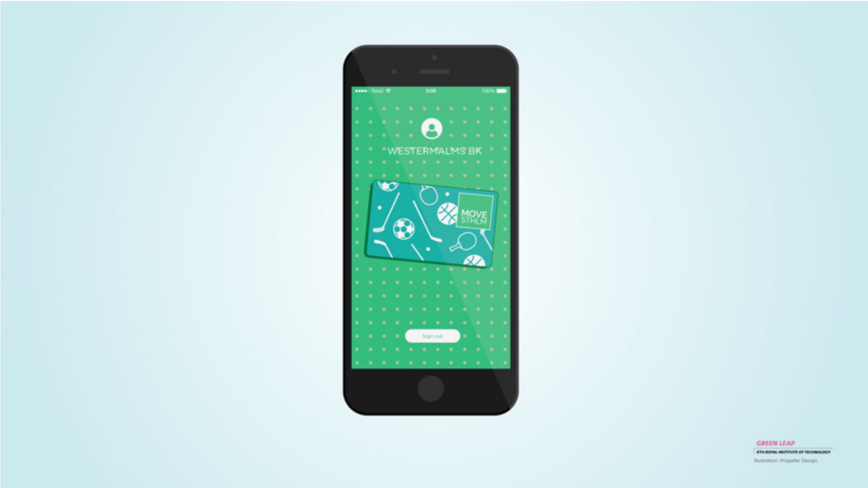

Figure 11: Concept of highlighting scenic routes for bikes both in the physical environment and in a digital tool.

The support could be extended to include alternative transportation modes – a box bike can take more than one child and there might also be options for parents to ride together with many children on bikes or take them with public transport. To challenge the car norm within sports teams, one of our concepts includes a digital public transport pass that can be shared between parents who take in turns to accompany children to activities with public transport (see Figure 11). In addition to encouraging a more sustainable mode of transport to sports activities in the short term, the use of such a system provides an opportunity for children who otherwise do not use public transport to become familiar with this transport mode and eventually be able to use it without the company of adults.

5.1.3 Housing cooperative energy management practices

For the case of housing cooperative energy management, the focus was not only on energy management practices. In order to understand housing cooperative energy management, it was important to also understand general housing cooperative management. Although most of the housing cooperative representatives who were engaged in our study were interested in energy management, we understood that energy reduction efforts were often pushed aside by other issues. Issues of priority were instead related to external regulations for housing cooperative management, such as requirements for making maintenance plans, and to internal concerns among the members, such as problems with garbage collection or with too low indoor temperatures. Furthermore, in housing cooperative management costs are a central concern. The housing cooperative board annually makes a financial report, and the finances of the cooperatives are important since they impact the value of the apartments in a cooperative as well as the monthly fees the members pay. However, while reducing energy use often is connected to cost reductions, many participants in our study also cared about the positive environmental impact of such reductions. In addition, some types of energy improvements result in other benefits, such as increased comfort due to more even indoor temperatures.

Although the cost for energy use is a significant part of the shared housing cooperative expenses, it might be difficult for cooperatives to know what is normal and not and if they should do something about their energy systems. Another challenge is that energy costs vary during the year, depending on the outdoor temperature and energy prices, which makes it difficult to detect changes in energy use caused by problems with the energy systems. The systems themselves, often controlled through technology placed in the basements (see Figure 12), do not necessarily indicate that something is wasting energy. Housing cooperatives in our study told us stories about a heat pump that had been broken for years without anyone noticing and a system for melting ice outside of entrances that was turned on also in the summers. The problems were only detected when people with more knowledge made thorough investigations of the buildings. Professional building managers are sometimes supposed to do check-ups on the systems as part of their regular work, but other stakeholders suspected that these check-ups are many times not thorough enough to discover any problems. Although the energy control systems in the basements are important for the energy use, they appear to often be neglected and not really be part of anyone's practices.

For those housing cooperatives that had taken actions to reduce their energy use, knowledge of energy technology and of practical implementation aspects was important. Energy reduction actions varied from smaller actions

Figure 12: Part of an energy system in the basement of one of the housing cooperatives in the study.

such as optimising existing systems to more extensive actions such as installing heat recovery systems. In some housing cooperatives, one board member was appointed "energy manager" and in charge of energy issues. Their knowledge of energy management varied, from those who had extensive previous knowledge that helped them in carrying out actions to others who had not worked with energy issues at all before. Acquiring new knowledge was often associated with uncertainty, particularly in terms of what the financial impact of energy reduction actions would be and which contractors could be trusted to install new technology. To support housing cooperatives in learning about energy reduction actions and implementation, a local energy initiative had been formed in the residential area where our initial housing cooperative study was conducted. Through the initiative, energy managers or other representatives of housing cooperatives were invited to information meetings where they also shared their own experiences of energy improvement work.

Another type of support that aimed to make it easier for housing cooperatives to carry out energy improvement work was a new service called target-driven energy management which was offered by energy management companies. The service includes an investigation of the potential for energy reduction within a cooperative, a goal for future energy performance, and activities to reach the goal. The company is responsible for carrying out the work, and the savings from reduced energy costs are shared between the company and housing cooperative. With this type of service, energy improvement actions are considered part of ongoing energy improvement work and the cooperative does not have to decide on every single action.

