THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

SUSTAINABILITY IN THE HOME ENVIRONMENT

Supporting households in circularity and smart energy use through design

SOFIE HAGEJÄRD

Department of Architecture and Civil Engineering

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2025

Sustainability in the home environment
Supporting households in circularity and smart energy use through design
SOFIE HAGEJÄRD
ISBN 978-91-8103-197-3

Doktorsavhandlingar vid Chalmers tekniska högskola
Ny serie nr 5655
ISSN 0346-718X

Department of Architecture and Civil Engineering
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

All photographs and illustrations by Sofie Hagejärd, unless otherwise stated.

Cover: Image to the left: Prototype of the circular kitchen prototype CIK 1.0, installed in an apartment of the HSB Living Lab, photograph by Paul Björkman.
Image to the right: Home energy management system prototype Ero 2.0, photograph by Sofie Hagejärd.

Chalmers Reproservice
Gothenburg, Sweden 2025

ABSTRACT

Consumption related to households' everyday practices and lifestyles accounts for an important share of global resource use and emissions. This thesis aims to identify opportunities for more sustainable consumption within and for the home. This has been addressed by investigating households' thoughts and practices in relation to product and service solutions aimed at reducing environmental impacts.

The research uses a mixed methods approach and combines qualitative methods, such as interviews and workshops, with quantitative methods, such as surveys and diary tools. Four empirical studies have been conducted as part of two themes representing different pathways towards sustainable consumption. The first theme is focused on contributing to the circularity of domestic kitchens by investigating possibilities for implementing circular economy principles, both in the design and business models of kitchens. The second theme is focused on opportunities for households to become more flexible in their energy demand to support a more sustainable energy system.

The findings indicate that households have varying preconditions for engaging in sustainable consumption practices. Thus, several approaches need to be considered to achieve substantial reductions in environmental impact. In the case of supporting a circular economy of kitchens, different approaches are suggested involving varying levels of flexibility and durability in the design. Suggestions for business models that could support the circularity of each approach are given, together with recommendations about which kinds of housing should be targeted. In the case of enabling energy demand flexibility, suggestions are given for different approaches in the design of home energy management systems, involving varying levels of manual control or automation in relation to different knowledge levels among users.

In order to achieve a societal transition towards circular economy and sustainable energy systems, current consumption practices and mindsets need to be challenged. However, the responsibility of lowering the environmental impact of home-related consumption cannot be placed on households alone. Households need to be supported not only by sustainability-oriented products and services but also by systemic changes and dwellings that support less resource-intensive lifestyles.

To conclude, this thesis contributes insights into home-related consumption from a household perspective and highlights opportunities for design to enable greater levels of circularity and sustainable energy use at home. The thesis is relevant for researchers as well as practitioners working with circular products and service offerings, energy provision and management, and housing.

Keywords: circular design, circular business models, household energy use, smart home technologies, demand-side management, design for sustainability, social practice theory

SAMMANFATTNING

Konsumtion kopplad till hushållens vardagspraktiker och livsstilar står för en viktig del av global resursanvändning och utsläpp. Denna avhandling syftar till att identifiera möjligheter för mer hållbar konsumtion inom och för hemmet. Detta har adresserats genom att undersöka hushållens tankar och praktiker i relation till produkter och tjänster som syftar till att minska miljöpåverkan.

Forskningen kombinerar kvalitativa metoder, som intervjuer och workshops, med kvantitativa metoder, som enkäter och dagboksverktyg. Fyra empiriska studier har genomförts som del av två teman, vilka representerar olika vägar mot hållbar konsumtion. Det första temat fokuserar på att bidra till mer cirkulära kök genom att undersöka möjligheter att implementera principer för cirkulär ekonomi, både i kökets design och affärsmodeller kopplade till köket. Det andra temat fokuserar på möjligheter för hushållen att bli mer flexibla i sin efterfrågan av energi för att stödja ett mer hållbart energisystem.

Resultaten indikerar att hushållen har olika förutsättningar för att engagera sig i hållbara konsumtionspraktiker. Därför behöver flera olika tillvägagångssätt tas i åtanke för att åstadkomma betydande minskningar i miljöpåverkan. När det gäller att stödja en cirkulär ekonomi kring kök föreslås olika tillvägagångssätt som involverar olika nivåer av flexibilitet och hållbarhet i designen. Förslag på affärsmodeller som kan stödja de olika cirkulära designstrategierna ges också tillsammans med rekommendationer om vilka typer av bostäder som de kan riktas mot. När det gäller att möjliggöra flexibilitet i energibehovet ges designförslag för energihanteringssystem för hemmet som involverar olika nivåer av manuell styrning eller automatisering i förhållande till olika kunskapsnivåer hos användarna.

För att uppnå en samhällelig omställning mot cirkulär ekonomi och hållbara energisystem behöver nuvarande konsumtionspraktiker och tankesätt utmanas. Ansvaret för att minska miljöpåverkan från hemrelaterad konsumtion kan dock inte enbart läggas på hushållen. Hushållen behöver stödjas inte bara av hållbarhetsinriktade produkter och tjänster utan också av systemförändringar och bostäder som stödjer mindre resurskrävande livsstilar.

Sammanfattningsvis bidrar den här avhandlingen med insikter i hemrelaterad konsumtion ur ett hushållsperspektiv och belyser möjligheter för design att möjliggöra högre nivåer av cirkularitet och hållbar energianvändning i hemmet. Avhandlingen är relevant för såväl forskare som praktiker som arbetar med cirkulära produkter och tjänsteerbjudanden, energiförsörjning och förvaltning, samt bostäder.

Nyckelord: cirkulär design, cirkulära affärsmodeller, hushållens energianvändning, smarta hemteknologier, styrning av efterfrågan, design för hållbarhet, social praktikteori

ACKNOWLEDGEMENTS

Many people have inspired and supported me on my PhD journey, and I want to express my warmest gratitude to you all. First of all, I would like to thank the people who made this PhD possible. Paula Femenías, my main supervisor, thank you for your invaluable feedback and for helping me develop as a researcher. Monica Billger, my examiner, I greatly appreciate your guidance and enthusiasm. Ida Nilstad Pettersen, my co-supervisor for the second part of my PhD, I am thankful for your insightful feedback that helped me move the research forward. Ulrike Rahe, my co-supervisor for the first part of my PhD, thank you for giving me the opportunity to get involved in research and for your encouraging feedback. I also want to thank Maja Kovacs for supporting me throughout this journey.

Second, I want to extend my deepest gratitude to my colleagues, both current and former, for making the work more fun and rewarding. Thank you for all the inspiring discussions, for motivating me, and for your contributions to this work.

Third, through the research projects, I have had the privilege to collaborate with talented people from various disciplines, both within academia and industry. Thank you for our inspiring workshops and discussions together. I want to direct a special thanks to my PhD colleagues in the Circular Kitchen project, both at Chalmers and TU Delft; Anita Ollár, Giliam Dokter, Anne van Stijn, and Bas Jansen. I have truly enjoyed our sharing of knowledge and ideas. To those who made the studies technically feasible, thank you for the development of the digital tools used in the studies and for the technical support throughout the process. I also want to thank the funding organisations for making this research possible.

Fourth, I want to direct a warm thank-you to everyone who participated in the studies. Without your valuable contributions, this thesis would not exist.

Finally, my heartfelt thanks to my family and friends for supporting me, keeping me going, and contributing to my wellbeing. Johan, thank you for always being there, for your unwavering support, and for all the joy you bring to me. Elon and Amelia, thank you for brightening my life and reminding me of what is most important.

APPENDED PUBLICATIONS

PAPER A

Hagejärd, S., Ollár, A., Femenías, P., & Rahe, U. (2020). Designing for Circularity – Addressing Product Design, Consumption Practices and Resource Flows in Domestic Kitchens. *Sustainability*, 12(3), 1006. https://doi.org/10.3390/su12031006

Contribution: Hagejärd planned the study together with Ollár, with input from Femenías and Rahe. Hagejärd and Ollár performed the data collection and analysed the data together. Hagejärd wrote the paper with contributions from Ollár. Femenías and Rahe reviewed the paper.

PAPER B

Hagejärd, S., Femenías, P., & Pettersen, I.N. (forthcoming) User perspectives on circular value propositions for kitchen furniture and appliances. *Accepted for publication in Circular Economy and Sustainability.*

Contribution: Hagejärd planned the study together with Femenías. Hagejärd and Femenías performed the data collection. Hagejärd analysed the data and wrote the paper with input and support from Femenías and Pettersen.

PAPER C

Hagejärd, S., Dokter, G., Rahe, U., & Femenías, P. (2021) My apartment is cold! Household perceptions of indoor climate and demand-side management in Sweden. *Energy Research & Social Science*, 73, 101948.
https://doi.org/10.1016/j.erss.2021.101948

Contribution: Hagejärd planned the study together with Dokter and Rahe. Hagejärd and Dokter carried out the study. Hagejärd analysed the data and wrote the paper. Dokter, Rahe and Femenías reviewed the paper.

PAPER D

Hagejärd, S., Dokter, G., Rahe, U., & Femenías, P. (2023) "It's never telling me that I'm good!" Household experiences of testing a smart home energy management system with a personal threshold on energy use in Sweden. *Energy Research & Social Science, 98*, 103004. https://doi.org/10.1016/j.erss.2023.103004

Contribution: Hagejärd planned the study together with Dokter and Rahe. Hagejärd and Dokter carried out the study and analysed the data. Hagejärd wrote the paper and Dokter, Rahe, and Femenías reviewed the paper.

ADDITIONAL PUBLICATIONS

Some of the following papers are published in my former name, Andersson.

Andersson, S. & Rahe, U. (2017). Accelerate innovation towards sustainable living: exploring the potential of Living Labs in a recently completed case. *Journal of Design Research*, *15*(3/4), 234–257. https://doi.org/10.1504/JDR.2017.089914

Andersson, S., Ollár, A., Femenías, P., & Rahe, U. (2018). Retrofitting from the Inside/Insight Perspective: Adapting to Users' Needs with the Kitchen as a Starting Point. *Paper presented at Retrofit Europe! Innovation Meets Market SBE19 Conference, 5-6 November 2018, Eindhoven, Netherlands.*

Andersson, S., & Rahe, U. (2019). All Doors Lead to the Kitchen – Sustainability and Wellbeing Challenges in a Shared Centrepiece of Living. In T. Ahram, W. Karwowski, & R. Taiar (Eds.), *Human Systems Engineering and Design: Proceedings of the 1st International Conference on Human Systems Engineering and Design (IHSED2018): Future Trends and Applications, October 25–27, 2018, CHU-Université de Reims Champagne-Ardenne, France* (Vol. 876, pp. 111–116). https://doi.org/10.1007/978-3-030-02053-8

Dokter, G., Andersson, S., Thuvander, L., & Rahe, U. (2019). Co-creation – a facilitator for circular economy implementation? A case study in the kitchen industry. In N. Nissen & M. Jaeger-Erben (Eds.), *PLATE Product Lifetimes and The Environment 2019 – Conference Proceedings. TU Berlin University Press.*

Renström, S., Andersson, S., Jonasson, A., Rahe, U., Merl, K., & Sundgren, M. (2019). Limit My Energy Use! An In-Situ Exploration of a Smart Home System Featuring an Adaptive Energy Threshold. *Paper presented at the 19th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP): Circular Europe for Sustainability – Design, Production and Consumption. Barcelona, Spain.*

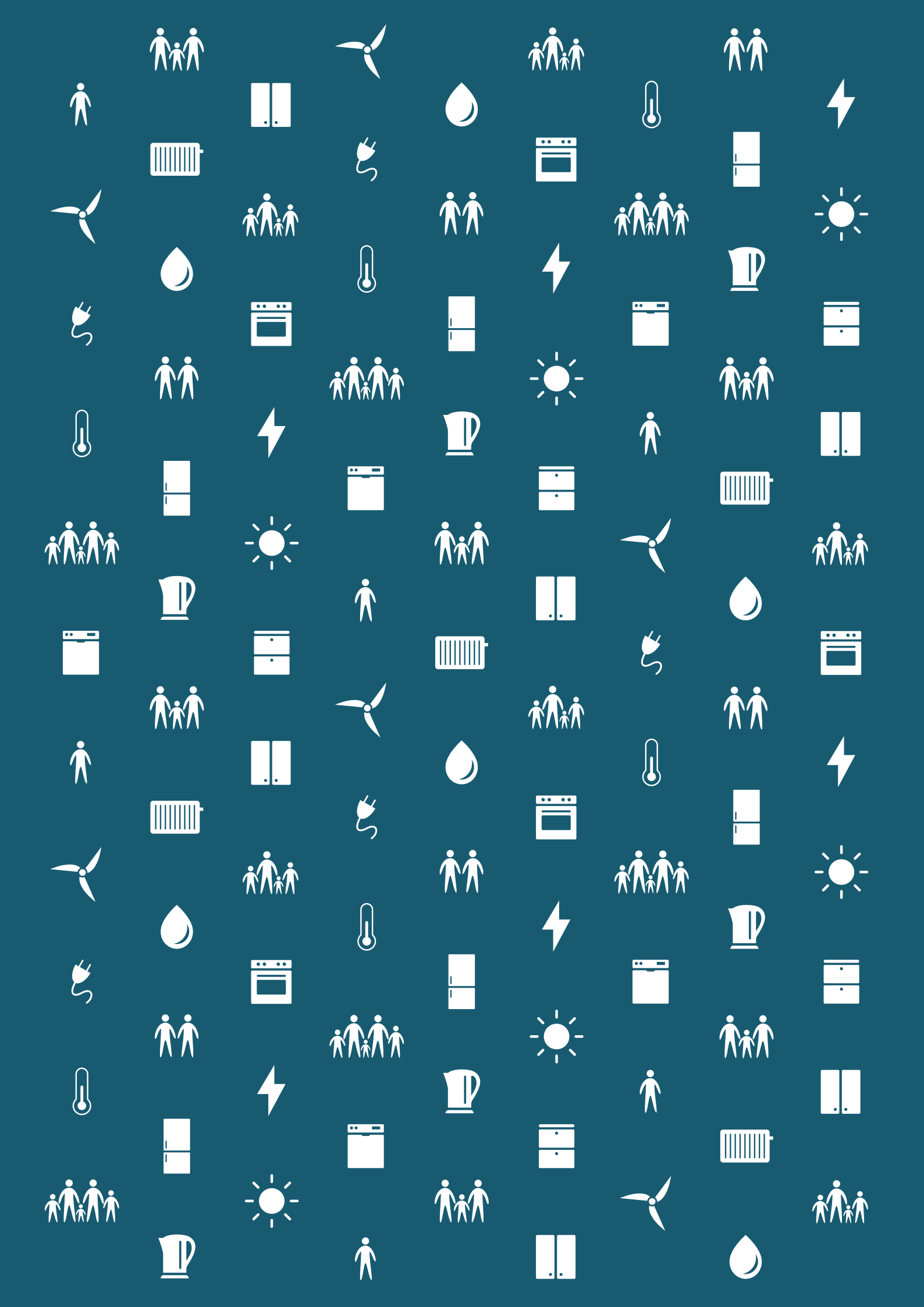
Ollár, A. Femenías, P. Granath, K. & Hagejärd, S. (2022) Determining spatial characteristics for circular building design: The case of kitchen alterations. *IOP Conference Series: Earth and Environmental Science, 1085*, 012065. https://doi.org/10.1088/1755-1315/1085/1/012065

Dokter, G., Boks, C., Rahe, U., Wouterszoon Jansen, B., Hagejärd, S., & Thuvander, L. (2023). The role of prototyping and co-creation in circular economy-oriented innovation: A longitudinal case study in the kitchen industry. *Sustainable Production and Consumption*, 39, 230–243. https://doi.org/10.1016/j.spc.2023.05.012

Dokter, G., Cohen, J., Hagejärd, S., Rexfelt, O., Thuvander, L. (2024). Mapping the practice of circular design: a survey study with industrial designers and architects in the Netherlands and Sweden. *Journal of Design Research*, 21(3-4), 177-209. https://doi.org/10.1504/JDR.2024.143685

Malakhatka, E., Hagejärd, S., Mazidi, M., Corcoran, K., Röderer, K., Wallbaum, H. (2025). Optimal time recommendation model for home appliances: HSB living lab + dishwasher study. *Energy Efficiency*, 18(3). https://doi.org/10.1007/s12053-024-10290-1

TABLE OF CONTENTS



1

INTRODUCTION

This chapter introduces the background to the research presented in this thesis, followed by a description of the aim and research questions posed. The chapter continues with an explanation of the research scope and context. Finally, an outline of the thesis structure is provided.

1.1 Background

The urgency of reducing our negative impact on the environment cannot be stressed enough. A recent study by Richardson et al. (2023) indicates that we are no longer within the safe operating space for humanity on Earth, with six out of the nine planetary boundaries transgressed. Despite this, the global use of material resources continues to grow by an average of 2.3% per year and has grown more than threefold in the last 50 years (United Nations Environment Programme, 2024). Additionally, the use of secondary materials has declined in recent years, from 9.1% in 2018 to 7.2% in 2023, meaning that global circularity is decreasing (Circle Economy Foundation, 2024). The extraction and processing of material resources represent more than 55% of greenhouse gas emissions and cause negative effects on human health (United Nations Environment Programme, 2024). A continuation of current trends and policy ambition levels will clearly not be successful in meeting either the Paris Agreement on climate change or the UN sustainable development goals (Soergel et al., 2024). Although technological innovations and efficiency improvements have been given predominant focus in strategies to mitigate climate change, a growing body of research highlights that lifestyle changes will be central in limiting global warming to 1.5°C above pre-industrial temperature levels (Akenji et al., 2021; Cap et al., 2024; IPCC, 2022; Koide et al., 2021; Vita et al., 2019).

At home, we use resources in most everyday practices, such as cooking, doing laundry, showering, or simply relaxing in front of the television in a nicely heated living room. Household consumption has been estimated to account for between 50% and 80% of the global use of resources and over 60% of global greenhouse gas emissions (Ivanova et al., 2016). The carbon footprint related to household consumption includes both direct emissions, from practices relying on the direct use of energy or fuels, and indirect emissions, from the embodied carbon in consumed products and services. Major life events, such as having children, or major decisions,

such as renovating the home, may have a significant impact on the resource use and environmental footprint of households (Dubois et al., 2019).

Through their demand for goods and services, households contribute to forming patterns in society regarding emissions, technologies, infrastructures, and practices (Dubois et al., 2019). At the same time, it is difficult for individual households to break free from locked-in patterns of consumption that depend on larger sociotechnical systems (Lorek & Fuchs, 2013; Maréchal, 2010). Achieving widespread changes in lifestyles and consumption patterns is not only a matter of targeting individual attitudes and behaviour but also requires addressing cultural norms, economic and political systems, and the physical environment (Sandberg, 2021).

This thesis addresses home-related consumption in a broad sense from the perspective of households, focusing on energy use as well as the consumption of products and material resources. The included studies are part of two research themes focusing on different pathways towards sustainable home-related consumption. *Theme I: Towards circular kitchens* focuses on opportunities for implementing circular economy principles in the context of domestic kitchens. *Theme II: Towards sustainable energy use at home* focuses on opportunities for improving households' energy demand flexibility to support a more sustainable energy system. By combining the two themes, this thesis provides a nuanced understanding of home-related consumption and contributes to two different research fields sharing the goal of minimising environmental degradation and resource depletion while supporting quality of life. The themes will be further introduced in the following two sections, and a summary of previous research related to the themes will be presented in Chapter 2.

1.1.1 Theme I: Towards circular kitchens

Kitchen furniture and appliances represent a significant contribution to the environmental impact of domestic buildings (Hoxha & Jusselme, 2017). Domestic kitchens have become a target for frequent renewal and are often exchanged at a point when they are still functional. A Swedish study estimated that over 15 years, replacements of kitchen appliances and furniture together accounted for 57% of the climate impact from interior renovations of owner-occupied apartments (Femenías et al., 2018).

Of the 10 million tonnes of furniture discarded each year in the European Union, kitchen furniture represents about a quarter (Forrest et al., 2017). Most of the furniture that is thrown away is either incinerated or ends up as landfill, while only about 10% is recycled (Forrest et al., 2017). Circular business models have been proposed to be of high relevance to extending the product lifetimes of furniture because, in this product category, the highest environmental impact is connected to the raw materials extraction and production phases (Donatello et al., 2017). A recent

report by Naturskyddsföreningen (2023) claims that buying pre-used kitchen furniture instead of new can reduce the climate impact by 92%.

Circular business models are also relevant for home appliances to mitigate environmental problems connected to appliance waste and resource depletion (Bressanelli et al., 2020; Sigüenza et al., 2021). In the last decades, the lifetime of home appliances has declined (Bakker et al., 2014; Krych & Pettersen, 2024; Wang et al., 2013). The global amount of electronic waste is steadily increasing and reached 62 million tonnes in 2022 (Baldé et al., 2024).

Moving towards a circular economy of kitchen furniture and appliances is thus an important part of the societal transition to a circular economy, but so far, this area has been underexplored. There is currently a lack of research exploring design implications to minimise the environmental impact connected to kitchen renewal and opportunities to apply circular business models for both kitchen furniture and appliances from a household perspective.

1.1.2 Theme II: Towards sustainable energy use at home

To reduce the dependency on fossil fuels and mitigate climate change, a substantial increase in the use of renewable energy is needed (IEA, 2023). In 2023, renewable energy constituted 24.5% of the final energy consumption in the European Union (European Commission, 2025). The EU Renewable Energy Directive has the goal of increasing the share of renewable energy to at least 42.5% by 2030, aiming for 45% (European Commission, 2025). With a higher share of renewable energy sources that depend on weather conditions, such as wind and solar power, comes the need for managing a more fluctuating energy supply. Facilitating a match between energy demand and supply thereby becomes crucial.

Domestic energy use accounts for over a quarter of the final energy consumption in the European Union (Eurostat, 2022). This has motivated the development of various smart home technologies to support households in both reducing their energy use overall and shifting their energy use to times when there is a higher availability of energy with a low carbon footprint. The introduction of smart technologies has, however, shown varied results in shifting and reducing households' energy use. Some research has even pointed to the possibility that smart technologies bring new expectations of comfort and more energy-intensive lifestyle images (Hargreaves et al., 2018; Jensen et al., 2018; Strengers et al., 2020). A better understanding of users of smart home technologies in their home environments is thus crucial (Gram-Hanssen & Darby, 2018; Hargreaves et al., 2018; Mennicken & Huang, 2012; Nyborg, 2015a; Reisinger et al., 2022; Wilson et al., 2015).

1.2 Aim and research questions

The overall aim of this thesis is to study opportunities for shifting towards more sustainable consumption in connection to the home environment. By gaining insight

into how home-related consumption is influenced by households' life situations, practices, needs, and challenges, this thesis explores design implications to support households in minimising the environmental impact of their home-related consumption. The research also aims to understand how sustainability-oriented products and services for the home are perceived from the households' point of view. Finally, the research explores how the introduction of sustainability-oriented products and services shapes everyday practices at home. The following research questions are posed:

RQ1: How could the design of products and services support home-related sustainable consumption, focusing on circularity and smart energy use?

RQ2: How do people perceive and evaluate products and services aimed at reducing the environmental impact of home-related consumption?

RQ3: How are everyday practices shaped by the introduction of products and services aimed at reducing the environmental impact of home-related consumption?

1.3 Research scope and context

This thesis focuses on the perspectives of people in the roles of household members, residents, practitioners, and users on different pathways towards sustainable home-related consumption. The sustainability pathways studied in this thesis are circular economy, with a specific focus on domestic kitchens, and sustainable energy use, with a specific focus on energy demand flexibility and smart technologies. There are, of course, other pathways towards sustainable consumption, which will be briefly presented in Section 2.1. The different pathways overlap in many aspects but differ somehow in vision and strategies to achieve a sustainability transition. The word "transition" refers to large-scale and long-term shifts from one socio-technical regime to another (Schot et al., 2016). In other words, transitions lead to systemic changes on a societal level, covering dimensions such as technology, infrastructures, policy, markets, and user practices (Geels, 2002). A discussion regarding how the two themes studied in this thesis show both synergies and dissonance in some respects is provided in Section 7.4.

Within Theme II, the phrase "smart energy use" is used to describe households' energy use supporting demand flexibility, with or without the use of smart technologies. Thus, this thesis explores the use and potential of smart technologies to achieve energy demand flexibility but strives to adopt a non-normative view on the role of smart technologies in future sustainable energy systems. Furthermore, the phrase "energy demand flexibility" is used in a broad sense, not only referring to the flexibility of shifting energy use in time but also to energy demand reductions and shifting to other forms of energy, in accordance with the categorisation identified by Grunewald & Diakonova (2018).

An important thing to note is that the studies included in Theme II were carried out in 2019 and 2020, before the European energy crisis of 2022. The findings from these studies should, therefore, be interpreted with this in mind. If the studies had been carried out during or after the energy crisis, it is possible that the findings would have turned out differently due to rising energy prices and media attention on the subject.

While Theme II focuses on energy use in the home environment, Theme I specifically focuses on the kitchen. Although the findings regarding the potential to apply circular design strategies and circular value propositions preliminary focus on kitchen furniture and appliances, they are of relevance to other categories of furniture and appliances in the home. However, some findings are specifically connected to the kitchen context.

The participants in the four studies represent different demographics, but the samples are limited to a Swedish context, and the predominant part of the participants live in urban environments. In Theme I, different tenures are represented, from rental apartments to owner-occupied detached houses. In Theme II, only rental apartments of multi-residential buildings are represented. In this type of dwelling in Sweden, heating is often included in the rent, but residents pay for their electricity use separately, which was also the case for the participants.

The intended audience for this thesis is found in academia as well as industry and policy. The research contribution of this thesis is of relevance for researchers within the area of sustainable consumption and specifically in the fields of circular design, circular business models, smart energy research, user research, design for sustainability, and social practice theory. The practical implications of this thesis are of relevance for companies involved in kitchen production, appliance production, energy provision and management, and housing companies. Furthermore, findings related to the role of the kitchen in the dwelling and the impact of building characteristics on households' possibilities to be flexible in their energy demand are of relevance for architects, landlords, and policymakers.

The following sections will describe the Swedish context and the project context, which has contributed to shaping the scope of this thesis.

1.3.1 Swedish context

In Sweden, 50% of the households live in apartments in multi-residential buildings, of which 58% are rental apartments and 42% are owner-occupied apartments (SCB, 2023). 42% of all Swedish households live in single-family houses (SCB, 2023).

Swedish building regulations require dwellings to include furnishings and equipment for food preparation and storage, including a stove, refrigerator, and freezer (Boverket, 2024). Thus, when a dwelling in Sweden changes owner or tenant, the kitchen furniture and appliances stay in the dwelling.

In 2023, Swedish electricity production consisted of 42.5% hydropower, 30% nuclear power, 22% wind power, 4.5% heat power, and 1% solar power (excluding

self-produced electricity by households and industry) (Svenska Kraftnät, 2024). This results in an energy mix that is 98% fossil free (Energiföretagen, 2023). However, when electricity demand exceeds supply, electricity can be imported from neighbouring countries, which may impact the share of fossil-based electricity (Energiföretagen, 2023).

More than half of all residential buildings and facilities in Sweden are heated by district heating, and for multi-residential buildings, the share is around 90% (Energiföretagen, 2024). In 2015, the energy sources used in the Swedish district heating supply were mainly biomass (46%) and waste incineration (24%), while only 7% were represented by fossil fuels (Werner, 2017).

1.3.2 Project context

The research presented in this thesis has been part of several research projects. Connected to Theme I, the research was part of the project the Circular Kitchen (CIK), carried out between 2018 and 2021 and funded by EIT Climate-KIC and industry partners. This project was a collaboration between TU Delft, Chalmers University of Technology, and industrial partners, including housing developers, kitchen manufacturers, and appliance producers. This project has been continued, funded by Formas and Västra Götalandsregionen from 2022 until 2025. It involved Chalmers University of Technology and some new as well as some of the original partners.

The CIK project aimed to contribute to improved knowledge of how kitchens are used in everyday life and renewed by households. The goal of the project was to develop kitchen furniture and appliances based on circular economy principles to achieve a reduction in resource use, environmental pollution, and greenhouse gas emissions related to kitchens.

Based on circular economy principles, three kitchen prototypes (CIK 1.0, 2.0, and 3.0) have been developed. The first two prototypes are designed with a focus on modularity and longevity, using a frame construction with flexible connectors and durable materials such as plywood with bio-based lignin. CIK 1.0 was finalised in 2021 and installed in an apartment of the HSB Living Lab. During the second part of the project, it was used on a daily basis by a researcher who participated in the project and lived there. CIK 2.0 was finalised in 2022 and updated slightly from the previous version in terms of construction, measurements, and surface coatings. It was installed in Garveriet, a venue focused on sustainable and local food production located outside of Gothenburg. CIK 3.0 was finalised in 2023 and focused on balancing durability and affordability, opting for a chipboard made of recycled material and biobased glue for the cabinet frames instead of the more expensive plywood. The surface material is easily removed for recycling the chipboard. An important detail is the connector, which enables quick assembly and delivery in flat packages for the professional market. The connector also permits the cabinets to be dismantled 6-7 times before the chipboard is worn out.

In the Swedish CIK project, we were three doctoral students, all sharing the goal of contributing to the development of more circular kitchens but with different research focuses. My role was to explore the perspectives of households and users on circular design and circular value propositions in relation to the everyday use and renewal of kitchens. Another doctoral student focused on the spatial design and adaptability of kitchens to identify factors contributing to circularity in residential buildings (Ollár, 2024). The third doctoral student focused on co-creation and the practical implications of designing for a circular economy (Dokter, 2023). The Dutch CIK project involved two doctoral students. One of them focused on design guidelines and life cycle assessment tools for circular building components (van Stijn, 2023). The other one focused on the economic performance of circular building components through a life cycle costing method and stakeholder decisions in the development of the Dutch circular kitchen (Jansen, 2024). In the CIK project, the doctoral students and senior researchers collaborated in both the circular kitchen development and in research studies, resulting in several co-authored publications.

Connected to Theme II, the research was part of the projects FIWARE for Smart Energy Platform (FISMEP), carried out between 2018 and 2020 and funded by ERA-Net Smart Energy Systems via Energimyndigheten, and Intelligent FIWARE-based Generic Energy Storage Services for Environmentally Responsible Communities and Cities (I-GReta), carried out between 2021-2023, also funded by ERA-Net Smart Energy Systems via Energimyndigheten. Both projects aimed to enable increased flexibility in the energy system by developing solutions for both its planning and operation. The projects were a collaboration between several partners from academia and industry in Sweden, Germany, Romania, and Austria. The Swedish team focused on end-user perspectives on energy use in everyday life and ways of supporting energy demand flexibility.

1.4 Outline of the thesis

This thesis is structured as follows. Chapter 2 provides a background and presents previous research within the research fields that this thesis contributes to. Chapter 3 explains the theoretical framework that has been applied in the analysis of the studies. Chapter 4 describes the overall methodology and methods used in the different studies and reflects on the choices made. Chapter 5 summarises findings from the two studies contributing to Theme I: Towards circular kitchens. This is followed by a summary of the two studies contributing to Theme II: Towards sustainable energy use at home in Chapter 6. Chapter 7 discusses the findings in relation to the research questions and reflects on the research scope and limitations. Finally, Chapter 8 outlines the contribution of the thesis to research and practice and suggests directions for future research.

2

BACKGROUND

This chapter starts with an introduction to the research field of sustainable consumption. The following sections then summarise previous research within the two research fields that this thesis contributes to: circular economy and sustainable energy systems. Parts of this chapter have been adapted from my licentiate thesis (Hagejärd, 2020).

2.1 Sustainable consumption

Sustainable consumption research aims to understand and contribute to consumption patterns that support sustainable development (Reisch & Thøgersen, 2015). The widely cited "Brundtland definition" of sustainable development reads: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987, p. 41). Thus, a central aspect of sustainable consumption is care for the environment and future generations (Lorek & Spangenberg, 2014; Quoquab & Mohammad, 2020). It promotes the rational use of resources to satisfy basic human needs and support quality of life while avoiding overconsumption (Quoquab & Mohammad, 2020).

Sustainable consumption is a broad research field with contributions from many different disciplines, including environmental science, social science, and economics and finance, among others (Liu et al., 2017). The research field is still in its infancy and there is a lack of consensus among scholars on what the concept incorporates (Quoquab & Mohammad, 2020).

The two themes included in this thesis contribute to the research fields of circular economy (Theme I) and sustainable energy use (Theme II), both of which are part of the wider research field of sustainable consumption. Another research field that is related to both circular economy and sustainable energy use is sufficiency. The sufficiency approach involves changes in both consumption patterns and levels to reduce the environmental burden connected to the consumption of high-consuming societal classes, also referred to as strong sustainable consumption (Lorek & Fuchs, 2013; Sandberg, 2021). Thus, sufficiency aims at a maximum and minimum level of consumption that is within ecological limits and allows a decent life (Spengler, 2016). Sandberg (2021) identified four types of sufficiency strategies: (1) absolute reductions, (2) modal shifts (shifting to a less resource-intensive form of

consumption), (3) product longevity, and (4) sharing practices. As will be explained in the following two sections, the research fields of circular economy and sustainable energy use overlap with these strategies, although the focus on maximum levels of consumption and what is enough are less pronounced.

2.2 Circular economy

Today, our economy is dominated by a linear model in which raw materials are extracted and used to manufacture products. These are then sold to and used by consumers, then disposed of when no longer needed. This model causes unnecessary waste, emissions, and resource depletion. By contrast, a circular economy "is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles" (Ellen MacArthur Foundation, 2015, p. 2). Ideally, in a circular economy, waste no longer exists. Non-toxic biological materials are returned to the soil, while technical materials are reused and recycled in closed loops. The energy used to power the circular economy should be obtained from renewable sources (Ellen MacArthur Foundation, 2015).

The circular economy can be understood as an umbrella concept (Blomsma & Brennan, 2017) that integrates features from several theories. As summarised by Geissdoerfer et al. (2017, p. 759), "Some of the most relevant theoretical influences are cradle-to-cradle (McDonough and Braungart, 2002), laws of ecology (Commoner, 1971), looped and performance economy (Stahel, 2010), regenerative design (Lyle, 1994), industrial ecology (Graedel and Allenby, 1995), biomimicry (Benyus, 2002), and the blue economy (Pauli, 2010)", all sharing the idea of closed loops. According to a recent review by Kirchherr et al. (2023), the most widely cited definition of circular economy is provided by Geissdoerfer and colleagues, who describe the circular economy as "a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al., 2017, p. 759). The terminology of slowing, closing, and narrowing resource loops was presented by Bocken et al. (2016) as guiding principles for circular design and business model strategies. Slowing means to extend and/or intensify the use phase of products, closing refers to enabling circular flows of resources through recycling, and narrowing means to reduce the quantity of resources per product (Bocken et al., 2016). Each of these principles involves different circular strategies for preserving the value of resources. The 9R framework by Potting et al. (2017) provides a hierarchical overview of circular strategies, in which the top strategies represent the highest level of circularity and potential to reduce environmental impacts from resource use. A system diagram of the circular economy, also referred to as the butterfly diagram, is provided in Figure 2.1. This

has been adapted from the Ellen MacArthur Foundation (2015), with circularity strategies from the 9R framework by Potting et al. (2017) integrated.

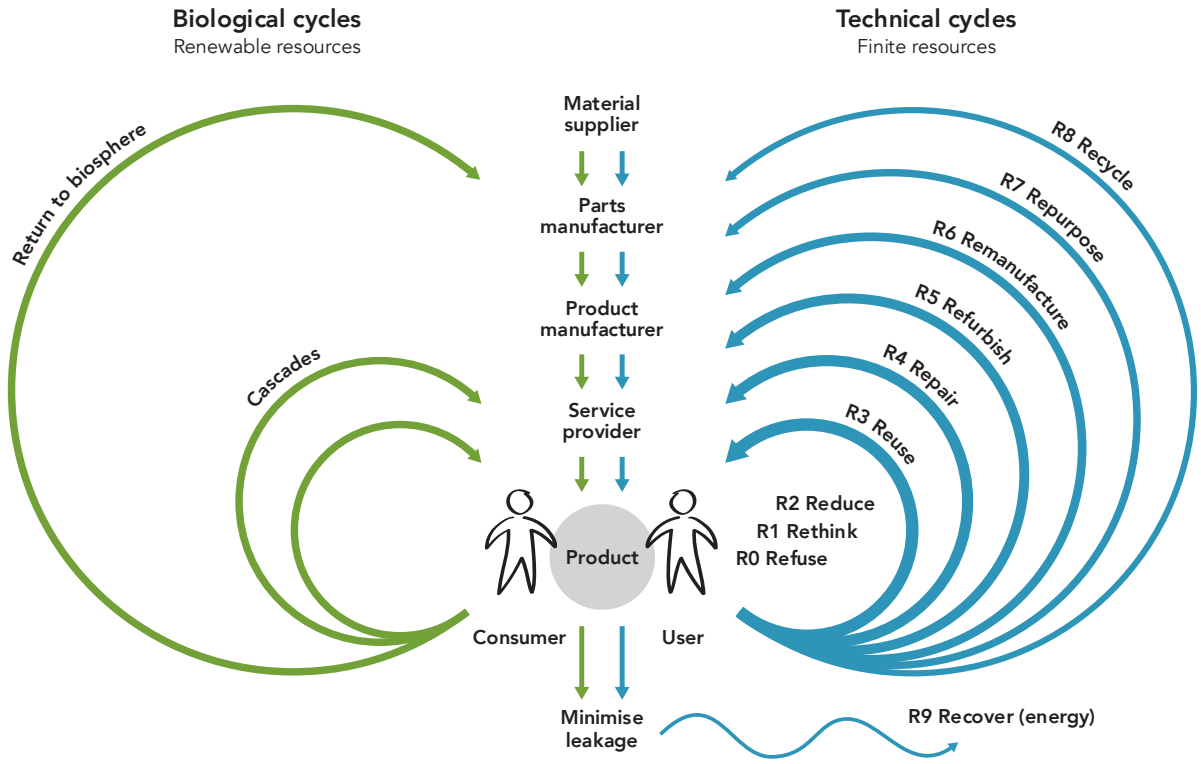


Figure 2.1. Circular economy system diagram, adapted from the Ellen MacArthur Foundation (2015) and Potting et al. (2017)

According to Ghisellini et al. (2016), by implementing radically new patterns, a circular economy has the potential to achieve improved sustainability and wellbeing in society at minimal material, energy, and environmental costs. However, the transition to a circular economy remains at an early stage (Ghisellini et al., 2016). A first Circular Economy Action Plan was launched by the European Commission in 2015 as part of the European Green Deal – an agenda for sustainable growth (European Commission, 2020). The newest version of this plan proposes actions for such things as making sustainable products the norm in the European Union, making circularity work for people, regions, and cities, and ensuring less waste.