5.1.4 Design concept for supporting housing cooperative energy management

In a housing cooperative energy context, one opportunity for ICT is to support local energy initiatives by providing digital platforms for sharing experiences. This was the starting point for our design work, which resulted in the design of a web app targeted at energy managers in housing cooperatives. The design was iterated and the latest version is shown in Figure 13. With the app, users can see the energy use together with energy improvement actions, such as optimisations of current energy systems or installations of energy

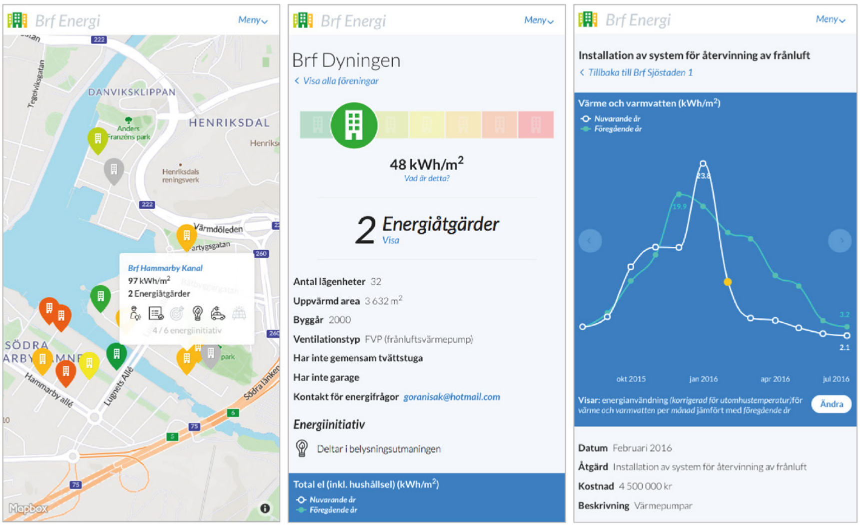

Figure 13: Screenshots from the latest design of the housing cooperative energy app. Left: Overview of housing cooperatives, their energy performance and energy initiatives taken. Middle: Housing cooperative information relevant for understanding energy performance. Right: Energy improvement action (installation of heat pump) mapped to changes in energy use compared to previous year.

efficient technology, taken in their own and other housing cooperatives. Energy actions are added by the cooperatives and include details such as type of action and cost. In this way, less experienced energy managers can learn from cooperatives that have done more energy work. Energy managers can also share their contact information to allow for further interaction outside of the app.

An important design aspect has been to support housing cooperatives in taking energy action. While the board members make decisions that could affect the energy use, they often depend on experts for actually taking action. To support housing cooperatives in making energy relevant decisions and seeking help with taking actions, one of the key features in the app is the mapping of energy reduction actions to energy usage data and making the data open for other cooperatives. However, for other cooperatives to be able to interpret the data, and compare it to their own cooperative, it is important to provide contextual information that affects the energy use. We included, among other things, information about the buildings' type of ventilation, year of construction, heated area and number of apartments.

With the app, we also explored ways of supporting energy improvement actions promoted and supported by other stakeholders. The local energy initiative in our study worked on supporting six specific actions, from switching to LED lights to installing shared electric car chargers. In the later version of the energy app, we included information about which cooperatives had started working on the different actions. The purpose was both to give the local energy initiative an overview of the member cooperatives' progress and to make it easy for energy managers to see which cooperatives they could learn from.

The app may also be valuable as documentation of actions within a cooperative over time. The turnover of housing cooperative board members is high, and when energy managers leave the board previous energy reduction actions may be forgotten or not well maintained after some years. However, we see a challenge in encouraging board members to continuously add information about new energy actions. One way of addressing this could be to include building or energy management companies as users of the app and allow them to add actions they take on behalf of the housing cooperative. Furthermore, this could contribute to transparency and trust in energy management work, such as the target-driven energy management initiative where building managers take more responsibility for energy improvements.

In contrast to many other energy visualisation apps, the goal with the housing cooperative energy app was not to encourage frequent use, but to make it work well for the rare occasions when the users need it in their energy management work. There might be months when the app is not needed at all in a cooperative and intense periods when it is more useful. Furthermore, some energy improvement actions take a long time to implement, and there will be cases when energy work is started by an energy manager who leaves the cooperative before the action is completed. Consequently, an important design aspect is to make such tools work well for rare use and handovers between different users – together with other, non-digital, materials and documentation of the work. Also here, the involvement of other stakeholders may be valuable. Energy professionals could provide continuity between housing cooperative use and bring the app to housing cooperatives at times when it is useful.

5.2 Stakeholder influence and energy responsibility

In both the case of sustainable mobility practices and the case of housing cooperative energy management, it was apparent that many other people than the car-free families and the housing cooperative representatives were involved in and had an influence on the practices. This influence was sometimes directly related to energy use and included explicit responsibility for elements of the practices, and sometimes the link to energy use was less obvious and responsibilities were implicit or missing. The families and housing cooperatives of course also had an influence on, and felt responsible for, their individual practices. However, when working towards sustainable practices on a societal scale, changing practices cannot be made into only a matter of individual choice; the influence of more powerful actors has to be recognised (Shove, 2010). In my work, the limitations of individual power could be seen in that many of the families who applied to the car-free year project expressed a desire to live “car free” but they did not know how to manage without their cars. Similarly, some of the housing cooperative energy managers in our study wanted to take action to reduce energy use but found it difficult due to lack of time, knowledge and support for figuring out what to do and implementing improvements. The research projects provided support for sustainable mobility and housing cooperative energy management to different extents, but we also identified stakeholders that influence or may influence important elements of these practices on a larger scale.

There are many different ways for stakeholders to influence and take responsibility for the formation, transformation and disappearance of practices. I present the findings from my studies, mainly based on the results presented in Paper III and Paper V, divided into to how stakeholders such as governments, companies and other types of organisations may influence *adoption* of less energy-intensive practices, *maintenance* of less energy-intensive practices, and "*death*" of energy-intensive practices.

5.2.1 Adoption of less energy-intensive practices

Less energy-intensive practices can be different from previous practices to lesser or greater extent. Spurling and McMeekin (2015) suggest that efforts to influence practices can take the forms of *recrafting practices*, *substituting practices* or *changing how practices interlock*. I use these forms of changes to discuss how stakeholders in my studies can influence the adoption of less energy-intensive practices for the cases of mobility and housing cooperative energy use.

Recrafting practices, with the purpose of optimising energy use within energy-intensive practices, was common in the housing cooperative case. Most stakeholders did not aim to radically change household practices resulting in energy use, but rather aimed to optimise current energy systems or supporting investments in new technology or other materials that would improve the energy efficiency of buildings. Companies did this by providing services for energy optimisation or products for energy efficiency. However, for housing cooperatives to invest in these services and products, housing cooperative energy management practices have to change as well: cooperatives have to understand their own energy situation, investigate actions to take, and make decisions on what to do and which companies to contract. One common way for stakeholders to support this work was through energy advice. Stakeholders such as energy providers, municipal energy advisors, and housing cooperative organisations worked to increase knowledge on energy improvement actions in housing cooperatives. However, this was often not enough to support housing cooperatives in taking action. In order to influence adoption of energy services and technology, companies need to prove that they are trustworthy and that energy investments not only have a positive environmental impact but also pay off financially or result in other benefits such as improved indoor climate.

While recrafting practices have rather small implications on how practices are performed, substituting practices requires greater change. One type of substitution that received particular attention among stakeholders in the mobility case was replacing commute trips by car with commute trips by bike or by public transport. During the discussions of the car-free mobility concepts, the City of Stockholm expressed interest in inspiring their own employees to go by bike to work. Furthermore, to support overall increased commuter cycling in Stockholm, the city carried out a winter cycling project during the winter of 2017/2018[11]. The project participants were provided with crucial materials such winter tyres and they also received tips and inspiration on winter cycling. A large company in our study, situated outside of Stockholm, described during the concept discussions how they supported commute trips by bus through a dedicated office bus on which the employees were allowed to work. In these cases, substitution of commuting practices was encouraged by the stakeholders through provision of materials or services in combination with new knowledge (in the cycling case) and a work policy that made commuting by bus more attractive (in the bus case).

Whether or not the goal is to support sustainable mobility, workplaces influence their employees' mobility practices for example through their location, availability of parking spaces for different vehicles, benefits such as leasing cars and policies for travel and remote work. However, while substituting commuting practices for sustainability purposes was of great interest to the City of Stockholm and the company in our study, the families participating in the car-free year study found that commuting was relatively easy to solve without a car, for example by using public transport. The greater challenges of living a car-free life were associated with other situations, such as taking children to sports activities. Similar to workplaces, children's sports teams influence how children get to and from sports activities. One family in

11 More about the project on: http://www.stockholm.se/ByggBo/Leva-Miljovanligt/vintertramp/

our study described that in one of the children's teams ride-sharing was natural and coordinated by leaders through an online tool, while in other teams it was up to each family to solve their transport needs and most parents drove their children in their own car. In the sports teams, the official responsibility of the team leaders was to manage the team and their activities, but sustainability aspects could be a part of such responsibilities. In order to support car-free living, and not only substitution of one specific mobility practice for a less energy-intensive one, it may be equally important for stakeholders to focus on supporting ride sharing and alternatives means of transport to sports activities, or other more occasional transport needs, as it is to support sustainable commuting practices. Furthermore, when the car is needed for occasional trips, it may be used also for other trips, such as commuting, even though less energy-intensive options are available. The families in our study described how they previously used the car for trips where the car was not really needed, but since it was easily accessible they could for example allow themselves to run late and use the car as a backup option.

A different type of substitution was identified in the housing cooperative energy management case, where the target-driven energy management service aimed to change how energy management was approached. With this service, the responsibility for coordinating different energy management activities is moved from housing cooperatives to energy management companies. Thus, energy management practices carried out by amateurs in housing cooperatives are partly substituted by energy management practices carried out by professionals.

Finally, a more complex change of practices is to change how practices interlock through addressing energy needs and ways of using energy. One example of such a change from the car-free year study is the use of online grocery shopping services with home delivery. This service reduced the need for the families to travel to and from the grocery store, which separates shopping practices from travel practices. The City of Stockholm described during the discussion of the car-free mobility concepts their interest in how home delivery could be further supported through infrastructure for storage of delivered food in connection to homes, and how they investigated this as part of a large smart city project. The city also investigated possibilities of extending the support for transporting stuff away by increased use of mobile recycling stations for bulky waste. This would allow more people to dispose of bulky waste without having to arrange their own transport to recycling stations. However, for the more frequent recycling of packaging (paper, plastic, glass and metal) the city had limited influence on the availability of recycling stations since this was managed by other stakeholders.

In some cases, such as for energy management and recycling of bulky waste, clearly defined responsibilities for services appear to be beneficial for spreading alternative practices. However, we also found examples of clashing responsibilities that may inhibit efforts to support less energy-intensive practices. While the City of Stockholm is responsible for the local cycling infrastructure and expressed interest in further investments in cycling, the city would not directly benefit financially from improved citizen health due to increased cycling, since healthcare is managed on a regional level in Sweden. Thus, from a city perspective, reduced healthcare costs are not a good argument for budgeting for costly cycling investments.

5.2.2 Maintenance of less energy-intensive practices

Over time, practices may increase in energy-intensity or become less common when people turn to competing practices. Therefore, another important aspect of influencing practices is through maintenance of less energy-intensive practices once they have been adopted. This aspect was not addressed by the stakeholders in my studies to the same extent as support for adoption of "new" practices. Nevertheless, we identified opportunities for stakeholders to influence and take responsibility for maintenance of practices, both in terms of keeping the energy-intensity of current practices low and in terms of preventing adoption of more energy-intensive practices.