The Swedish government also published a strategy for conversion to a circular economy, comprising four focus areas: (1) circular economy through sustainable production and product design, (2) circular economy through sustainable ways of consuming and using materials, products and services, (3) circular economy through non-toxic and circular cycles, and (4) circular economy as a driving force for business and other actors through measures promoting innovation and circular business models (Regeringskansliet, 2020).

Despite its growing popularity, the circular economy concept is not without its challenges. Korhonen et al. (2018) presented six challenge areas that must be addressed if a circular economy is to contribute to environmental sustainability. First

of all, recycling requires energy and always generates some waste and by-products. Therefore, reusing, remanufacturing, and refurbishing products is more desirable than recycling just for raw-material value (Korhonen et al., 2018), while using renewable energy sources in these processes. The second challenge concerns spatial and temporal system boundaries. This involves achieving environmental impact reductions in one part of the system by shifting a problem to another part. Also, extending product lifetimes may cause long-term unsustainability, due to currently unknown negative impacts. Third, economic efficiency increases from the reuse, remanufacturing, and refurbishment of products may cause rebound effects, such as reduced product prices leading to an overall increase in consumption. Furthermore, Korhonen et al. (2018) list challenges related to path dependencies and lock-in, governance and management, and the definition of physical flows.

2.2.1 Circular product design

Design plays a key role in facilitating the transition from today's linear "take-make-dispose" model to a more circular economy (den Hollander et al., 2017; Ellen MacArthur Foundation, 2015). In recent years, various design strategy frameworks have been presented to guide designers in developing products and services for a circular economy.

One such framework is provided by Bocken et al. (2016), based on principles of slowing and closing resource loops (see Table 2.1). The omission of the narrowing approach is explained by the fact that reducing the quantity of resources per product does not influence the speed of resource flows and could even contribute to further acceleration of linear resource flows. Therefore, narrowing needs to be combined with slowing and/or closing approaches. Bocken et al. (2016) further underline the importance of applying systems thinking to understand the impact of changes in business models and design from a wider perspective.

Table 2.1. Circular design strategies, developed by Bocken et al. (2016)

Slowing resource loops	Closing resource loops
Design for attachment and trust	Design for a technological cycle
Design for reliability and durability	Design for a biological cycle
Design for ease of maintenance and repair	Design for dis- and reassembly
Design for upgradability and adaptability	
Design for standardisation and compatibility	
Design for dis- and reassembly	

Based on a systematic literature review of various design-for-sustainability approaches, Moreno et al. (2016) developed a circular design framework including the following design strategies: (1) design for circular supplies, (2) design for resource conservation, (3) design for multiple cycles, (4) design for long-life use of products,

and (5) design for systems change. Like Bocken et al. (2016), Moreno et al. (2016) stress the importance of systems thinking to progress beyond traditional design processes that follow the current linear economy. However, in an interview study with design professionals, Sumter et al. (2020) found no evidence of the systems thinking competency being applied in practice.

Another literature review of sustainable product design, eco-design, and circular economy was conducted by den Hollander et al. (2017) as a basis for developing a new typology, which they called "design for product integrity". Following the inertia principle introduced by Stahel (2010), den Hollander et al. (2017) define product integrity as "the extent to which a product remains identical to its original (e.g., as manufactured) state, over time" (p. 519). Design for product integrity involves approaches that resist, postpone, and reverse product obsolescence. Resisting obsolescence includes the strategies of designing for physical as well as emotional durability. This shares similarities with the first two slowing strategies proposed by Bocken et al. (2016), focused on "designing long-life products". Postponing obsolescence focuses on enabling extended use of products and includes the strategies of design for maintenance and upgrading. Finally, reversing obsolescence focuses on facilitating recovery and includes the strategies of design for recontextualising, repair, refurbishment, and remanufacture (den Hollander et al., 2017).

However, extended product lifetimes do not necessarily result in lower overall environmental impact. For instance, with the introduction of new, more energy-efficient products, the environmental impact arising from continued use of the former product may exceed the embedded impacts of the new, more energy-efficient product, making replacement a better option (Bakker et al., 2014). Therefore, den Hollander et al. (2017) emphasise the need for product designers to be aware of the environmental consequences of their interventions. They also highlight the inevitable subjectivity connected to determining whether a product has become obsolete or not, which may complicate the selection of design strategies. Furthermore, circular design strategies need to be accompanied by suitable business models (Bocken et al., 2016; den Hollander et al., 2017).

2.2.2 Circular business models

A business model describes how a company or organisation creates, delivers, and captures value (Osterwalder & Pigneur, 2010; Teece, 2010). A linear business model relies on the sale of products produced preliminary from virgin materials, with limited inclusion of recycled materials or remanufactured parts (Linder & Williander, 2017). The value creation logic in a circular business model is instead centred around strategies for utilising economic value that is retained in products after their first use cycle in new offerings, which may require activities such as repair, refurbishment, or remanufacturing of products (Linder & Williander, 2017). Circular business model strategies include the cycling of resources, extending and intensifying the use phase

of products, and dematerialising resource loops by substituting products with service and software solutions (Geissdoerfer et al., 2020). These strategies concern all dimensions of a business model, including the value proposition (the product or service offer), value creation and delivery (how value is provided), and value capture (how the company makes profit) (Geissdoerfer et al., 2020; Lüdeke-Freund et al., 2019; Nußholz, 2017).

For new businesses, developing feasible sustainability-oriented value propositions is a demanding task for which experimentation plays an important role (Keskin et al., 2020). According to Bocken et al. (2021), a central aim of circular business model experimentation is to trial value propositions in real-life contexts with customers and other stakeholders to test their viability from a customer perspective, circular economy perspective, and systemic perspective.

Product-service systems (PSS) are a group of circular business models that combine or replace the selling of products with services. This gives companies an incentive to make sure that products are used for as long and intensively as possible, which might contribute to a reduction in resources needed to meet user needs (Tukker, 2015). However, the environmental soundness of PSS is not certain. For instance, people might be less careful with products that they do not own themselves, which might instead reduce product lifespans (Tukker, 2015).

Access-based consumption is a form of PSS in which companies provide users access to products rather than ownership, for instance, through renting, leasing, sharing, or pay-per-use models. Renting, leasing, and sharing are examples of use-oriented PSS (Tukker, 2004). Pay-per-use models are examples of result-oriented PSS, in which companies offer a functional result or output rather than a specific product (Tukker, 2004). For instance, the company HOMIE offers a service for washing machines in which customers pay per wash (with the price depending on the temperature of the wash cycle) and get installation and maintenance of the appliance for free (Bocken et al., 2018).

In product-oriented PSS, products are sold to customers but in combination with additional services, such as repair and maintenance (Tukker, 2004). Companies may also offer take-back management of products, which means that the company takes responsibility for a product after its end of use and makes sure that it is properly taken care of, either through recycling or preparing it for a second use cycle. Circular business models centred around the reuse of products may offer customers second-hand products in their current condition or products that have been refurbished or remanufactured.

2.2.3 People in a circular economy

Even if circular design strategies and business models are implemented to prolong the lifespan of a product, ultimately, its actual lifetime depends largely on decisions and actions by its user(s). End-users play a central role in enabling a circular economy because their decisions determine how products are obtained, the extent to which

they are used, and what happens to them once they are no longer needed (Selvefors et al., 2019). Despite this, most of the present literature on circular design has focused on technical product aspects rather than how to design products that fit people's needs, desires, and behavioural patterns (Wastling et al., 2018).

Based on a literature review on consumption in the circular economy, Camacho-Otero et al. (2018) concluded that the main part of the existing literature has focused on factors driving and hindering the acceptance of circular solutions, while less attention has been given to issues of how to trigger change on both collective and individual levels to support their diffusion. Furthermore, only a small number of contributions have investigated the integration of user perspectives into the design process.

De los Rios & Charnley (2017) investigated what design skills were necessary to develop products for closed loops. They highlighted the need to understand user expectations and perceptions of value, use experience, and product wear during use. Sumter et al. (2020, p. 12) identified "circular user engagement" as one out of seven circular economy competencies for design, explaining that "the changing relationship with users in a circular economy requires designers working in practice to guide users in the decision-making, use and take-back phase in order to optimally employ certain business models".

Wastling et al. (2018) described a customer's engagement with a product as a three-phase process starting with the point of product acquisition, followed by the use phase, and finally end-of-use, in which the product may be kept, returned to the manufacturer, passed on to someone else, or disposed of. Based on a literature review, case studies, and expert interviews, they developed a framework for designing products and services to encourage 'circular behaviour'. Their model focuses on the use and end-of-use phases and lists key behavioural targets, distinguishing between user ownership and provider ownership of products.

Selvefors et al. (2019) introduced a user-centric perspective on product circularity, in which the focus is shifted from issues of production and business models to people's consumption processes. Like Wastling et al. (2018), they divide the consumption process into three phases, which they call obtainment, use, and riddance. With product exchange rather than resource recovery in focus, they highlight the following possibilities for reducing resource consumption: "users can obtain pre-used products from other users instead of buying new products", "users can avoid disposing of products as trash by passing them on to other users", and "users can increase product utilisation by passing on unused products to other users" (Selvefors et al., 2019, p. 1016). From this perspective, they outline four design strategies aimed at supporting the development of products and services for circular consumption: design for extended use, design for pre- and post-use, design for exchange, and design for multiple use-cycles.

2.3 Sustainable energy systems

To meet the Paris Agreement of not exceeding 1.5°C of global warming, it is estimated that the share of renewable sources in the total electricity generation needs to increase from 30% in 2022 to 89% in 2050 (IEA, 2023). Within the same period, it is estimated that the share of solar power and wind power needs to increase from 12% to 71% (IEA, 2023). However, a growing number of scholars suggest that a transition to 100% renewable energy is possible to achieve globally at a low cost (Breyer et al., 2022).

Realising a substantial increase in renewable, weather-dependent energy sources brings the challenge of dealing with a fluctuating supply and consequently places new demands on the energy system (Lund et al., 2017; Mathiesen et al., 2015). Some of the key strategies for dealing with variability in the energy supply are to strengthen regional interconnections, optimise the interaction between different sectors, utilise energy storage, and support demand flexibility (Breyer et al., 2022). The term "smart energy systems" is used to describe energy systems that combine electricity, heating, and transport sectors with energy storage to provide the flexibility needed to compensate for the variability of renewable energy sources (Lund et al., 2017; Mathiesen et al., 2015). Central to the realisation of energy systems relying largely on renewable energy sources is flexibility, both on the supply side and the demand side (Grunewald & Diakonova, 2018). This thesis focuses on flexibility on the demand side.

2.3.1 Energy demand flexibility and smart home technologies

Demand-side management (DSM) refers to strategies to adjust either the amount or timing of energy use to prevent energy demand from exceeding the supply (Adams et al., 2021). DSM strategies involve reducing energy use during peak hours (peak shaving), shifting energy use from critical to more favourable periods (load shifting), and increasing energy use during off-peak hours (valley filling) (Reynders et al., 2018).

For end users of energy, demand flexibility can either be a matter of choice or something that operates "behind the scenes" (Shove and Cass, n.d., as cited in Adams et al., 2021). The "behind the scenes" alternative, also referred to as "appliance led" shift mechanisms, involves load reductions due to more efficient appliances or features such as automatically switching off devices when not in use (Grunewald & Diakonova, 2018). It also involves shifts to other forms of energy and shifting loads either forward or backward in time (Grunewald & Diakonova, 2018). Furthermore, demand flexibility behind the scenes can be managed by a third-party actor, such as the energy provider, that remotely controls home infrastructures such as heating and ventilation, home appliances, or electric vehicle charging (Adams et al., 2021).

Demand flexibility as a matter of choice, or "practice led" shift mechanisms (Grunewald & Diakonova, 2018), refers to changes in user behaviour or energy-reliant practices in response to provided information, such as price signals or energy feedback (Adams et al., 2021). This alternative involves strategies such as shifting practices in time or substituting practices to achieve similar outcomes (Grunewald & Diakonova, 2018). For instance, instead of using a tumble dryer, the practitioner could hang wet laundry on a drying rack. Another strategy is to substitute an energy service with metabolic energy (Grunewald & Diakonova, 2018), for instance, sweeping the floor instead of using a vacuum cleaner. Finally, the practitioner could be substituted, for instance, by ordering food or going out for dinner, which means that someone else prepares the food, potentially impacting the energy efficiency, timing, and part of the grid where energy is used (Grunewald & Diakonova, 2018).

Smart technologies are widely suggested to play an important role in enabling demand flexibility (Guasselli et al., 2024; Robison et al., 2023). Home energy management systems (HEMS) can be used to coordinate energy use in relation to different parameters, including the energy supply as well as household preferences regarding comfort, price, and energy sources (Adams et al., 2021). HEMS typically include user interfaces, such as energy monitors, smart hardware (including smart plugs, appliances, and thermostats), and software platforms providing data analytics, but may also involve electric vehicles, solar panels, and battery storage (McIlvennie et al., 2020). Furthermore, HEMS can be designed to support different levels of automation (Adams et al., 2021). Based on previous categorisations by (Karjalainen, 2013) and (Sheridan & Verplank, 1978), Adams et al. (2021) describe four levels of automation: (1) full manual control without assistance from automation, (2) automation offers a narrowed-down set of alternatives, (3) automation executes one alternative but informs the user, offering the possibility to reject it, and (4) full automation without involving the user.

Although smart technologies are widely expected to enable demand flexibility and energy savings, several researchers have highlighted the risk that they could instead contribute to more energy-intensive lifestyles and increased expectations of comfort (Hargreaves et al., 2018; Jensen et al., 2018; Sovacool & Furszyfer Del Rio, 2020; Strengers et al., 2020). Thus, the environmental advantages of smart technologies are not indisputable (Darby, 2018; Herrero et al., 2018) and an improved understanding of users of smart technologies in their home context is needed (Gram-Hanssen & Darby, 2018; Hargreaves et al., 2018; Nyborg, 2015a; Reisinger et al., 2022; Wilson et al., 2015).

2.3.2 Households' demand flexibility and roles in future smart energy systems

Raising the expectations on households to provide flexibility in their energy use places households in a central role in the transition towards sustainable energy systems (Adams et al., 2021; Nyström, Börjesson Rivera, et al., 2024; Schot et al.,

2016). However, the flexibility capital, meaning the capacity of end users to shift energy use in time and space or change the intensity or form of energy to support the operation of the energy system (Powells & Fell, 2019), varies across society. According to Fjellså et al. (2021), a household's flexibility capital depends on the following factors: (1) having technological capacities installed at home, such as smart appliances, (2) having the capacity to engage with flexibility, such as practical competences, and (3) financial resources. People with lower economic assets are less likely to own technologies that facilitate demand flexibility, and their flexibility capital, therefore, relies to a higher degree on changes in everyday practices, potentially leading to sacrifices in comfort and convenience to avoid additional costs (Powells & Fell, 2019). According to Woods et al. (2024), the efforts of low-income households to reduce their energy consumption remain largely unseen, and energy injustices, therefore, receive little recognition in society.

Previously, Nyborg & Røpke (2013) identified four factors affecting the flexibility of households to change practices: (1) their willingness and motivation to shift energy use, (2) the composition of the household, (3) life situations, and (4) home infrastructures and installation of smart technologies.

Previous research has contributed to categorising energy-reliant practices according to how flexible they are to time-shift. Practices involving cooking, eating, and leisure are generally inflexible because they often involve several household members and contribute to both relaxation and the nurturing of social bonds within the household (Smale et al., 2017). Practices that involve lighting, heating, and cooling of spaces have been suggested to be better suited for automation rather than active management by households (Smale et al., 2017). Cleaning practices, such as laundering and dishwashing, have been identified as relatively flexible to shift in time (Friis & Christensen, 2016; Gram-Hanssen et al., 2020; Nicholls & Strengers, 2015; Nyborg & Røpke, 2013; Smale et al., 2017; Verkade & Höffken, 2017). However, shifting one practice in time may affect other practices as well. For instance, Friis & Christensen (2016) found that an unwelcome consequence of running the dishwasher or washing machine during nighttime was that the work of unloading the dishwasher or hanging laundry to dry had to be squeezed into already time-pressured mornings.

Nicholls & Strengers (2015) describe peaks in energy use to be the result of several energy-reliant practices being performed at the same time. In a study involving households with children, they discovered that some practices seemed to be tightly connected, either practically or emotionally (Nicholls & Strengers, 2015). Many peak practices were centred around daily routines and followed external time frames such as work and school hours or were dependent on several household members to be available to take part in the practice together.

The role of households in future energy systems has, by policy and industry stakeholders, been envisioned mainly according to two contrasting narratives (Goulden et al., 2018; Nyström, Katzeff, et al., 2024). One narrative imagines households as active managers of energy who are interested in their energy data and rationally respond to it to change their consumption, in line with the "Resource

Man" stereotype described by Strengers (2014). The second narrative sees households as disengaged and lazy, in line with the "Indifferent Consumer" described by Goulden et al. (2018), emphasising the need for automation to control energy use instead. However, people imagine their roles in future smart energy systems in diverse ways (Renström, 2019b), and a more nuanced understanding is needed (Goulden et al., 2018; Nyström, Katzeff, et al., 2024). To support diverse roles of households in future energy systems, there needs to be recognition of varying levels of interest, knowledge, and engagement among users, which may change over time (Cockbill et al., 2020).

Different expectations of smart home systems, levels of technological proficiency, and roles taken on by different members of the same household may lead to challenges and conflicts (Hargreaves et al., 2018; Nyborg, 2015b). Although smart technology may improve control over the home for some household members, it may simultaneously reduce the perceived control for other members (Aagaard, 2022; Gram-Hanssen & Darby, 2018). Thus, the household should be treated as a system, and both users and non-users of smart home technologies need to be understood.

2.3.3 The use of feedback to support households' energy demand flexibility

Energy feedback conventionally refers to the provision of information about households' energy consumption levels through energy bills, metering, or displays (Hargreaves, 2018). In later years, energy feedback has become more and more digitalised, and the data it presents is becoming increasingly personalised, detailed, and disaggregated (Martin & Strengers, 2024). Furthermore, the objective of energy feedback has shifted from achieving primarily energy savings to achieving a balance between energy supply, storage, and demand to support the integration of renewables in the energy system (Agarwal et al., 2023; Cockbill et al., 2020; Martin & Strengers, 2024).

Based on a meta-review analysing 114 energy feedback experiments, Zangheri et al. (2019) indicate that energy feedback realistically contributes to between 5% and 10% reductions in households' energy use. They conclude that the use of direct feedback (through user interfaces, smart hardware, or software platforms), communicated continuously, contributed to the greatest savings. An earlier performed meta-review found an average reduction in electricity consumption of 7.4% from analysing 156 field trials using information-based strategies (Delmas et al., 2013). From an analysis of 33 studies, including energy feedback interventions, Agarwal et al. (2023) found that although most experiments resulted in energy savings, a few experiments led to increased energy use instead.

There is currently a lack of meta-reviews primarily examining the effectiveness of load shifting in energy use at home, but findings by Kendel et al. (2017) and Agarwal et al. (2023) suggest that feedback focused on load shifting is more effective when it

is disaggregated at appliance level. Geelen et al. (2019) suggest that for energy feedback to be effective, it needs to be personalised and context-specific, providing concrete and actionable information. Christensen et al. (2020) argue that to make changes in energy-reliant practices meaningful, it is important to not only focus on financial incentives but to combine them with nonfinancial factors as well. Furthermore, they highlight the risk of providing too much information as that may lead to disengagement. Öhrlund et al. (2019) suggest that educating households may be more effective in supporting changes in energy use than providing energy feedback.

As argued in social science research, one of the problems with conventional efforts to engage people in sustainable energy transitions is that they assume there is an information deficit among people that needs to be solved by providing more (numeric) information on energy use (Hargreaves, 2018; Martin & Strengers, 2024; Strengers, 2013). This strategy misses out on the amateur knowledge and the various skills people use and continuously develop in relation to energy-reliant practices in everyday life (Martin & Strengers, 2024). Research by Hargreaves (2018) and Strengers (2013) suggests going beyond energy feedback and instead focusing on "practice feedback", aiming to "situate energy feedback within the broader dynamics of everyday life and social practices" (Hargreaves, 2018, p. 335). Practice feedback refers to various informal and evaluative judgments regarding the performance of a practice, which have an impact on how that practice will be performed in the future (Hargreaves, 2018).

Building on the concept of practice feedback, Martin & Strengers (2024) introduced the concept of "non-energy feedback", referring to the sensory, social, material, and systemic feedback that may contribute to shaping energy-reliant practices in daily life. They conclude that "the answer lies in understanding and supporting existing forms of non-energy feedback, and combinations of non-energy and conventional energy feedback" (Martin & Strengers, 2024, p. 10). This may, for instance, include local weather forecasts, suggestions for low-energy lifestyles, or updates and warnings regarding the local grid's "health" (Martin & Strengers, 2024).

2.3.4 Households' perceptions of demand flexibility in residential space heating

So far, there has been a limited number of studies exploring residents' experiences during load control trials for space heating (Christensen & Petersen, 2023). This section summarises findings from trial studies in which residents' perspectives are in focus.

In a Danish field trial, Larsen & Johra (2019) found that although smart home technologies were associated with convenience in controlling the indoor temperature, they may also promote higher temperatures and comfort expectations. Improvements in residential heating demand flexibility may also be challenged by varying preferences regarding the indoor climate and practices such as opening

windows to let in fresh air (Larsen & Johra, 2019). Furthermore, the task of managing increased flexibility in heating demand was met with scepticism, and most participants preferred this to operate automatically or be controlled by a third-party actor (Larsen & Johra, 2019).

Several studies have highlighted the necessity of explaining the economic and environmental benefits of participating in demand response programs for residential space heating (Christensen et al., 2022; Christensen & Petersen, 2023; Sweetnam et al., 2019). From a field trial with load shifting in residential heating in the United Kingdom, Sweetnam et al. (2019) suggested that communication should also be used to inform residents how the heating system operates and give them advice on how to maintain their comfort.

In a small Danish trial, Christensen et al. (2022) found that for households that reduced their indoor temperatures during the night, an intervention that turned off the heating for two hours during the morning peak was initially perceived as unacceptable. However, the participants accepted to abandon this routine as the benefits of the heat load control system were explained to them. From the same study, Christensen & Petersen (2023) conclude that when indoor temperatures are at the lower end of what is perceived as comfortable by residents, preheating may need to be applied before reductions in the heating load.

Focusing on control, Larsen et al. (2023) found that when space heating is increasingly managed automatically, this may lead to residents feeling a loss of control and bypassing the system to maintain their comfort, possibly raising the level of comfort required. They also conclude that smart home technologies "were generally too simple in their representation of daily rhythms" (Larsen et al., 2023, p. 11) and suggest that more attention should be given to how to support flexibility in everyday practices.

To provide energy flexibility in heating, it has been recognised that deeper insights are needed regarding households' everyday heating practices (Andersen et al., 2019) and to what extent they may accept external control of the indoor climate (Larsen & Johra, 2019).

3

FRAME OF REFERENCE

This chapter describes the theoretical framework that has guided the analysis of some research findings presented in this thesis. Social practice theory and practice-oriented design were chosen because they are useful for understanding the dynamics of resource use and identifying opportunities for change. This chapter has been adapted from my licentiate thesis (Hagejärd, 2020).

3.1 Social practice theory

One approach to understanding households' resource use, originating in social science, is social practice theory. Practice theory has been proposed as a relevant approach to understanding the "multiple dynamics of everyday life" (Shove et al., 2012) and for envisioning change beyond the status quo (Kuijer & Bakker, 2015). Furthermore, it has been argued that a practice theory approach supports closer scrutiny of the everyday routines through which people commit to unsustainable lifestyles (Hoolohan & Browne, 2020).

Practices are activities in everyday life in which many people engage, following collectively shared ideas about what is desirable and acceptable (Pettersen, 2016). According to Schatzki, a practice may be understood as "a temporally evolving, open-ended set of doings and sayings linked by practical understandings, rules, teleoaffective structure, and general understandings" (Schatzki, 2002, p. 87). Another definition is given by Reckwitz, explaining practice as "a routinised type of behaviour which consists of several elements, interconnected to one other: forms of bodily activities, forms of mental activities, 'things' and their use, a background knowledge in the form of understanding, know-how, states of emotion and motivational knowledge" (Reckwitz, 2002, p. 249). Individuals are seen as "carriers" of practices, carrying patterns of bodily behaviour as well as "routinised ways of understanding, knowing how and desiring" (Reckwitz, 2002, p. 250). Such mental activities are thereby regarded not as individual attributes but as "necessary elements and qualities of a practice in which the single individual participates" (Reckwitz, 2002, p. 250). Furthermore, practices are social, meaning that they are carried out at different times and places by different "bodies and minds", or different individuals. This does not mean that a practice necessarily involves any interaction between people.

3.1.1 Elements of practices

Several researchers have proposed various categorisations of elements that, when linked together, form a practice. An overview is given by Gram-Hanssen (2011). One aspect that gives rise to certain disagreement among practice theorists is what role material objects and technologies play in practices (Gram-Hanssen, 2011; Kuijer, 2014). Gram-Hanssen (2011) argues that technologies are an essential element in holding practices together and contributing to changes within practices. In her empirical study of households' energy use, she summarises the following four elements of practices as most relevant: (1) know-how and embodied habits, (2) institutionalised knowledge and explicit rules, (3) engagements, and (4) technologies.

Based on the classification introduced by Reckwitz (2002), Shove and colleagues have developed a simplified version including only three elements: *materials*, *competences,* and *meanings*, sometimes alternatively phrased as *stuff, skills,* and *images* (cf. Shove et al., 2012; Shove & Pantzar, 2005). This model has been widely adopted in design research (Kuijer, 2014; Scott et al., 2012) and will be used in this thesis.

Materials (or stuff) include objects, technologies, tools, infrastructures, materials from which objects are made, and even the body itself (Shove et al., 2012). Competences (or skills) refer to multiple forms of understanding and practical knowledge; these include know-how, technique, and shared understandings of what is good or appropriate. Meanings (or images) include mental activities, emotions, and motivational knowledge representing "the social and symbolic significance of participation at any one moment" (Shove et al., 2012, p. 24).

The elements are influenced and shaped by each other, with some overlap between the categories (Kuijer, 2014). Of equal importance to the elements themselves are their links. Kuijer (2014) has further developed the images-skills-stuff model by picturing the elements as groupings of elements and the connections between them as a multitude of links.

3.1.2 Dynamics of practices

When speaking about practices, a distinction is made between "practices-as-entity" and "practices-as-performance" (Kuijer, 2014, based on Schatzki, 1996). Practice-as-entity represents a guiding structure, containing all elements and links that together form the practice and make it recognisable as such (Kuijer, 2014). Practice-as-performance, on the other hand, is the moment of doing in which a specific combination of elements is integrated into a specific situation. This may be slightly different each time the practice is carried out. Practice-as-entity is thereby formed through a variety of performances through which it becomes gradually established over time and upon which its ongoing existence depends (see Figure 3.1). For instance, the practice of cooking may vary significantly in performances depending on the food, occasion, setting, skill level of the practitioner, appliances and utensils

used for that specific dish, and so on. Still, cooking (as entity) is recognised as one practice that may involve many different elements.

According to Warde (2005, pp. 140–141), practices "have some considerable inertia", although they simultaneously "contain the seeds of constant change". Adaptation, improvisation, and experimentation by people in various situations contribute to the dynamic nature of practices (Warde, 2005). Shove et al. (2012) maintain that "practices emerge, persist and disappear as connections between defining elements are made and broken" (p. 35) and that "practices change when new elements are introduced or when existing elements are combined in new ways" (p. 87). Thus, the elements have "histories and futures of their own" and are transformed through their integration into practices (Pantzar & Shove, 2010). According to Kuijer (2014), some elements and links may be more central in a practice than others (for instance, when they are present in multiple performances). Additionally, some links may be more difficult to break than others.

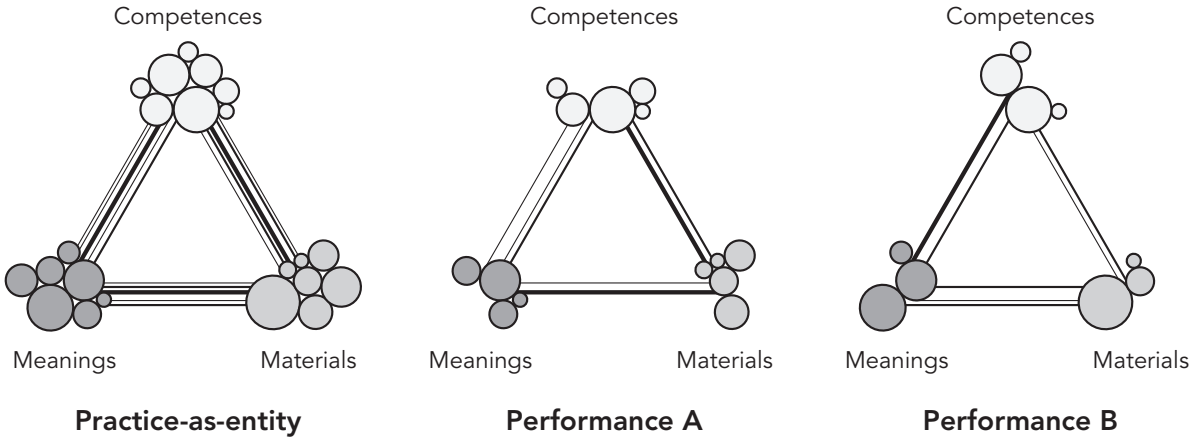


Figure 3.1. The practice-as-entity is the sum of a variety of performances, each of which integrates a different set of elements and links. Adapted from Kuijer (2014, p. 53)

As mentioned above, practices go through different phases. "Proto-practices" are described as emerging practices for which elements exist, but their links are not yet established, making them prone to changes in the near future (Pantzar & Shove, 2010; Suski et al., 2023). For practitioners, the term "appropriation" is used to describe "the process of mentally and physically learning the enactment and embodiment of particular social practice", which involves experimentation and variation of practice elements (Rabiu & Jaeger-Erben, 2022, p. 3). The "routinisation" phase is instead characterised by normalisation and continuous reproduction of a practice (Rabiu & Jaeger-Erben, 2022). In "ex-practices", links between elements are no longer being made and sustained, and the practice is no longer reproduced (Pantzar & Shove, 2010).

In everyday life, people take part in various practices, and sometimes, these have one or more elements in common. Thus, as one practice changes, there is a chance that another will be affected due to their shared element(s) (Gram-Hanssen, 2011). Practices that co-exist within the same space, such as cooking and washing dishes in

the kitchen, can be described as practice "bundles" (Shove et al., 2012). Such bundles can evolve "into stickier forms of co-dependence", referred to as "complexes" (Shove et al., 2012, p. 87). Practices that are part of complexes can be interrelated either temporally, by being performed simultaneously or in sequence, or spatially by requiring proximity to each other. Sometimes a practice would not exist without the existence of another practice. Thus, there are collaborative aspects of practices, but there are also aspects of competition (Rabiu & Jaeger-Erben, 2022; Shove et al., 2012). Different practices require different levels of coordination with other people and practices and constantly compete for time (Southerton, 2012). The performance of practices is shaped by personal and collective "temporal rhythms" (Southerton, 2012). Personal temporal rhythms are individual strategies for managing time, and examples of collective temporal rhythms are school and work hours.

3.2 Practice-oriented design

According to practice theory, the consumption of resources rarely occurs for its own sake but "within and for the sake of practices" (Warde, 2005). A practice theory perspective enables the targeting of consumption levels by questioning what is taken for granted and by introducing sufficiency goals (Pettersen, 2016). According to Kuijer (2014, p. 95), the central question of a practice-oriented design process is "what could be less resource intensive reconfigurations that work?".

Pantzar & Shove (2010) define innovation in practice as the making and breaking of links, that is, new combinations of elements. Although practices are carried out by individuals in specific situations, innovations within practices are always a collective achievement and a continuous process (Pantzar & Shove, 2010). In practice-oriented design, users or practitioners largely become active participants in the design process. Thus, this approach shares similarities with the concept of co-creation (Scott et al., 2012).

Kuijer (2014) has proposed a practice-oriented design approach, divided into two models: one that takes practices as a unit of analysis and one that takes them as a unit of design. When a target practice has been selected as a unit of analysis, Kuijer (2014) suggests that the first step (as a basis for determining a target level) is to gain an overview of the resource consumption levels connected to the target practice, including current averages, extreme values, and past consumption levels. This is important because if no target level is defined, or if it is set too close to the current average level, it is unlikely that anything more than incremental reductions will be achieved. The following steps include tracking the historic development of the practice, exploring similar practices, analysing the target practice by mapping configurations of elements in relation to resource use, and finally, identifying opportunities and directions for change. The second model – taking practices as a unit of design – moves from identified opportunities for change to reconfigurations that work through the iterative process of suggesting and triggering, facilitating performances, and combining, refining, and evaluating.

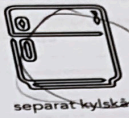
Based on previous research from Pantzar & Shove (2010), Shove et al. (2012), and Pettersen (2013), regarding how to foster change in less resource-intensive directions, Pettersen (2015, pp. 209–210) suggests four targets for design: (1) "the circulation and promotion of practice elements and links", (2) "the composition and performance of practice", (3) "how different practices relate", and (4) "how the careers of practice and practitioners develop over time". Pettersen (2015, p. 210) summarises that "taking the social practice as a unit of analysis may help designers understand the dynamics of consumption, by pointing their attention to the composition, performance and development of practices in space and time". This, in turn, may help identify opportunities to overcome inertia and resistance to change.

As noted previously, changes in one practice may also affect others. This, in turn, may lead to load shifts in consumption, making it reasonable to zoom out and address changes on the household level rather than just changes in individual practices (Pettersen, 2016). When introducing interventions aimed at changing practices, an assessment of their effects should be conducted over a long period (Pettersen, 2016).

Vilka vitvaror har ni i ert kök? Ringa in de ni har och skriv ned ifall ni har någon annan apparat som inte finns med bland symbolerna.

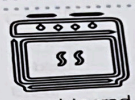

kombinerad kyl och frys

ELLER


separat kylskåp


separat frys


diskmaskin


kombinerad ugn och spis

ELLER


separat ugn


separat spis


mikrovågsugn

Dag 1

datum

Köksapparater

Vilka köksapparater har ni i ert kök? Ringa in de ni har och skriv ned ifall ni har någon annan apparat som inte finns med bland symbolerna.