Examples of increased energy use over time, without connections to changes in practices, were identified in the housing cooperative case. These were related to poor maintenance of the energy systems, such as lack of cleaning of ventilation systems and failure to detect that a heat pump had broken down. In our study of housing cooperative stakeholders, it was pointed out that the quality of basic building management services, carried out by building management companies on behalf of housing cooperatives, varies considerably. With better basic services, problems such as the ones above could be detected and taken care of to prevent increases in energy use. Practices for maintenance should be considered not only for energy technology in buildings, but also for other types of material elements of practices that come with risks of increased energy use if they are poorly managed.

Poor maintenance of materials needed for a practice can also cause people to abandon practices. A broken bike that is difficult to repair may make its user go back to using a car for trips that previously were made by bike. Hence, it is important for stakeholders such as companies or governments that support the introduction of new vehicles, for example through subsidies for bikes or electric vehicles, to also consider and support maintenance of the vehicles.

Another reason for abandoning less resource-intensive practices can be changes in life, i.e. “crises of routines” (Reckwitz, 2002). Moving, changing jobs or having children are examples of situations that may affect mobility practices. Disruptive changes can also be caused by other stakeholders, for example when a company moves offices and the employees have to adjust their practices of how to get to work to the new location and available infrastructure. In the follow-up interviews of the car-free year study we found another example of crisis of routine in children learning to drive. For this situation, car sharing services were perceived as inadequate for the family’s new needs, which led the family to purchase a car. Providers of car sharing services could potentially influence such situations by better designing their services to take these types of crises of routines into account.

Crises of routines affected practices also in the housing cooperative energy management case. When board members engaged in energy issues leave a housing cooperative or quit board work, the cooperative might lose the energy management knowledge. Changes in board members also affect stakeholders working with housing cooperatives and their work can be disrupted. Thus, maintenance of knowledge and relations across generations of board members should be a central concern for stakeholders working with housing cooperatives.

5.2.3 Death of resource-intensive practices

Some practices naturally die out over time (Shove et al., 2012) and for environmental purposes it may be particularly beneficial to study the process of killing practices (Røpke, 2009). However, in my studies, the ambitions among stakeholders were not to completely eliminate resource-intensive practices related to mobility and energy use in buildings. They rather aimed to increase the share of less energy-intensive alternatives by making such alternatives more attractive or to mitigate the effects of resource-intensive practices through energy efficiency measures or increases in renewable energy. In some cases, stakeholders were interested in eliminating specific outcomes of practices, such as peaks in energy use, or unsustainable technologies, such as fossil fuel cars. This would require changes in practices, but perhaps not changes radical enough for the practices to be considered completely new and for the old practices to be declared dead.

5.3 The role of HCI and design implications

Interactive systems are part of many energy-intensive practices as well as of more sustainable alternatives. Throughout my PhD research I have identified opportunities for ICT to support transitions towards more sustainable practices, but also risks of technology working against such transitions. In this section, I suggest design sensitivities for HCI and other types of interventions aiming to support sustainable practices such as mobility or housing cooperative energy management. The suggestions are discussed in relation to stakeholder responsibility and stakeholder influence on adoption and maintenance of more sustainable practices.

5.3.1 Considering odd-norm tensions

In the mobility case, the car-free families' transport practices were in some contexts very different from those of most other people. Going by public transport to a summer house or by box bike to sports activities was unusual, and the families got questions about how they managed all the hassle of not owning a car. In the housing cooperative case, those cooperatives that made bigger investments in energy improvements were also breaking norms. While investments in solar panels or heat recovery systems may in many ways be perceived as positive changes, energy managers suggesting such investments had to face housing cooperative members' concerns of financial risks and payback times.

Designing to support alternative practices or introduction of new technology inevitably includes breaking norms, and there might be tensions between the new, and possibly odd, and the norm that need to be considered. ICT could contribute by supporting sharing of knowledge or other resources between people engaged in alternative practices, such as through the Facebook cargo bike group that was used by one of the families in our study. Similarly, in our housing cooperative study we aimed to support amateur energy managers interested in specific energy actions by connecting them to other cooperatives with experiences of such actions. The interactive tool for this was intended as a complement to face-to-face meetings organised by other stakeholders that promote energy improvement actions. In contexts where it is particularly sensitive to break norms, interactive systems can also make it easier for those who are different by hiding the oddness and supporting sharing of responsibilities with others. In the car-free year study, the online tool for coordinating ride-sharing by car, which was used by one of the families' sports teams, saved the family from the awkwardness of always asking for a ride to matches. The tool made the team's transport a shared responsibility among all parents, rather than each family's responsibility. However, while the tool indeed made it easier for the car-free family to solve their transport needs, it contributed to maintaining car-dependent practices related to sports activities and made it impossible for the family to contribute to the team's transports. Thus, the design of the tool supported car-free living on a small scale but worked against wider adoption of car-free living.

5.3.2 Designing for interaction over different time scales

Considering long time scales is crucial when addressing issues of sustainability (Silberman et al., 2014). In research focussing on interactive systems as a means for encouraging or supporting individuals in changing how they use energy, interactive systems appear to be designed with the aim of being continuously and frequently used for long times. That has, however, proven challenging; many studies have seen a declining interaction with feedback systems over time (Prost et al., 2015). If energy users are considered the main influencers of their practices, this is of course problematic and designing for continuous user engagement becomes a natural goal. But if we instead consider energy users as only one of many stakeholders that may influence energy-intensive practices, there might be other, more relevant, interaction goals. Systems could be designed to allow different types of users to have different interaction patterns over time. In the case of housing cooperative energy management, it may be more productive to focus on professional energy managers, who work continuously with maintaining good energy management practices in housing cooperatives, as the users who provide continuity of the energy app.