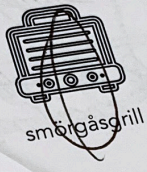

vattenkokare


elvisp


stavmixer

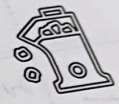

glasmaskin

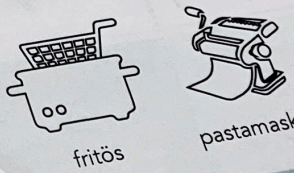

mixer


smörgåsgrill


våffeljärn


brödmaskin


popcorn-maskin

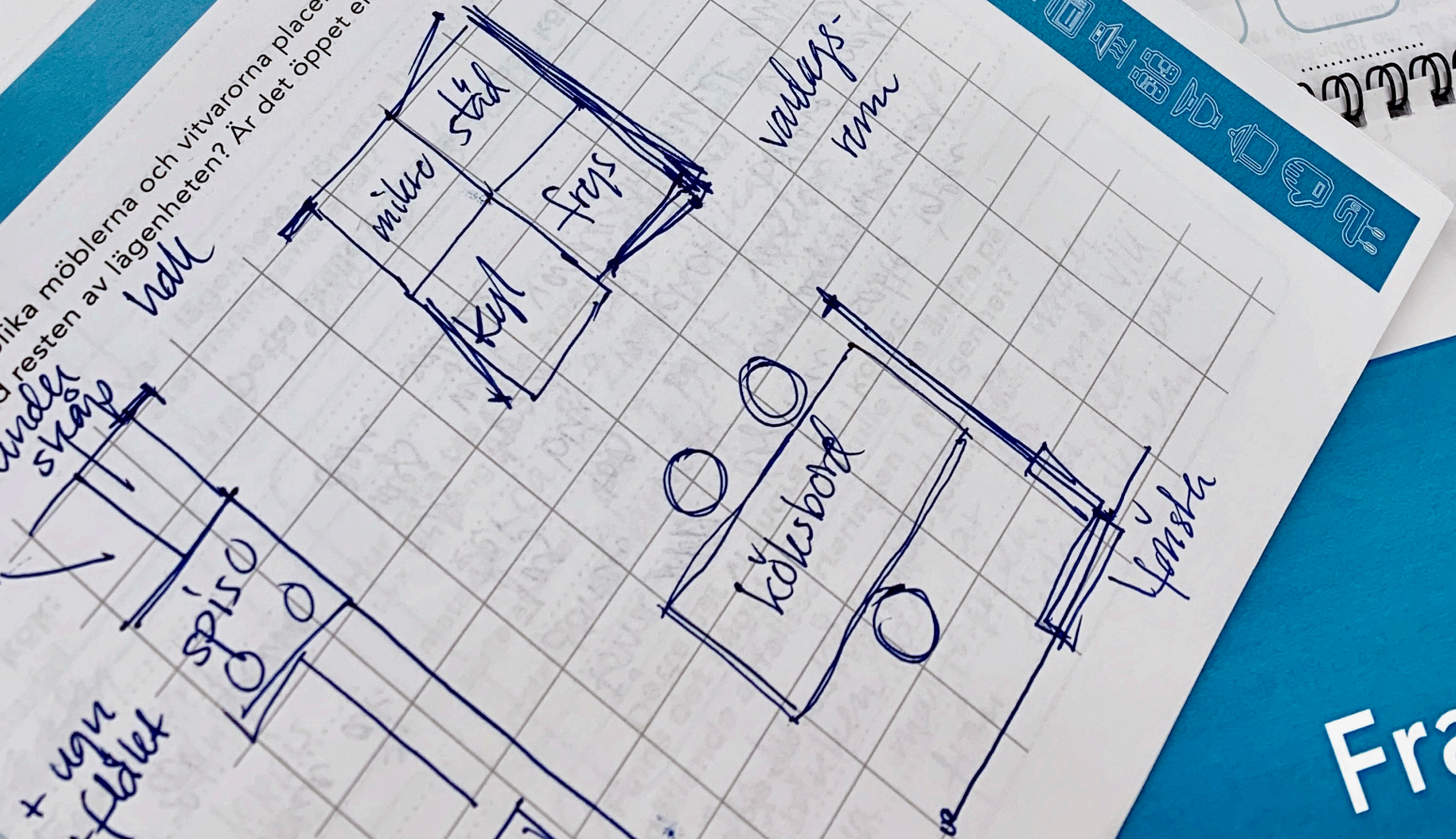

fritös

pastamaskin


våg

Vårt kök

Vilka möblerna och vitvarorna placerade? Hur hänger köket ihop resten av lägenheten? Är det öppet eller separerat med väggar?



Fra

4

METHODOLOGY

This chapter explains how the research was conducted. It starts with a brief description of my personal background and the research context, explaining the connection between the included studies, the research questions, and the timeline of the PhD. The following section introduces different factors contributing to the research approach. This is followed by detailed descriptions of the research design of the studies and a final section reflecting about the methodological choices. Parts of this chapter have been adapted from my licentiate thesis (Hagejärd, 2020).

4.1 Personal background and research context

Through my undergraduate education in Industrial Design Engineering at Chalmers University of Technology, I was introduced to a design approach centred around people who, in various contexts, use products to achieve goals, fulfil needs, or tackle everyday challenges. I also developed a deeper understanding of the environmental problems fuelled, to varying degrees, by product development. A growing interest in these issues inspired a profiling of my education towards design for sustainability and, later on, the initiation of my PhD journey.

My research as a PhD student started in two parallel research projects within different research areas, part of the wider topic of sustainable consumption, as described earlier in Section 2.1. My focus area within these projects has developed over time and has been shaped by my personal interest as well as the project goals and research focus of my PhD colleagues. To combine the research areas of the two projects, I chose to focus on design aspects in relation to the perspectives of people who acquire, use, or are affected by different products and services in their everyday lives.

The research in this thesis is mainly based on empirical data collected in four studies, resulting in four papers. Studies A and B were carried out within the CIK project, and their findings are presented as part of Theme I: Towards circular kitchens. Studies C and D were carried out within the FISMEP and I-GReta projects, and their findings are presented as part of Theme II: Towards sustainable energy use at home. An overview of the studies, their aim, methods, and connection to the research questions is illustrated in Figure 4.1.

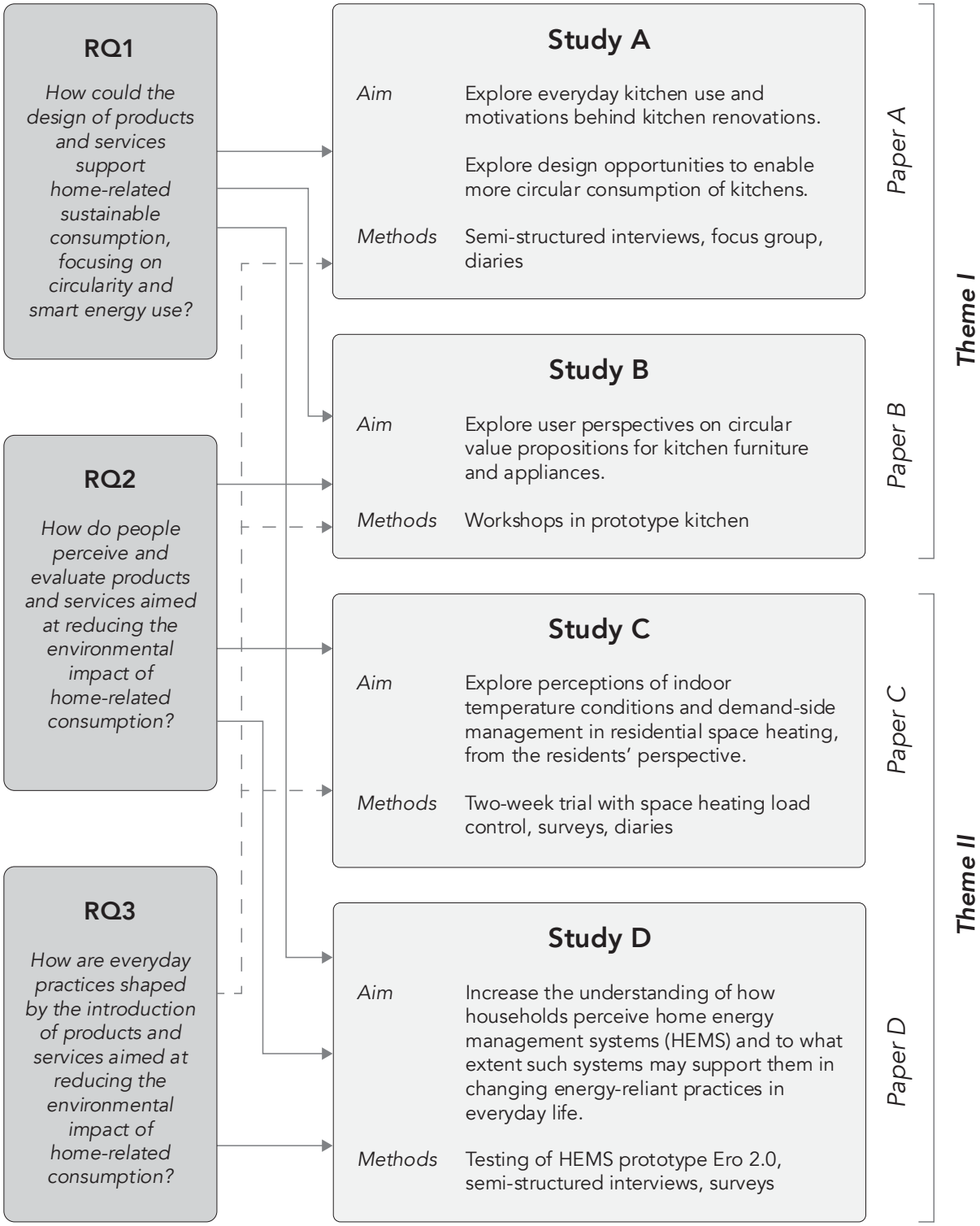


Figure 4.1. Overview of the studies and corresponding papers in relation to the research questions.

The order of the studies from A to D was selected to fit the structure of the thesis but was not the actual order in which they were carried out. Several factors have affected the time and duration of each study. First, the research projects had their timelines and deliverables that needed to be followed. Second, my own learning process contributed to new research interests being formed along the way. Third,

the PhD studies have been paused during two periods of parental leave. A timeline of the research studies in relation to each other is shown in Figure 4.2.

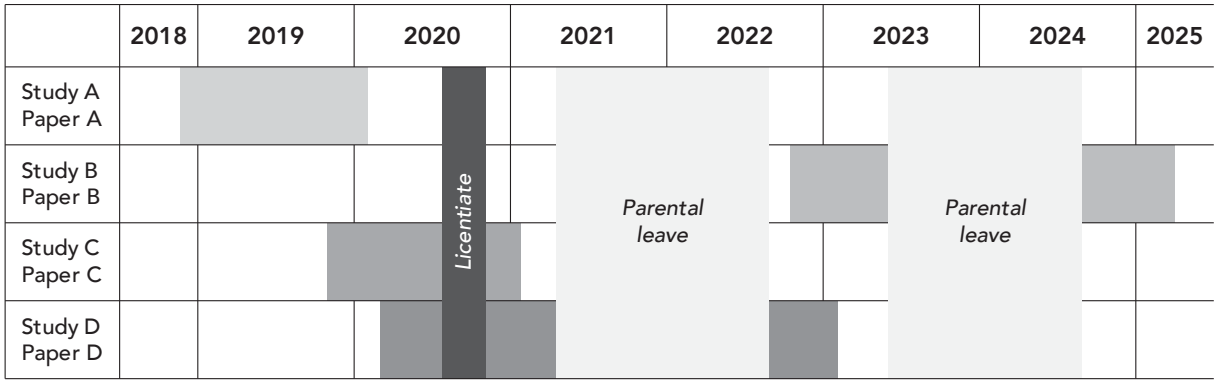


Figure 4.2. *Timeline of the included studies and publications.*

4.2 Research approach

The research approach has been shaped by my personal background and interests as well as the research field. The research shares philosophical assumptions with the pragmatic paradigm and adopts a mixed methods approach for collecting and analysing data. It is inspired by social practice theory and belongs to the domain of design research. The following sections will describe how these aspects have contributed to the overall research approach.

4.2.1 Philosophical worldview

Pragmatism is a value-oriented approach focused on conducting research that benefits people, striving to use the methodology that best contributes to gaining knowledge (Kivunja & Kuyini, 2017). In a pragmatic approach, research is treated "as a human experience that is based on the beliefs and actions of actual researchers" (Morgan, 2014, p. 1051). Pragmatism is not committed to a single system of philosophy and reality (Creswell, 2014) but is pluralistic and oriented towards "what works" (Creswell & Plano Clark, 2011). The ontological standpoint of pragmatism is that "there is no single reality and all individuals have their own and unique interpretations of reality" (Kivunja & Kuyini, 2017, p. 35). Furthermore, the pragmatic approach recognises the importance of both the natural or physical world and the social and psychological world (Johnson & Onwuegbuzie, 2004).

Pragmatism has been called the third research movement and represents a middle ground between (post)positivism and interpretivism/constructivism (Johnson & Onwuegbuzie, 2004). In a purely quantitative approach (following the positivist paradigm), there is a risk that the knowledge created becomes too abstract and general to apply in individual cases or specific contexts (Guba & Lincoln, 1994; Johnson & Onwuegbuzie, 2004). In a purely qualitative approach (following the

constructivist paradigm), there are limited possibilities to generalise data and make quantitative predictions (Johnson & Onwuegbuzie, 2004). By adopting the pragmatic paradigm, this research has strived to benefit from multiple perspectives while avoiding some of their weaknesses.

4.2.2 Mixed methods research

In line with pragmatism, the research in this thesis follows a mixed methods approach and makes use of both qualitative and quantitative methods, depending on the purpose of each study (Creswell, 2014; Johnson & Onwuegbuzie, 2004). In mixed methods research, the most fundamental thing is the research question (Johnson & Onwuegbuzie, 2004). Thus, the research methods for each study have been selected based on their potential to provide answers to the research question and feasibility within the projects.

An overview of the research design for the different studies is shown in Figure 4.3. Study B was partly motivated by findings in Study A, and both studies were mainly qualitative. Studies C and D combined quantitative and qualitative data collection and analysis, with a stronger focus on quantitative data in Study C and a stronger focus on qualitative data in Study D.

Using a mixed methods approach allows for triangulation, meaning that the issues under study are approached from different perspectives to strengthen the research quality (Flick, 2018). According to Eisenhardt (1989), multiple data collection methods allow deeper understanding, as well as identification of relationships and prevention of false conclusions. Ideally, both qualitative and quantitative methods should be combined (Eisenhardt, 1989). Looking at the research design as a whole, both qualitative and quantitative methods are represented, although with a slightly stronger weight on qualitative methods.

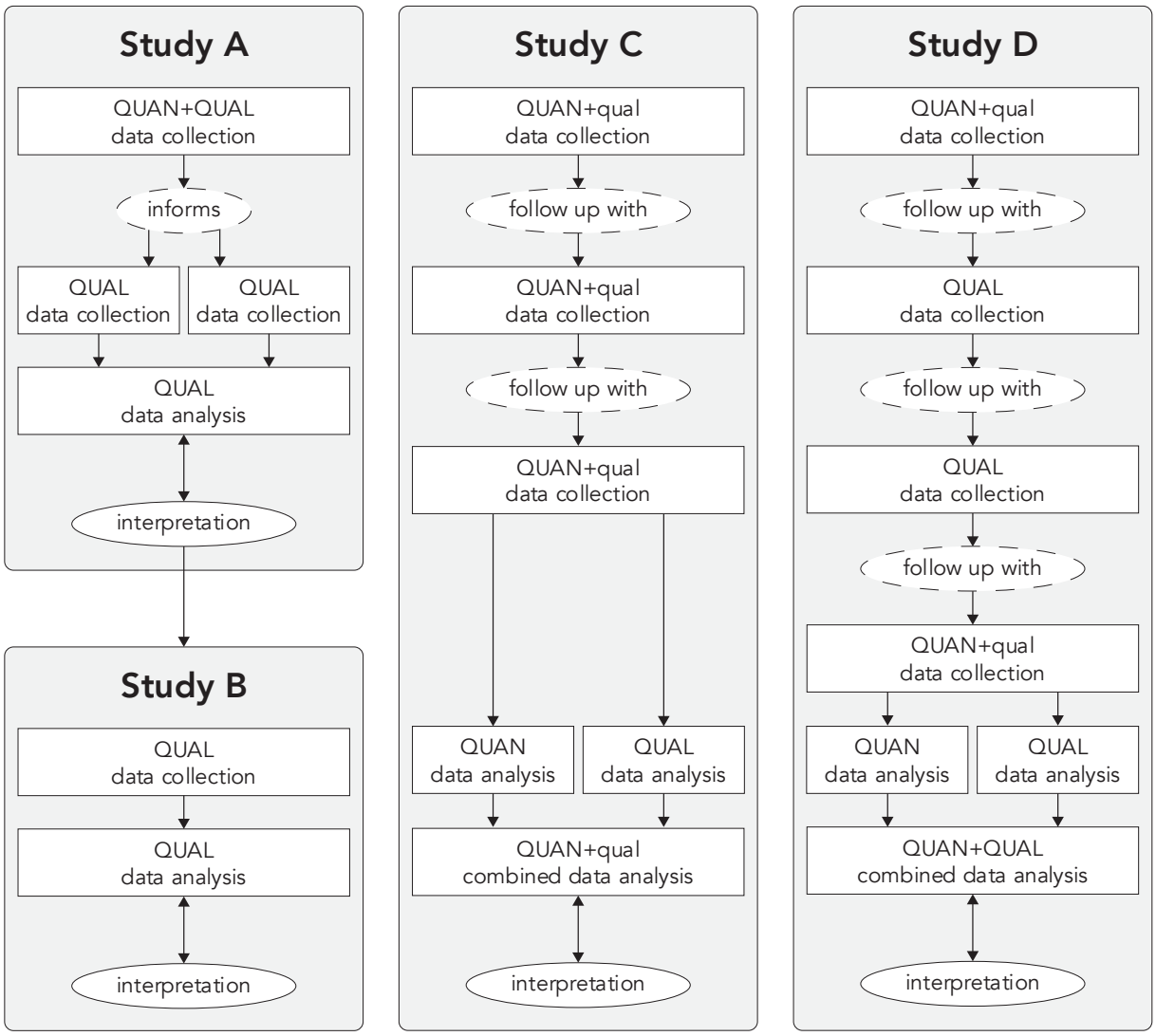


Figure 4.3. Overview of the research design.

4.2.3 Theoretical lens on methodology

From a social practice theory lens, there are different perspectives on the use of methods. This thesis follows Browne et al. (2014), who encourage the use of mixed methods to study practices. They mean that combining rich qualitative data with quantitative data that captures practices across a population can provide a nuanced understanding of practices, reveal how they bundle in complex ways, and explain their emergence, maintenance, and disappearance.

Nicolini (2017, p. 29) claims that "whenever possible, we should position ourselves in the midst of the scene of action" and that "studying practices through interviews is second best, which is, of course, better than nothing". Similarly, Bueger (2014) argues that participant observation is the primary method for studying practices but due to the difficulties associated with performing observations, he recognises that interviews and document analysis are often needed as well. Document analysis may include studying manuals, self-descriptions such as activity

reports, or visual artifacts such as videos, photos, and paintings (Bueger, 2014). Finally, he suggests that researchers studying practices should create their own mix of methods and strategies according to their specific research context. Similarly, Nicolini (2009, p. 196) suggests that "because of its multifaceted and complex nature, practice can never be captured by a single method or reproduced through one single style of writing".

Although social practice theorists have sometimes considered the use of interviews as inappropriate to study practices, Hitchings (2012) argues that people can often talk about their practices in quite revealing ways. However, some practices might be more difficult than others to talk about. Hitchings (2012), therefore, suggests some aspects that can help, for instance, being clear about the purpose of the study, using comparisons and hypothetical situations, allowing time, and being attentive to how interviewees react.

Browne (2016) lists several benefits of using focus groups to study practices. For instance, group discussions about everyday practices may improve the understanding of their diversity and dynamics, expose ideas around shared routines and cultural conventions, or challenge social norms by revealing incongruences between participants.