Furthermore, in order to support alternative, more sustainable, practices, design should not only aim to design for “everyday life” but also consider how to support adoption of new practices at “tipping points” or “crises of routines”, when current practices anyway are disrupted. Energy-related practices naturally change when circumstances in people’s lives change, such as when moving, having children or changing jobs. While crises of routines can increase the energy-intensity of practices, such in the case of the car-free family that bought a car when their son wanted to practice for the driving licence test, they can also provide opportunities for adoption of less energy-intensive practices. For housing cooperatives, natural disruptions of practices include when cooperatives face extensive renovations or after a cold winter with higher energy costs than what was budgeted for. In such situations, configurations of practices change, which provides opportunities for other stakeholders to influence elements of the practices. Interactive systems could be used to support people themselves in configuring less energy-intensive practices at times of crises of routines, for example through online community groups, but also to support other stakeholders in sharing responsibility by identifying situations of crises of routines and in intervening at the right time.

5.3.3 Supporting other values than resource optimisation

ICT is often used to optimise resource use, for example by minimising time, cost or kilowatt hours. However, while a focus on optimising resource use sometimes results in overall reduced environmental impact, ICT can in other cases increase the energy intensity of practices. For example, by optimising people’s time, ICT allows for more practices to be carried out within the same time (Røpke & Christensen, 2012). Furthermore, a focus on quantitative values such as time, cost or kilowatt hours leaves out other values of more sustainable practices. For the case of transport people do not necessarily consider travel time as wasted time (Watts & Urry, 2008), which was reflected also in our mobility study. Thus, the goal of mobility interventions does not always need to be to minimise travel time.

Design can contribute to highlighting different values of time spent on travelling – such as being outdoors, getting exercise, or taking a scenic route – and to support alternative optimisation goals. Similarly for energy management in housing cooperatives, while cost is an important factor that has to be taken into account, there are other values of energy improvements that should not be forgotten. Increased comfort might be an equally good argument as financial benefits for taking some types of energy actions. Designing for alternative values has also been suggested for energy interventions focussing on matching time-of-use of energy with local energy production. Pierce and Paulos (2012b) suggest to design for "slow" energy practices as positive experiences, such as doing laundry when it is windy outside, by emphasising the contextuality and seasonality of renewable energy production. This links back to considering the temporality of engagement and designing for interaction over different time scales.

5.3.4 Supporting shared energy responsibility

The design sensitivities above are not limited to the design of interactive systems and should be considered also for design of other products, services, infrastructure and policies. Furthermore, it is important to design interactive systems in relation to other activities aiming to change practices. To create social change, Toyama (2015) argues that technology alone is not enough and it should rather be considered an *amplifier* of other activities. In my studies, there are many examples of activities carried out by various stakeholders that could be amplified by interactive systems, such as ride-sharing in children's sports teams and target-driven energy management services for housing cooperatives. These activities are examples of where other stakeholders (i.e. team leaders and energy management companies) shared responsibility for energy use with energy users (i.e. families and housing cooperatives).

Sharing responsibility for energy use can be more or less controversial. In the case of ride-sharing in sports teams, the team leaders' support for ride-sharing was appreciated by the family in our study and they would have liked this support in more sports teams. However, for the case of energy management in housing cooperatives it was challenging for stakeholders to convince housing cooperatives to buy their services and let the companies take more responsibility for energy management. Hence, designing for shared responsibility includes both to push more powerful stakeholders to take responsibility and to support powerful stakeholders that want to take responsibility in being allowed to share responsibility.

To support the latter, it may be useful to design interventions that allow people to try out new practices in ways that do not require long-term commitment or large investments, and where responsibility is clearly shared between stakeholders. Although the car-free year study was a radical change for the participating families, we believe that the study setup provided them with a "safe space" to try out new mobility practices. They did not have to sell their cars and buy the rather expensive light electric vehicles, but instead they rented the vehicles and a partner in the study stored the cars for the duration of the car-free year. The access to experts was also appreciated, particularly in situations such as winter cycling that were new to the families. The concept of leasing contracts for electric vehicles was built on these elements from the study setup, but in a more scalable way than a research project.

Another example of a service that aims to make it easy to try new practices is the target-driven energy management contracts. They promote a new type of energy management, where energy professionals take more responsibility, at a relatively low effort and risk for housing cooperatives. The idea is that it should be easy for housing cooperatives to try this instead of, or in addition to, traditional building management services. In this case, stakeholders want to take more responsibility for energy use, but lack of trust among housing cooperatives may make it difficult for the service to spread. Interactive systems could support adoption of new practices through such try-out schemes for example by clarifying responsibilities of involved stakeholders, by facilitating transparency of results needed for holding stakeholders accountable, and, in the long term, by supporting trust between energy users and more powerful stakeholders.

It has previously been suggested that interactive systems can be used to empower people by revealing power structures and by providing means for citizens to put pressure on those with power (Prost et al., 2015). However, since energy use is not a goal in itself, but parts of practices with very different purposes, it may in many situations not be obvious even to people who influence energy practices that they have that power. Although team leaders in children's sports teams can influence how children travel to and from team activities, the official responsibilities of the leaders typically do not include to make sure that the team's carbon footprint is as low as possible. Energy responsibility is in this case "hidden" behind responsibilities for organising practicalities around team activities. In the housing cooperative case, there are also examples of activities that primarily are conducted for other reasons than reducing energy use, but they could nevertheless influence the energy performance of a building. One example is long-term maintenance planning for larger renovations, where the focus is on keeping the buildings structurally sound but the work could at the same time provide a good opportunity for energy improvements. Hence, in addition to revealing power structures with the purpose of empowering people to put pressure on stakeholders, design could play a role in supporting other stakeholders in understanding their influence on energy practices and opportunities of sharing responsibility for energy use.

In other cases, the links between responsibilities and energy are explicit, such as for the work of the Swedish municipal energy advisors. The sole purpose of the energy advisors is to support households, companies and other organisations in reducing the environmental impact of energy use. However, their influence on energy practices is mainly in the form of making knowledge available. As we saw in the study of housing cooperatives, this knowledge needs to be linked to other elements and practices in order to influence housing cooperative energy management practices. Supporting such connections could be another opportunity for design.