4.2.4 Design research

Groat & Wang (2013, p. 23) suggest that "design and research are most appropriately and usefully understood as relatively distinct kinds of activity, but they indeed embody many important similarities, including many complementary and overlapping qualities". While research strives to develop understanding of the past or present state of the world, design "is seen as being concerned with establishing a working effect (creating a product) in a possible future, realising successful instantiations in a world that does not yet exist and is not yet known" (Stappers, 2007, p. 82). Something that research and design have in common is that they are both "characterised by iterative cycles of generating ideas and confronting them with the world" (Stappers, 2007, p. 82). Design can be informed by research and in turn, the design process or designed artifacts can generate new questions to be investigated (Groat & Wang, 2013).

Design problems are often ill-defined (Cross, 2006) or "wicked" (Rittel & Webber, 2017). Wicked problems are characterised by the fact that they are impossible to define without also finding a solution, and since there are no true or false answers, one can never guarantee that the "right" solution is found but rather assess if it is "good enough" (Rittel & Webber, 2017). The solution-focused strategy of "designerly ways of knowing" is, in those cases, preferable to a problem-focused strategy (Cross, 2006). Design has the potential to create spaces for discussion around wicked problems, such as sustainability, and deal with a wide range of perspectives (De Jong et al., 2016).

Forlizzi et al. (2009) describe three categories of design research: research on (or about) design, research for design, and research through design. The first category, research on (or about) design, is the most widely recognised form of design research and focuses on understanding the design process or design-related activities (Forlizzi et al., 2009). This type of design research is outside the scope of this thesis, which instead focuses on research for design.

Research for design is concerned with generating knowledge that can be applied in design practice, for instance, in the form of conceptual frameworks or guiding philosophies (Forlizzi et al., 2009). Investigations of people in specific contexts or evaluations of designed artifacts may also result in design implications that can guide the development of new products and services (Forlizzi et al., 2009). To some extent, all studies included in this thesis are examples of research for design, aiming to produce knowledge of value to both design practice and the research community.

In research through design, design activities and, typically, prototype development are central to the generation of knowledge (Stappers & Giaccardi, 2017). This approach "allows researchers to become active constructors of possible futures" and to deal with wicked problems (Forlizzi et al., 2009, p. 2894). Knowledge generated from the research through design approach may, for instance, take the form of new perspectives that improve the understanding of a problematic situation or new design methods that advance designers' ability to handle new kinds of challenges (Zimmerman & Forlizzi, 2014). Although prototype development was part of the research projects, a research through design approach was not applied in the studies included in this thesis.

4.3 Research design

This section presents the research design of the four studies. It outlines the research process, methods, and outcomes of each study.

4.3.1 Study A: Kitchen use, renewal & circular design opportunities

The first study carried out as part of the CIK project, Study A, aimed to create a deeper understanding of kitchens in relation to everyday life: how they are used, to what extent they support sustainable use of resources, how they are changed, and why. This study also had the purpose of guiding the development of the circular kitchen prototype in the CIK project and was partly carried out in the same period as the development of the first prototype. Thereby, a second aim was to explore opportunities for more circular kitchen design. Figure 4.4 shows an overview of the research design and outcomes of Study A.

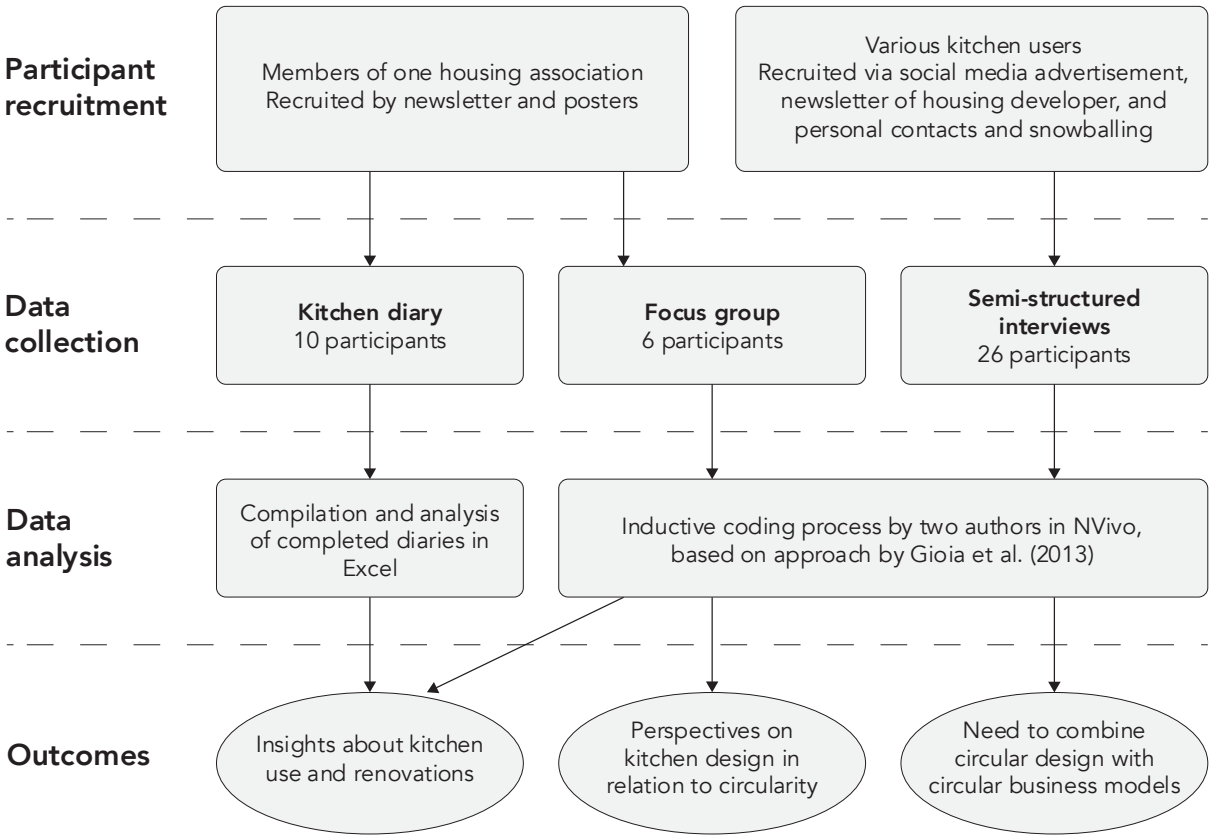


Figure 4.4. Overview of research approach and outcomes of Study A.

As a first step, participants were recruited from a housing association in Gothenburg with a connection to both the housing company and kitchen producer participating in the CIK project. Thus, the sampling was purposive (Collingridge & Gantt, 2019; Flick, 2018), to enable comparison of perspectives and changes made by households with similar dwelling conditions and kitchens. A kitchen diary was distributed in the post boxes for all members of the housing association, with an invitation to also take part in a following focus group. In this diary, the occupants were asked to answer simple questions about their households and kitchens and to log all activities taking place in their kitchen for one week. Due to a low response rate of completed diaries (n=10), their data was only briefly analysed. Instead, this method mainly served as a preparation for the focus group, encouraging the participants to start reflecting about their kitchens. An overview of the focus group participants (n=6) is given in Table 4.1.

Before the focus group, a protocol was prepared with a set of questions under the topics of (1) everyday kitchen practices, (2) resource use in the kitchen, (3) desired or implemented changes in the kitchen, and (4) thoughts about future kitchens. The focus group was semi-structured, leaving space for discussions and follow-up questions. A principal advantage of focus groups is that they encourage dynamics in discussions, which adds to the knowledge generation in the data collection Flick (2018). The interaction between participants may reveal attitudes and experiences that are not easily captured in more conventional research methods that rely on responses to direct questions (Kitzinger, 1995; Parker & Tritter, 2006).

However, focus groups are less suitable for in-depth analysis of individual experiences. Therefore, as a next step, the plan was to complement the focus group with interviews.

Table 4.1. Focus group participants in Study A.

Case	Gender	Age	Adults	Children	Dwelling type	Dwelling size (m2)	Number of rooms[1]	Nationality
F-1	Woman	75-84	1	0	Condominium	66	2	Swedish
F-2	Woman	75-84	1	0	Condominium	62	2	Swedish
F-3	Woman	65-74	1	0	Condominium	79	3	Swedish
F-4	Woman	65-74	1	0	Condominium	71	3	Swedish
F-5	Man	65-74	2	0	Condominium	107	4	Swedish
F-6	Woman	35-44	2	2	Condominium	-	-	Swedish

[1] excluding kitchen and bathroom

Additional channels were used to reach out to households representing a variety of constellations and tenures, from single households in rental apartments to families living in detached houses. Households who had recently renovated their kitchens were targeted but this was not a criterion for inclusion. Participants were recruited via a social media advertisement, the newsletter of a housing company, personal contacts, and snowball sampling (Noy, 2008). In total, 20 households signed up and were interviewed in their homes or via telephone/Skype. The interviews were semi-structured and guided by a prepared list of open-ended questions, which were adapted to the flow of each interview, allowing for additional topics to be explored. Compared to standardised interviews or questionnaires, the open design of semi-structured interviews facilitates the expression of participants' viewpoints (Flick, 2018). The interviews had a similar setup to the focus group, but with a stronger emphasis on performed or desired changes in the kitchen. In some cases, the registered participant's partner joined the interview, which resulted in a total of 26 interview participants. This contributed to deeper insights into how kitchen use and renovations were perceived within the household, as the different household members could build further on each other's thoughts and express their agreement or disagreement. An overview of the interviewee participants is given in Table 4.2.

The focus group session and interviews were audio recorded, transcribed, and imported to NVivo 12, where the content was thematically coded. Inspired by the approach suggested by Gioia et al. (2013), the analysis was carried out in stages: The first-order analysis stayed close to terms used by the informants in the labelling of codes, while less emphasis was placed on categorising them. The second-order analysis then focused on searching for emerging concepts and themes, which in turn were divided into aggregate dimensions. Two researchers (Anita Ollár and I) shared the work of coding the transcribed material and discussing the findings. The coding was reviewed and partly iterated to avoid missing out on interesting information in the data.

From Study A, many interesting design aspects of kitchens in relation to circularity and sustainable resource use emerged, while it became clear that circular design also requires circular business models to extend the life of the kitchen.

Table 4.2. Interview participants in Study A.

Case	Gender	Age	Adults	Children	Dwelling type	Dwelling size (m²)	Number of rooms[1]	Languages spoken in the household[2]
I-1	Woman	35-44	2	1	Condominium	83	3	-
I-2	Woman	35-44	2	3	Villa	133	5	-
I-3	Man Woman	25-34 -	2	2	Terraced house	106	4	-
I-4	Man	25-34	2	0	Condominium	74	3	-
I-5	Woman	25-34	2	1	Rental apartment	63	2	French, English
I-6	Woman Man	25-34 25-34	2	0	Condominium	65	3	-
I-7	Woman	35-44	2	2	Villa	120	5	-
I-8	Woman	45-54	2	2	Condominium	109	5	Somali
I-9	Woman	45-54	2	3	Villa	240	9	-
I-10	Man	35-44	2	3	Villa	170	7	German
I-11	Woman	55-64	2	0	Condominium	47	2	-
I-12	Woman Man	75-84 75-84	2	0	Condominium	89	3	-
I-13	Woman Man	45-54 55-64	2	0	Villa	180	8	German
I-14	Man	55-64	3	0	Villa	~90	4	-
I-15	Man	25-34	1	0	Rental apartment	72	3	Farsi
I-16	Woman	55-64	1	0	Rental apartment	51	2	-
I-17	Man	25-34	2	1	Rental apartment	75	3	-
I-18	Woman	35-44	3	0	Rental apartment	98	4	Bosnian
I-19	Woman Man	45-54 -	2	1	Rental apartment	90	3	-
I-20	Man Woman	55-64 45-54	2	0	Rental apartment	45	1,5	English

[1] excluding kitchen and bathroom, [2] beside Swedish

4.3.2 Study B: User perspectives on circular value propositions for kitchens

Study B was inspired by the insights from Study A and the need to understand more about the potential for circular business models in the context of the kitchen. Due

to time plans and deliverables of the other project, it was carried out at a later stage in my PhD studies, as the last study to be included in the thesis. An overview of the research design and outcomes is shown in Figure 4.5.

Study B was based on four workshops, with the aim of exploring people's perspectives on different circular value propositions for kitchen furniture and appliances. In total, 39 participants were recruited from different channels, such as posters, a social media event, and email invitations from the housing development partner to people in their housing queue. The aim was to reach people from a wide range of ages, household configurations, and housing types. Some of the participants had worked with kitchens, either through designing, selling, or building kitchens. An overview of the participants is given in Table 4.3.

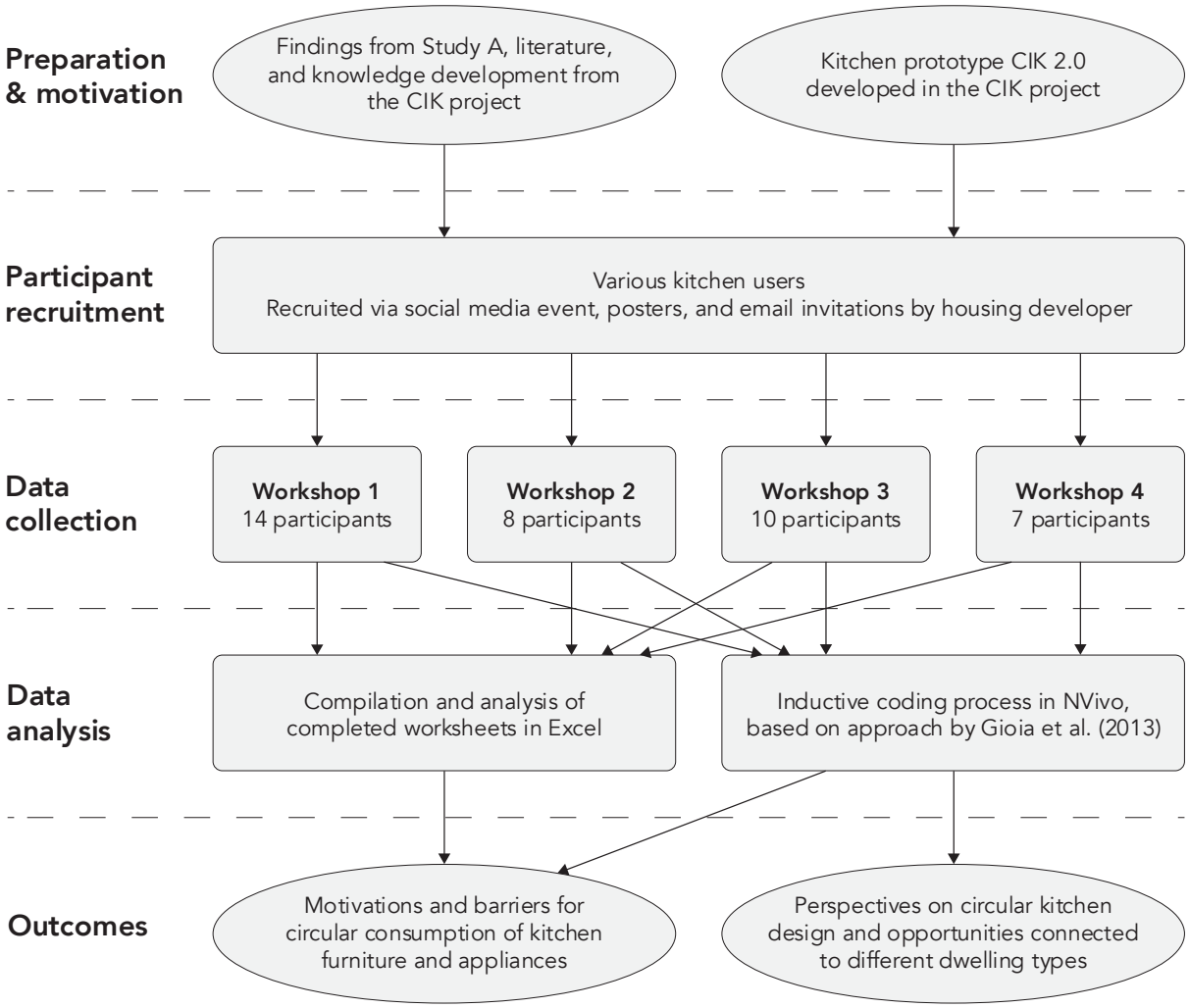


Figure 4.5. Overview of research approach and outcomes of Study B.

In these workshops, the participants were presented with six hypothetical scenarios in which different circular consumption models for kitchens were described. The first three focused on kitchen furniture and referred to the prototype kitchen CIK 2.0, developed in the CIK project and placed at the workshop venue

(see Figure 4.6). The following three scenarios focused on kitchen appliances and mainly the dishwasher. The scenarios were described without extensive details, leaving them open for discussions about positive and negative aspects in groups.

The qualitative method of using workshops with group discussions about different scenarios was selected to encourage reflections about circular value propositions that do not yet exist or that have not yet become widespread. The discussions were performed in groups of two to four participants and were guided by worksheets asking the participants to reflect on the positive and negative aspects of each scenario. They were also asked to discuss which scenario they would prefer and why.

Completed worksheets were compiled and analysed in Excel. The workshops were also recorded with audio (with the participants' permission), transcribed verbatim, and analysed in NVivo. The coding procedure was performed in several stages, following recommendations by Gioia et al. (2013).

Figure 4.6. *Prototype kitchen CIK 2.0 installed at the workshop venue and used as a reference for a modular kitchen in durable materials with a long technical lifetime in scenarios 1 – 3. The picture was taken before a dishwasher was installed. Photograph by Ulrike Rahe.*

Table 4.3. Workshop participants in Study B.

	W1	W2	W3	W4	Total
Number of participants	14	8	10	7	39
Gender					
Female	11	5	7	4	69%
Male	3	3	3	3	31%
Age					
0 – 19	0	0	0	1	3%
20 – 29	0	2	0	4	15%
30 – 39	2	3	0	2	18%
40 – 49	5	1	0	0	15%
50 – 59	5	1	0	0	15%
60 – 69	0	1	1	0	5%
70+	2	0	9	0	28%
Household size					
1	1	3	4	3	28%
2	1	2	6	3	31%
3	3	2	0	0	13%
4	6	1	0	1	21%
5	3	0	0	0	8%
Type of dwelling					
Rental apartment	1	4	1	3	23%
Condominium	2	0	3	3	21%
Single-family house	11	4	6	1	56%
Occupation					
Working full time	11	4	0	2	44%
Working part time	1	2	0	1	10%
Student	1	0	0	5	15%
Retired	2	0	9	0	28%
Job seeker	0	0	0	0	0%
Other	0	2	1	0	8%
Educational level					
Pre-secondary	0	2	4	0	15%
Upper secondary	1	2	0	0	8%
Post-secondary	13	4	6	7	77%
Not specified	0	0	0	0	0%
Monthly income (before taxes)					
< 25 000 SEK	1	2	5	5	33%
25 000 – 34 999 SEK	2	1	0	1	10%
35 000 – 44 999 SEK	4	0	1	0	13%
> 45 000 SEK	6	2	1	0	23%
Not specified	0	3	3	1	18%

4.3.3 Study C: Residents' perceptions of indoor climate & demand-side management

Study C investigated the thermal perceptions of people living in multi-residential buildings in Malmö during a two-week trial conducted in November and December 2019. The aim was to develop a better understanding of thermal comfort at home and the acceptance of centrally controlled load shifts in space heating. An overview of the research design and outcomes is shown in Figure 4.7.

The study consisted of three phases: (1) registration and initial survey, (2) a two-week trial, in which the participants used a diary tool to report on their temperature perception, while load control was applied in selected buildings, and (3) closing survey aimed at comparing opinions (after the trial) on thermal comfort and energy use at home with results from the initial survey.

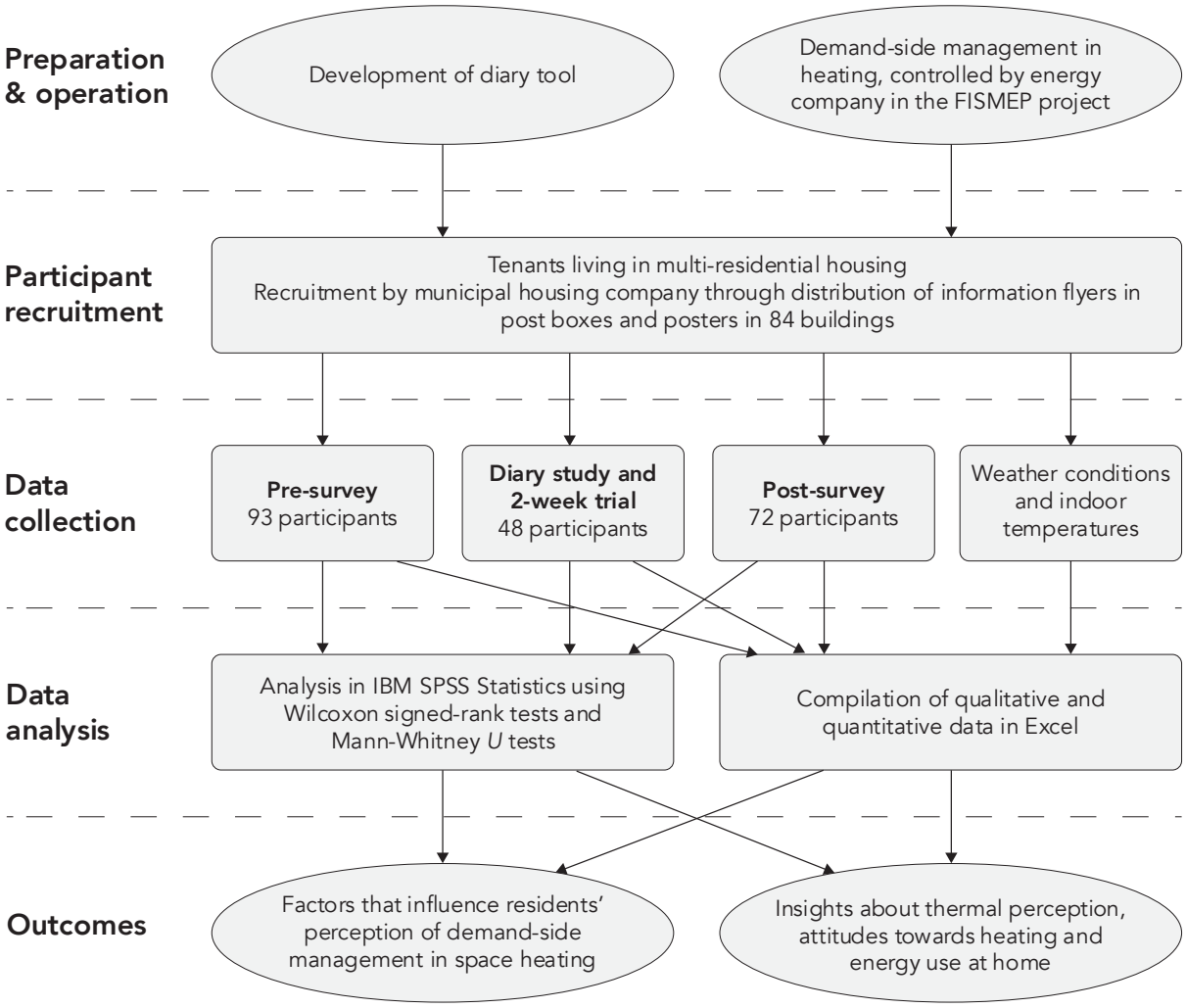


Figure 4.7. Overview of research approach and outcomes of Study C.

All participants were divided into four groups: (A) residents of buildings with load control who received notifications of planned load shifts, (B) residents of

buildings with load control but no notifications, (C) residents of buildings with neither load control nor notifications, and (AC) residents of buildings without load control but with false notifications about planned load shifts.

Purposive sampling (Collingridge & Gantt, 2019; Flick, 2018) was applied, targeting residents from 84 buildings, owned by the municipal housing company and connected to a Customer Energy and System Optimisation (CESO) system managed by the local energy provider. The CESO system uses the natural thermal inertia of the buildings to enable load shifting during short periods, to reduce peak generation in the district heating system. Demand-side management during the trial followed a predetermined control scheme including several load shifts of between 0.5 and 3 hours. Indoor temperatures were allowed to change by ±0.5°C.

Information flyers were distributed to residents' post boxes and posters were placed in the building entrances a couple of weeks before the trial. The printed material encouraged residents to sign up for the study via a web link and promised cinema tickets to those participants who completed the study. In total, 93 residents from 33 buildings registered and completed the initial survey, 48 of them participated in the following diary study during the trial, and 72 responded to the closing survey. An overview of the participants is given in Table 4.4.

Table 4.4. Participants in Study C.

	Pre-survey	Diary study	Post-survey
Number of participants	93 (A: 20, B: 20, C: 43, AC: 10)	48 (A: 12, B: 7, C: 23, AC: 6)	72 (A: 15, B: 15, C: 32, AC: 10)
Female participants (%)	57 (A: 45, B: 60, C: 58, AC: 70)	58 (A: 50, B: 71, C: 57, AC: 67)	58 (A: 40, B: 67, C: 59, AC: 70)
Participants over 65 (%)	15 (A: 20, B: 10, C: 14, AC: 20)	17 (A: 25, B: 0, C: 17, AC: 0)	15 (A: 20, B: 7, C: 16, AC: 20)
Participants speaking languages other than Swedish at home (%)	32 (A: 5, B: 30, C: 47, AC: 30)	25 (A: 0, B: 14, C: 43, AC: 17)	33 (A: 7, B: 36, C: 45, AC: 30)

During the trial, participants could report on their perception of the indoor temperature at any time of the day using either a digital (web-based) diary tool or a paper diary. Both options included the same set of questions, to make the results from both data collection tools comparable. Diary studies enable "capturing life as it is lived" (Bolger et al., 2003) and were considered the best method to encourage participants to reflect on their indoor climate and report momentarily on their thermal perception as well as practices that may influence it. The digital diary enabled participants to report either their current temperature perception or summarise their temperature perception for the day. Every evening of the trial period at 8 pm, a reminder to make a daily summary was sent out to all participants who had not yet

reported on their temperature perception that day in the digital diary. Figures 4.8 and 4.9 illustrate the two diary tools.

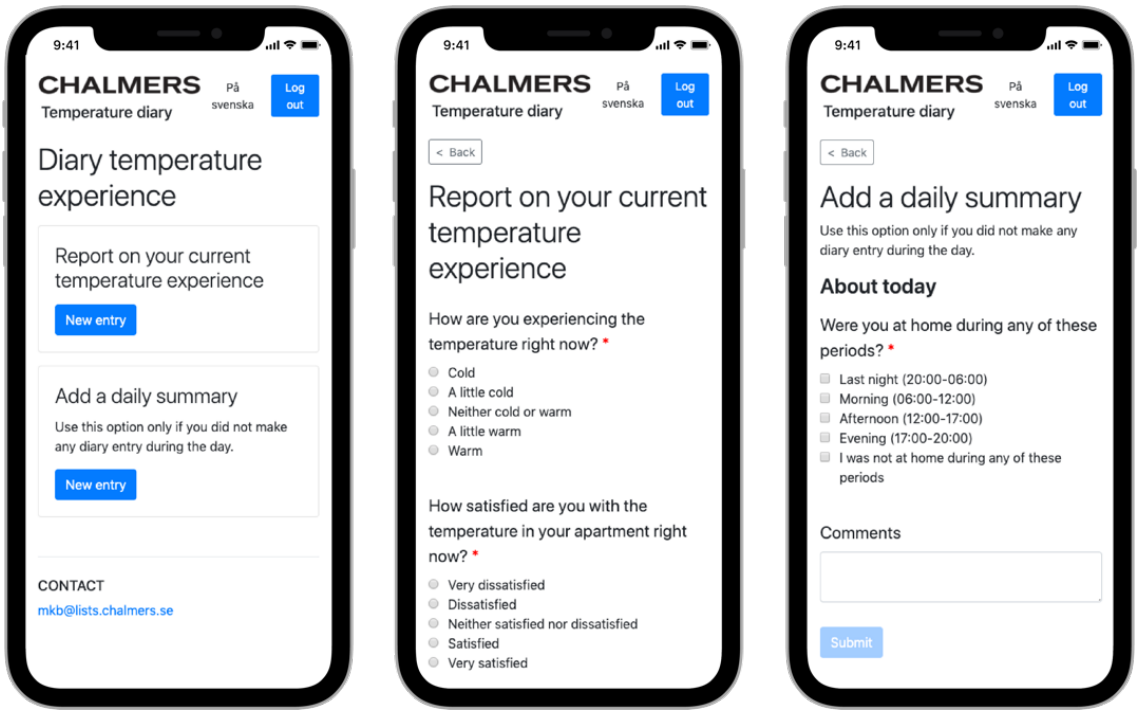


Figure 4.8. *Digital diary tool for reporting on current temperature perception or submitting a daily summary.*

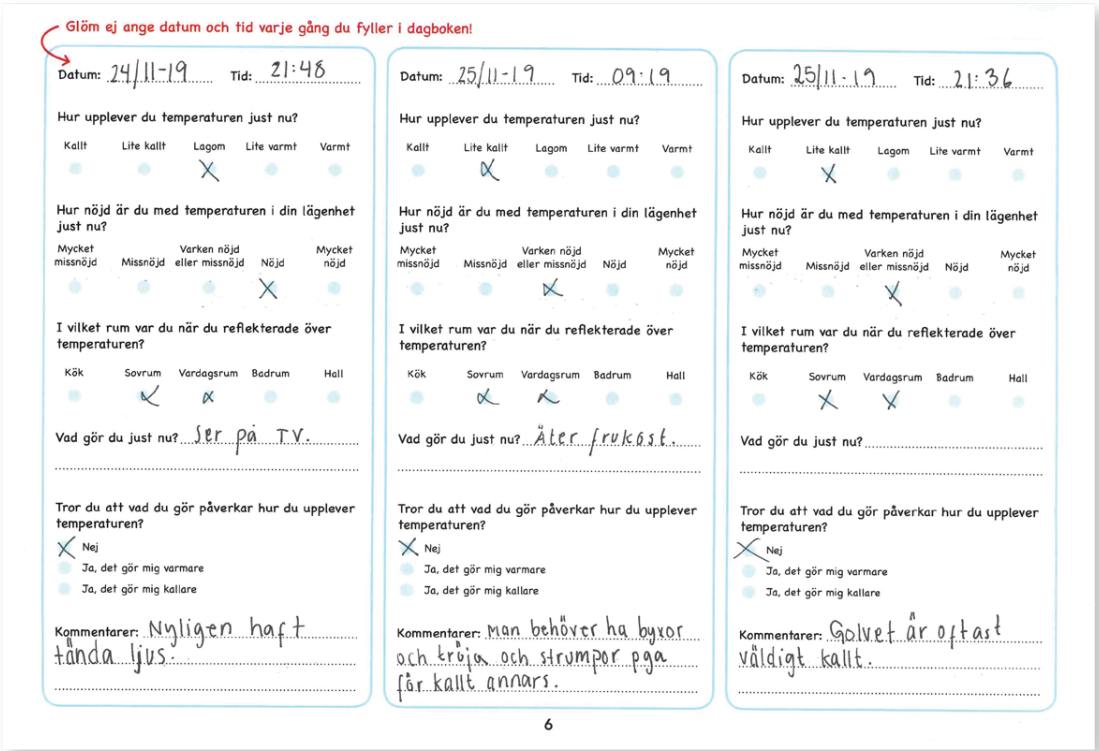


Figure 4.9. *Paper diary for reporting temperature perception.*

The diary study resulted in a total of 803 diary entries. Data from the diaries and surveys were analysed (alongside data on indoor temperatures and outdoor weather conditions) in Microsoft Excel and IBM SPSS Statistics using Wilcoxon signed-rank tests, Mann-Whitney U tests, correlation analysis, and regression analysis. Qualitative data from the surveys and diary entries in the form of comments were thematically categorised and summarised to complement the quantitative data. A few illustrative comments were picked out and translated to English if originally written in Swedish.

4.3.4 Study D: Household testing and evaluation of the home energy management system Ero 2.0

Study D explored the use of a home energy management system (HEMS) prototype, named Ero 2.0, with the aim to improve the understanding of different factors influencing the perception and impact on everyday energy-reliant practices. An overview of the research design and outcomes for Study D is shown in Figure 4.10.

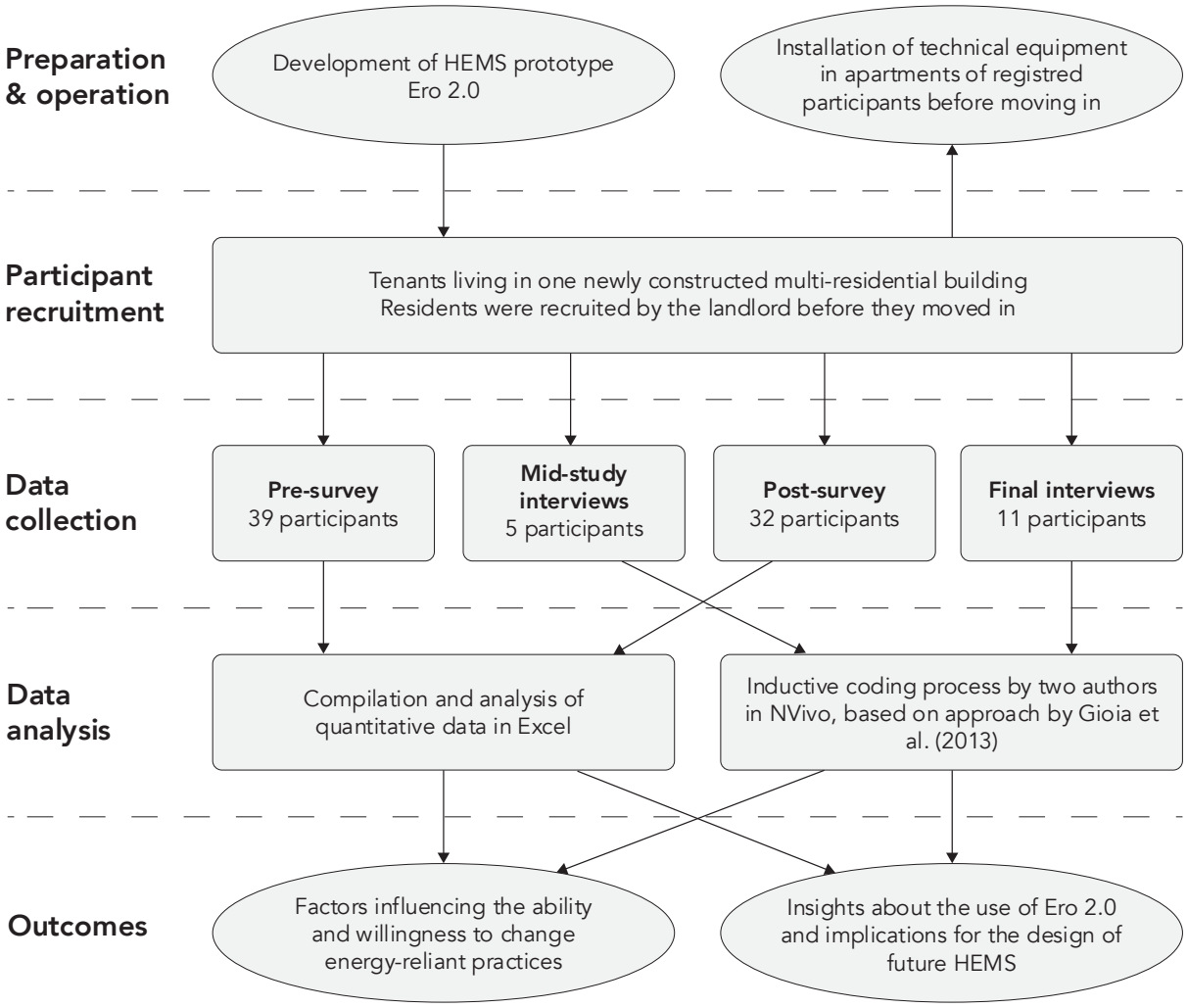


Figure 4.10. Overview of research approach and outcomes of Study D.

Ero 2.0 is the second version of an application designed to support people in adapting their energy use to the availability of their preferred energy sources, communicated by a personal energy threshold. While Ero 1.0 (described in Renström et al. (2019)) included a threshold for both electricity and district heating, Ero 2.0 only had an electricity threshold but also included information about hot and cold-water use.

Ero 2.0 was tested by people living in a multi-residential building in Malmö for about two and a half months. The participants signed up for the study before moving into the newly constructed building to enable the installation of technical equipment needed to facilitate the study. In total, 35 apartments were equipped with smart plugs connected to the washing machine, tumble dryer, dishwasher, and either a separate fridge or a combined fridge/freezer column. In Ero 2.0, the participants could monitor the consumption of these appliances as well as the floor heating, which could also be turned on and off via the app interface. Figures 4.11 and 4.12 show further details of the interface.

The participants were invited to an introduction event before the start of the study, where the research team presented the overall aim of the study and the functions of Ero 2.0. 26 participants took part in the event. Those who could not attend were sent information via email and invited to a digital introduction, which was attended by four. All participants were asked to fill in a pre-survey before starting to test the app, which focused on opinions and current practices connected to energy and water consumption.