6 Discussion

6.1 From influence to responsibility

When suggesting to design for shared responsibility, I make a link between power to influence energy-intensive practices and responsibility to consider and act upon such influence. While I believe this connection is necessary to make, I am also aware that it comes with several challenges. Having power to influence something is not the same as taking responsibility. In some cases, stakeholders may be unaware of their influence and any connections to sustainability. In other cases, responsibility may be undesired and stakeholders are unwilling to acknowledge or take on responsibilities. Furthermore, having the power to influence practices does not mean that there is intent to influence in a certain direction. Responsibility, on the other hand, recognises or assumes that there is power to influence and that the influence can have better or worse outcomes for different people and in different situations.

Since responsibility is connected to intent, responsibilities can be in conflict with each other. This was apparent for example in the engagement of energy companies in housing cooperative energy management practices. While the energy company in our study expressed that they would like to help housing cooperatives to reduce their energy use, the intent behind such efforts were questioned by some cooperatives. If the business model of an energy company is based on the premise that the more energy the company sells the more money they make, the intent to support customers to reduce their energy use clashes with intents of increasing profits. Hence, it is not surprising that energy users may be hesitant to share responsibility for their energy use with energy companies. Similar issues of people lacking trust in powerful stakeholders, who may be perceived as having vested interests, have been identified in other studies (Alan et al., 2016; Rodden, Fischer, Pantidi, Bachour, & Moran, 2013). In some cases, and depending on the context, the idea of certain stakeholders sharing responsibility for aspects of energy use that are considered personal may be controversial (Strengers, 2012). Should an employer try to influence how their employees get to work? And is it acceptable for politicians to try to influence where people spend their holidays?

When taking a practice perspective on energy use, it is obvious that stakeholders such as companies and politicians already influence these practices. If influence is connected to responsibility, stakeholders have to address the outcomes of this influence in terms of which outcomes are desired or not and for whom. While much of this is beyond the scope of HCI or design, I believe design of interactive systems, as well as other types of design, can support responsible influence on energy practices.

6.2 Designer and researcher responsibilities

For HCI researchers and designers, there are many aspects of sustainability to consider in our own practices. A fundamental question to ask ourselves when creating new systems and services is if their societal value outweigh the environmental costs (Preist et al., 2016). Although technology is central in HCI, it is also important to consider that there may be "no tech" or "low tech" approaches that are more appropriate than introduction of new technology when addressing sustainability issues (Baumer & Silberman, 2011). In both cases I have worked on, interactive systems seem to have a place in sustainable practices, but it is also clear that there are many other, possibly more important, elements of those practices. However, when presenting research results to stakeholders outside of academia, my experience is that tangible results such as apps attract a lot of attention while abstract aspects of practices, such as emotions or norms, are more difficult to communicate in relation to energy use. For Sustainable HCI to integrate a practice perspective also in public communication of research, I believe we need to find new ways of visualising interactive systems as part of practices that do not make technology appear as solutions in themselves.

Another responsibility for designers and researchers relates to who benefits from the results. In design, it is crucial to know who we are designing for, but from a sustainability perspective it is also very important to consider who we are *not* designing for. Already in the 1970's, the design profession was criticised for designing mainly for people living in abundance and for not addressing real needs of less fortunate people (Papanek, 1971). In the same line, Ekbia and Nardi (2016, p. 5000) encourage HCI researchers to reflect on: *"Which social class benefits from this technology, and might be there a way to work toward balancing benefits for different social classes more equitably?"*.

For research addressing energy-intensive practices, it is natural to focus on the middle class or high-income groups since they generally have the most energy-intensive practices. In the car-free mobility case, we only studied families who could afford having a car but wished to manage without owning a car. There are of course also families who are car-free not by choice, but because they have no other option. Such families were not present in the study, but they would nevertheless benefit from products, services and infrastructure that make life easier without a car. However, although there is a link between car-dependency and social exclusion (Mattioli, 2014), efforts to reduce car use are not necessarily inclusive. For example, our suggestion to include employers in making light electric vehicles more easily accessible only directly benefits people with an employment. More research would be needed to understand sustainable mobility practices of low-income groups and to translate that into implications for design.

Similarly, the housing cooperative research mainly benefits people who can afford to own their home. While the purpose of the research is to understand how the environmental impact of energy use in housing cooperatives could be reduced, this is primarily interesting for housing cooperatives for reasons of reducing energy costs or improving comfort. The research could be expanded to consider energy management practices in buildings with rental apartments, and in that way provide economic benefits to other social groups. Large companies owning apartment buildings in Sweden often have professional energy management in place, but buildings owned by small companies or private landlords may face similar challenges of lack of knowledge and time as housing cooperatives. In addition, supporting energy improvements and sharing of experiences in such contexts may be more relevant for countries where the housing cooperative form of building ownership is rare or non-existent.

6.3 Approaches to sustainability

While the two cases I have worked on have many similarities, they approach sustainability from different perspectives – corresponding to approaches of “technical fix” or “value change” (Robinson, 2004). The housing cooperative energy management work has mainly been concerned with realising the potential of technology to improve the energy efficiency in buildings, while the car-free mobility study is addressing changes in values and lifestyles. In order to radically reduce the environmental impact of energy use, I believe both increased efficiency of energy systems and reduced energy demand due to changes in lifestyles are important. However, so far most public efforts seem to address energy efficiency.

For the housing cooperatives we initially worked with, the energy reduction potential of an efficiency approach was significant; audits of the buildings indicated energy reduction potentials of 10-50% (Wintzell, Larsson, & Ociansson, 2013). But energy efficiency in terms of building energy performance, measured in kWh per square metre, is a poor measurement for discussing the value energy provides for people or to understand overall energy use. The buildings of the housing cooperatives in our study were new and already more energy efficient than older buildings, but at the same time the apartments were larger, and thus needed more heating (Svane, 2014). This made the total energy use per person similar to that of people living in older buildings. Our design intervention did not question such aspects of energy use, nor did it challenge expectations on comfort or convenience provided by the energy systems. A next step could be to take a more disruptive approach to lifestyles in a housing cooperative context and explore assumptions and conventions related to comfort and convenience in this context.

The car-free year study was indeed more controversial, and although many stakeholders found the results interesting the study was also questioned. From comments on the project’s Facebook page and after public presentations of the project results, we understood that researching car-free living was by some perceived as propagating for a car-free Stockholm or Sweden, and in that sense considered unrealistic or insensitive to the needs of people living in small towns or in the countryside. An alternative approach, which might have been considered more realistic by sceptics, could have been to include car-sharing services or the use of electric cars in the study. However, even though I believe electric cars and sharing services could be important parts of sustainable mobility practices, the insights from the car-free year study, in the form it had, resulted in different design opportunities than it would if the other transport options were included. The insights from the study can probably be combined with ideas for car-sharing services, but without the car-free experiences it may have become more a matter of optimising use of cars. For Sustainable HCI, I believe it is particularly important to explore the role of interactive systems in other ways than as a means for optimisation and efficiency.

6.4 Practice-oriented design research in the field

The two cases I have worked on include different types of interventions into practices that impacted the study participants' lives to different extents. The greatest change related to the research setup was in the car-free year study, where many everyday practices were disrupted. However, while disruption as a research method may provide insights that are difficult to obtain in any other way, questioning current lifestyles can be an unpleasant experience for participants (Poole, Comber, & Hoonhout, 2015). Removing the car certainly came with challenges for the participating families and we tried to be observant of unpleasant experiences. The close collaboration with the car-free families, together with recurring participant reflections on the car-free experiences, was helpful for discussing both positive and negative experiences during the study and we aimed to provide support or make adjustments (e.g. replacing vehicles) when necessary. Furthermore, we balanced the radical change of removing the car with the backup option of using taxi or rented or borrowed cars 24 times during the car-free year. The purpose was to provide an option for the situations when the participants saw no other solution than using a car. Since the participants had to register their car trips, this also provided insights into situations that were perceived as completely car-dependent, such as when a toilet unexpectedly broke down and urgently had to be replaced.

When exploring changes in practices it can be useful to balance stricter approaches, such as removing objects from practices or adding rules to practices, with softer approaches of adding new objects or softening rules (Hesselgren, Hasselqvist, & Sopjani, 2017). Adding a stricter approach to the housing cooperative case, where introducing the energy app to the housing cooperatives was only a marginal intervention for the participating cooperatives, could be one way of exploring more significant change in the future. This could be done by combining the energy app with other initiatives, such as target-driven energy management, that include stricter rules and greater changes in themselves.

Another difference between the two cases I have worked on is that the types of practices explored were very different. The mobility case includes more “everyday practices”, performed by people in their everyday lives, which Sustainable HCI research has been suggested to explore and design for (Kuijer et al., 2013; Silberman et al., 2014). Everyday life and everyday practices are not precise terms, but they appear to be used mainly for practices that are performed frequently in domestic or public settings and not for professional practices or practices that are performed more rarely.

From an energy perspective, it makes sense that the most frequently performed practices are likely to result in the highest overall energy use. Using a car every day for work results in higher carbon emissions than occasional car trips to a summer house. But if those few car trips per year to the summer house make owning a car worthwhile, the car might be used also for commuting even if there are other viable options. One family in our study commuted by car before the car-free year even though they could easily replace the car trips with cycling or public transport, but since they anyway had access to the car it was a convenient option. However, they found that commuting was not difficult to solve without the car – the challenges were related to more occasional trips, such as when going for outdoor activities or going on holidays. Thus, addressing only everyday practices would in the mobility case not support car-free living and probably result in an overall lower impact on energy use.

Furthermore, what is an everyday practice for one stakeholder might be an occasional practice for another – particularly if we also consider professional practices. Energy management practices are typically not an everyday concern for housing cooperatives, but for professionals working with energy management in housing cooperatives they are. For Sustainable HCI, I believe it is important to explore and design for both practices in everyday life, professional and non-professional, and more rare practices that are particularly resource intensive or that are linked to resource-intensive everyday practices.

Although a focus on the energy impact of practices in isolation may put focus on some practices and leave out others that are equally important, I agree with Kuijer (2014) that a useful starting point for practice-oriented design is to investigate the resource-intensity of practices and the potential for change. Otherwise, just as householders have been found to focus on energy actions perceived as green, such as turning off appliances to avoid standby power, rather than more resource-intensive practices, such as purchases of new energy-intensive appliances (Strengers, 2011a), researchers may address practices with only a marginal impact on energy use. A review of design research aiming to support sustainable behaviours found that most of the reviewed papers lacked a strategy for selecting which behaviours to address (Coskun et al., 2015). However, as it initially may not be obvious which practices are most energy-intensive, or strongly linked to energy-intensive practices, I believe it is necessary with an iterative process of exploring the energy impact of practices, identifying complexes of practices related to energy-intensive ones, and understanding the long-term impact and interdependencies of a selection of these practices. This includes to engage with not only energy users, but also with other stakeholders whose practices influence energy-intensive practices. For both my cases, the initial explorations of car-free practices and housing cooperative energy management opened up opportunities for involving, or exploring practices of, additional stakeholders that we did not think of in the beginning of the studies. Furthermore, some stakeholders were interested in the early results of the studies or the design artefacts and might have been more difficult to meet with before these results existed, even if we would have identified them as central stakeholders already from the beginning.

In my studies, the iteration of which practices to focus on was possible because the studies ran over long times. Furthermore, the long-term engagement with the study participants made it clear that supporting change towards more sustainable practices is not only about people adopting new practices and developing new habits, or about recrafting practices to make them less energy-intensive, but it is also about maintaining adopted practices and their energy level over time. From both of my studies it is apparent that there are always risks of crises of routines, when circumstances naturally change, and risks of unintended increases in the energy-intensity of practices. Although the car-free year study lasted for a whole year, some of the families' practices changed rather soon after the study ended. The end of the study was in itself a crisis of routines, but there were also other factors that influenced changes, such as a teenager being old enough to practice driving. Thus, longitudinal studies are not only useful for investigating if practices are actually adopted, but also for identifying new types of crises of routines that may increase energy use.

Despite working with the same cases for a long time, there are still many unexplored opportunities related to the cases. It would for example be interesting to collaborate with sports teams to explore sustainable mobility or to design the housing cooperative energy app also for energy professionals. Furthermore, when focussing on specific practices, it can be useful to map the historical changes of a practice and investigate similar, but less energy-intensive, practices as inspiration for design (Kuijer, 2014). Since my main interest has been to understand complexes of practices, rather than analysing a few specific practices in detail, both my cases could benefit from such analyses in the future.

7 Conclusion

For HCI to contribute to addressing the complexity of energy-intensive practices, there is a need for a better understanding of the perspectives of different stakeholders, not only energy users, and their influence on energy-related practices. In my research I have explored stakeholder influence on car-free mobility practices and energy management in housing cooperatives. One opportunity for the design of interactive systems in these contexts is to support shared responsibility for energy use between different stakeholders. However, designing for shared responsibility is not a quick design process – it needs to be grounded in an understanding of energy use, of practices resulting in energy use, and of how different stakeholders may influence these practices. Going through these stages has helped me to answer my research questions, which I come back to below to summarise the take-away points.

RQ1: In what ways do stakeholders influence, and could share responsibility for, resource use in energy-intensive practices?

» In my studies, I mainly found examples of stakeholders aiming to contribute to rather small changes in practices and the efforts were typically focused on isolated practices. However, considering complexes of practices, and how practices interlock, may be equally important for supporting overall decreased energy use, such as in the case of addressing car dependency.

» In addition to support adoption of new practices, it can be useful to understand how less energy-intensive practices can be maintained over time. Compared to adoption of new practices, maintenance is less discussed both in research and among stakeholders in my studies, but nevertheless important to understand as there is always a risk that practices will be abandoned due to crises of routines or that the energy-intensity of a practice increases with time. Stakeholders could contribute both to overcoming crises of routines and to maintaining reduced energy use levels of a practice.

» Stakeholders may also cause crises of routines that could influence both how practices are adopted and abandoned. This could provide opportunities for supporting changes towards more sustainable practices as well as risks of increased energy intensity of practices.

» While stakeholders influence energy-related practices all the time, there are some challenges to actual responsibility being taken. Stakeholders may lack awareness of their influence or lack interest in taking responsibility. There can also be clashes in responsibilities between stakeholders that work against changes in practices, such as clashes between who pays for investments needed for sustainable practices and who benefits from the intended change. Furthermore, there can be clashes between stakeholders and energy users that make shared responsibility undesired from a user perspective, such as when the energy users' trust in a certain stakeholder is low.

RQ2: What design sensitivities are important to consider when aiming to support the types of stakeholder influence and opportunities for shared energy responsibility identified in RQ1?

» *Considering odd-norm tensions*: To address tensions between "odd" and "normal" practices, and make sustainable alternatives more attractive, ICT could support sharing of knowledge or other resources among practitioners of odd practices, as well as support sharing of responsibilities between people engaged in normal and odd practices. However, when aiming to reduce discomfort related to engaging in odd practices, designers also need to pay attention to risks of reinforcing norms that may inhibit alternative practices to spread in the long term.

» *Designing for interaction over different time scales*: Considering different stakeholders, and shared responsibility between stakeholders over time, opens up for designing for interactions over different time scales for different stakeholders. Energy users may not need to be engaged and interact with systems regularly but could be engaged at strategic times, such as when experiencing crises of routines. For other stakeholders, such as energy professionals, it may be more appropriate to design for frequent interaction over longer times.

» *Supporting other values than resource optimisation*: While ICT is useful for optimising quantitative data, such as time and cost, this type of values might not be the only elements of practices worth highlighting in interactive systems. Other values related to mobility include for example to take a scenic route and to get exercise, and for energy management indoor comfort is an important value of energy improvements.

» *Supporting shared energy responsibility*: Since various stakeholders already influence energy-related practices, and aim to contribute to less energy-intensive alternatives, one design opportunity for ICT is to amplify such activities. In cases when stakeholders struggle with being allowed to take more responsibility due to lack of trust from energy users, interactive systems could support transparency and trust, and promote interventions that allow energy users to try out new practices at a low effort and risk. Interactive systems could also contribute to revealing influence on energy use that is "hidden" behind other responsibilities, such as management of a sports team for children or long-term maintenance of a building.

Exploring and supporting shared energy responsibility requires a different approach to practices than what is normally taken in Sustainable HCI studies. To understand the complex interdependencies between practices, and the many ways stakeholders may influence these, we need to embrace the "mess" of practices related to different types of energy use and not single out a specific practice to analyse and design for. Furthermore, even when addressing energy use of domestic practices, it is necessary to combine studies of these with studies of professional practices that may influence the domestic ones. Studies of specific practices may provide interesting starting points for such broader explorations of practices as well as provide insights into selected parts of complexes of practices at later stages of the research. For my cases there are many practices that could be further analysed and design opportunities that could be developed, and I believe that the studies I have conducted provide a good foundation for selecting specific practices that are important to further analyse and design for in collaboration with relevant stakeholders.

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