In the middle of the test period, the participants were invited to participate in a short interview about their experiences with the app so far. At the end of the test period, they were sent a post-survey with an invitation to also take part in a final interview. Both the post-survey and final interview aimed to explore how the app had been perceived and used and if it had contributed to any changes in everyday energy-reliant practices. An overview of the participants is given in Table 4.5.

Unfortunately, since the study was carried out at the beginning of 2020 during the Covid-19 pandemic, all interviews needed to be performed digitally, and it was not possible to visit the homes of the participants to get a better understanding of their home contexts and the integration of Ero 2.0 in everyday life. Both Swedish and English were used in the interviews, and audio was recorded with permission from the participants, then transcribed verbatim and imported to NVivo.

Two researchers (Giliam Dokter and I) coded half of the interviews each and discussed the findings together. The coding followed the approach described by Gioia et al. (2013). The two coding files were then combined into one, and the structure was reviewed. Some additional coding was carried out, and some categories were adjusted to ensure that all information of value was included in a comprehensive way. A few illustrative quotes were selected and translated to English, if originally in Swedish.

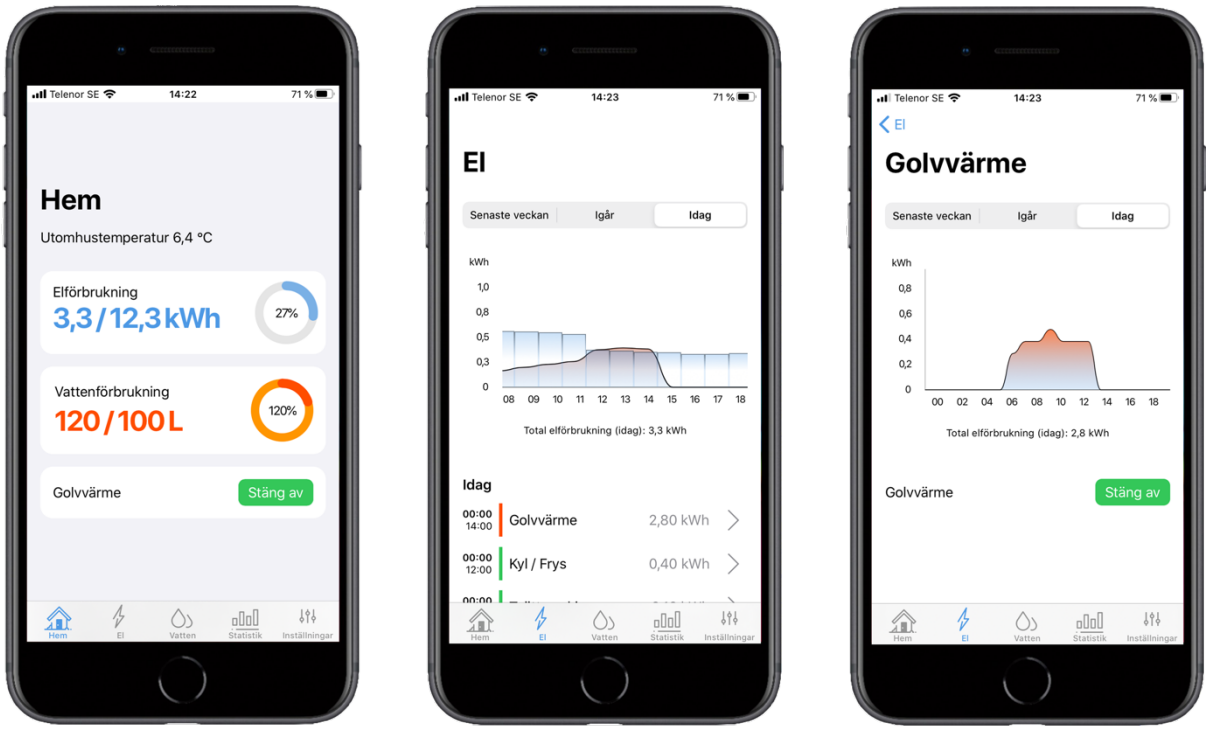


Figure 4.11. Ero 2.0 in light mode. Home screen with momentary electricity use, daily water use, and control of floor heating (left), electricity use in relation to personal electricity threshold (middle), and electricity use of a specific function (right).

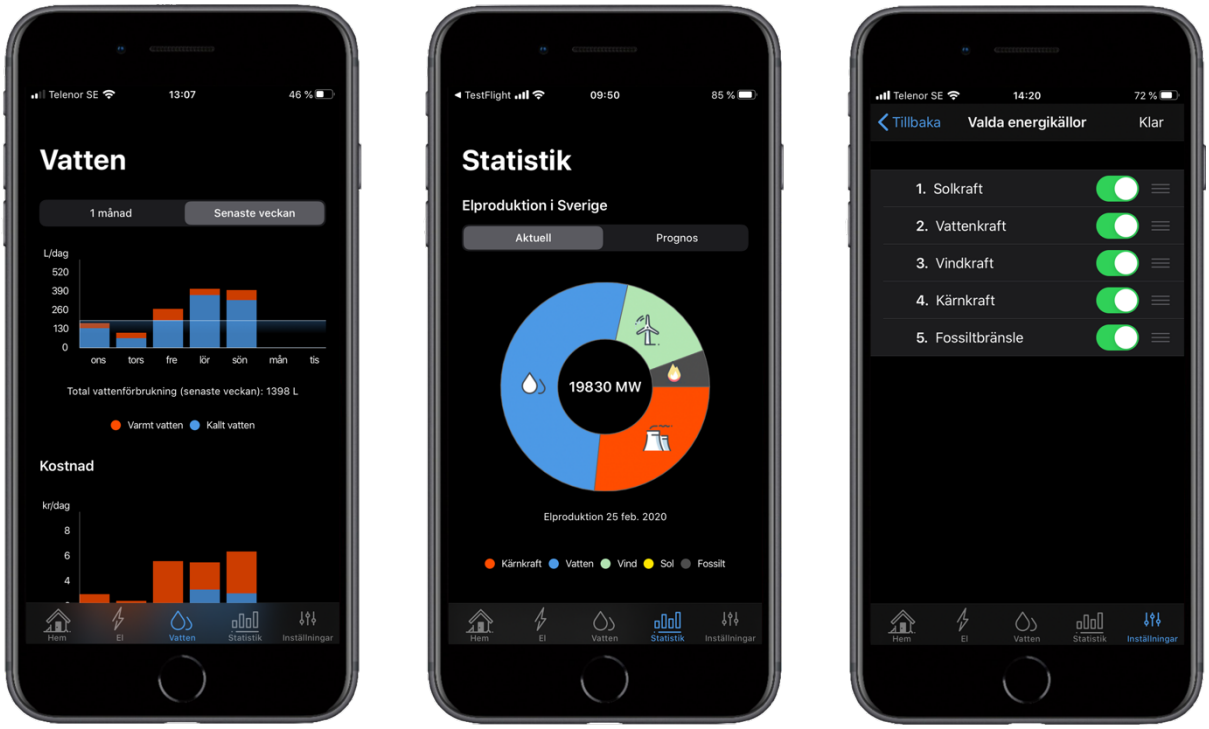


Figure 4.12. Ero 2.0 in dark mode. Water consumption screen (left), energy production statistics (middle), and personal electricity threshold settings (right).

Table 4.5. Participants in Study D.

Household	Participant ID	Age	Adults	Children	Dwelling size (m²)	Rooms	Pre survey	Mid-study interview	Post survey	Final interview
1	1-F	25-34	1	-	40-49	2	yes	-	yes	-
2	2-F	35-44	2	2	90-99	4	yes	-	yes	-
	2-M	45-54					yes	-	-	-
3	3-M	18-24	1	-	60-69	2	yes	-	-	-
4	4-M	25-34	2	-	40-49	2	yes	yes	-	-
	4-F	25-34					yes	yes	yes	-
5	5-F	45-54	2	-	60-69	3	yes	-	-	-
6	6-M	45-54	2	-	80-89	4	yes	-	yes	yes
7	7-F	25-34	2	-	40-49	2	yes	-	yes	-
8	8-F	25-34	2	-	80-89	4	yes	-	yes	-
9	9-F	25-34	2	-	60-69	2	yes	-	yes	-
	9-M	25-34					yes	-	yes	-
10	10-F	18-24	1	-	40-49	1	yes	-	yes	yes
11	11-M	55-64	2	-	90-99	4	yes	-	yes	-
12	12-F	25-34	1	-	30-39	1	yes	-	yes	yes
13	13-F	55-64	1	-	90-99	4	yes	-	-	-
14	14-F	35-44	1	-	40-49	2	yes	-	yes	-
15	15-M	35-44	2	1	90-99	4	yes	yes	yes	yes
	15-F	35-44					yes	-	yes	-
16	16-M	45-54	1	-	40-49	2	yes	-	-	-
17	17-F	45-54	1	1	70-79	3	yes	-	yes	-
18	18-F	45-54	2	-	90-99	4	yes	-	-	-
	18-M	45-54					yes	-	-	-
19	19-M	35-44	1	-	50-59	2	yes	yes	yes	-
20	20-M	25-34	1	-	30-39	1	yes	-	yes	-
21	21-M	25-34	2	-	70-79	3	yes	-	yes	-
	21-F	25-34					yes	-	yes	-
22	22-M	25-34	1	-	90-99	4	yes	-	yes	yes
23	23-M	55-64	2	-	80-89	4	yes	yes	yes	-
	23-F	55-64					yes	-	yes	-
24	24-M	25-34	1	-	40-49	2	yes	-	yes	-
25	25-M	35-44	1	-	50-59	2	yes	-	yes	-
26	26-M	45-54	2	1	70-79	3	yes	-	yes	yes
27	27-M	25-34	1	-	30-39	1	yes	-	yes	yes
28	28-M	25-34	1	-	30-39	1	yes	-	yes	yes
29	29-F	18-24	2	-	50-59	2	yes	-	yes	yes
	29-M	25-34					yes	-	yes	yes
30	30-F	25-34	1	-	40-49	2	yes	-	yes	-
31	31-M	55-64	1	-	60-69	2	yes	-	yes	yes
32	32-M	-	-	-	50-59	2	-	-	yes	-

4.4 Reflections on the research approach

This section reflects on the methodological choices of the research in relation to the theoretical framework and the context of the research projects. It also discusses the validity and generalisation of the findings, followed by ethical considerations concerning the research.

The overall aim of the research has been to improve the understanding of sustainable consumption at home in relation to the design of products and services. The pragmatic approach and the use of mixed methods have been useful for addressing this multifaceted topic as it encourages the research design to be adapted to the specific context and purpose of each study. However, a limitation of the pragmatic approach is that the research contribution may be perceived as more practical than theoretical (Johnson & Onwuegbuzie, 2004). This research has relied primarily on empirical data and has had a strong focus on generating knowledge to be applied in practice, such as design implications and considerations about the roles of different actors in relation to the home environment. Theoretical contributions have been provided as well by highlighting relationships between different factors, important research areas, and methodological considerations for future studies. However, the research could have benefitted from a stronger connection to theory, as will be discussed in the following section.

4.4.1 Methodological choices in relation to the theoretical framework

In this thesis, I have used social practice theory to analyse some of the findings. However, from the start, I was only vaguely familiar with the theory and not sure if and how I would apply it to my research. Studies A, C, and D were planned quite early on in my PhD studies and have therefore mainly been planned independently from any theory. Throughout my research process, I learned more about social practice theory and was inspired to use it in the analysis of my research findings. Although Study B was planned at a later stage, social practice theory did not guide the overall design of the study because no specific practice was targeted, and it was expected to make the scope too wide for Paper B. Still, I found it relevant to apply at least some practice theoretical aspects in the analysis presented in this thesis. Of course, this is not an optimal strategy for performing practice-oriented research, but it has been an important learning process for me.

By applying a practice theory perspective in the analysis of the findings, some new insights were generated. First, it helped identify different elements and highlighted their relationships within studied practices. Second, it revealed some elements and connections that may be stronger than others and more difficult to change. Third, this perspective contributed to a greater understanding of how some practices are related to other practices.

In the analysis of Study A, practice theory was applied to understand the dynamics of everyday kitchen use and how the practice of renovating the kitchen

related to other practices connected to the kitchen. In Study B, practice theory was used to identify meanings and competences associated with circular consumption models. To some extent, the findings also suggested ways in which everyday practices may be affected by the implementation of circular consumption models in the kitchen context. Study C was more focused on the perception and acceptance of heat load shifting than the actual effects on residents' heating practices. Still, some general insights emerged about residents' strategies for maintaining or improving thermal comfort and some of the practice elements involved. Finally, Study D explored how the introduction of Ero 2.0 affected energy-reliant practices at home and how the practice of using Ero 2.0 changed over time.

To develop a deep understanding of a practice, observation would have been the preferred method, as suggested in previous literature (Bueger, 2014; Nicolini, 2017). Observation has, however, not been possible to apply in any of the studies in this thesis. In Study A, the investigation included several practices connected to the daily use of kitchens, such as cooking and waste management, but also the practice of renovating the kitchen, which is performed not as a routinised form of behaviour, but as infrequent events performed over a longer time. Observation of both the daily use of kitchens and renovations would have demanded considerable resources not available within the context of the research project. Therefore, the primary methods used were interviews and a focus group, which still generated rich, qualitative data. Because most of the interviews were carried out in the participants' homes, it was also possible to get a good understanding of the kitchen space in relation to the interviewees' verbal descriptions.

In Study C, neither observation nor interviews were possible options for collecting data about practices related to staying warm and maintaining a comfortable indoor climate. This study had to rely on diary entries, which is a form of document analysis (Bueger, 2014), and survey answers, with limited possibilities to collect qualitative data. Although these methods allowed the study of practices across a wider population than if only using qualitative methods, it would have enriched the understanding if also qualitative methods could have been used.

In Study D, a combination of qualitative and quantitative methods was used to study energy-reliant practices at home, which has the potential to create a thorough understanding of practices (Browne et al., 2014). However, the investigation was limited by the fact that the homes of the participants could not be visited during the study, due to the Covid-19 pandemic.

If I were to re-design the studies from a practice theoretical lens, I would state more clearly from the beginning which practices would be targeted, and which other practices might be interesting to study as well to understand their relationships. I would combine qualitative and quantitative data collection methods and, if possible, include small elements of observation. The use of more visual material, such as videos and photos collected and recorded by the participants themselves, could have enriched the material in a less intrusive way than entering the participants' homes to observe practices. Furthermore, studying how practices have evolved historically

could have improved the understanding of why practices are performed in the way they are today.

In Study D, Ero 2.0 was introduced as an intervention to change energy-reliant practices and evaluated by the participants. However, as suggested in the practice-oriented design approach by Kuijer (2014), interventions to change practices could be introduced, refined, and evaluated in an iterative process with several cycles of testing. The participants could be included in co-creation sessions targeting specific practices and ideating about opportunities for change, allowing them to be active participants in the design process, as suggested by Scott et al. (2012). Also, after the introduction of an intervention aimed at changing practices, longer periods of evaluating the effects over time would be needed, as recommended by Pettersen (2016). Before introducing any interventions, analysis of baseline consumption levels and defining a new target level for the specific practice would allow better evaluation of the effects of practice changes (Kuijer, 2014).

4.4.2 Research progress in relation to the project contexts

The CIK project early on involved several workshops with project partners. In particular, the research team had frequent meetings and workshops with the Swedish kitchen developer due to the project deliverable of developing a prototype of a circular kitchen already within the first six months of the project. My PhD colleagues and I were greatly involved in the preparation, implementation, and analysis of these workshops, as well as further communication about the development and installation of the prototype. During this period, I learned a lot about the kitchen industry, circular design strategies, and workshop techniques.

Study A was initiated in the early phase of the CIK project, and findings from the study were presented to the other team members in different contexts, including consortium meetings and workshops with the kitchen developer. The study both provided new insights and confirmed some decisions that had already been taken in the prototype development process. However, as in all product development, the final design of the CIK prototypes involved compromises between many different factors. Besides providing knowledge for the CIK project, my research also benefitted from the project through the inclusion of the CIK 2.0 prototype in the workshops as part of Study B.

The FISMEP project had a strong influence on the research design of Studies C and D, as those studies were part of the project deliverables with an overall purpose and approach communicated from the start. In Study C, the control schedule for load shifting was determined by the energy company, and the recruitment was handled by the municipal housing company that was part of the project. The research team was not allowed to contact the participants directly, and the study was therefore limited to mainly quantitative research methods. The control schedule included relatively few periods of load shifts, which were sometimes not applied in all buildings as planned. This limited the possibility to analyse the impact of the load

shifts on the residents' thermal perception. Before this study, I had limited experience in performing quantitative research and learned a lot about both data collection and analysis of quantitative data.

Overall, the research projects have provided an inspiring context for my research. The different research areas have fitted my personal research interest well, and the studies have provided different pieces to the puzzle of sustainable consumption. Often, the planning, implementation, and analysis of the studies took place in parallel, alongside other project activities, and the analysis sometimes had to wait until several months after the data collection for a study was completed.

4.4.3 Validity and generalisation

Validity is one measure of research quality that questions whether the researchers "in fact see what they think they see" (Flick, 2018, p. 543) or "whether a study investigates the phenomena intended to be investigated" (Kvale, 1995, p. 26). Validation means continuously controlling the quality throughout the research process by checking, questioning, and theoretically interpreting the research findings (Kvale, 1995). To ensure the validity of the research in this thesis, different forms of triangulation have been applied, which allow "different facets of problems to be explored" (Tracy, 2010, p. 843). Studies A, C, and D combined several data collection methods, which may be referred to as methodological triangulation (Denzin, 1989, as cited in Flick, 2018). Furthermore, Studies A, C, and D used data triangulation, which involves investigating phenomena at different times and places and involving different people (Denzin, 1989, as cited in Flick, 2018). Studies A, B, and D also included investigator triangulation, meaning that several researchers took part in the data collection and analysis to compare findings and avoid biases (Denzin, 1989, as cited in Flick, 2018). In all studies, several researchers have reviewed the material used for data collection to ensure that the questions mirror the research focus and are easy to understand.

Generalisation refers to whether research findings are valid independently of, and outside, the specific context of the study (Flick, 2018). According to Flick (2018), generalisability depends largely on the sampling approach. Overall, studies that rely mainly on qualitative data collected from a relatively small sample will result in low generalisability. This is the case for Studies A, B, and D. However, the generalisability has been slightly improved by the inclusion of a diversity of household configurations, dwelling types, and ages among the participants. Still, the samples are not representative of the Swedish population. Study C aimed at achieving better generalisation opportunities through quantitative data collection in a larger sample. However, the sample size turned out smaller than anticipated and was scattered, with few participants spread across a relatively high number of buildings.

Although the included studies demonstrate low statistical generalisability, "knowledge generated through qualitative methods can still transfer and be useful in other settings, populations, or circumstances" (Tracy, 2010, p. 845). Focusing on

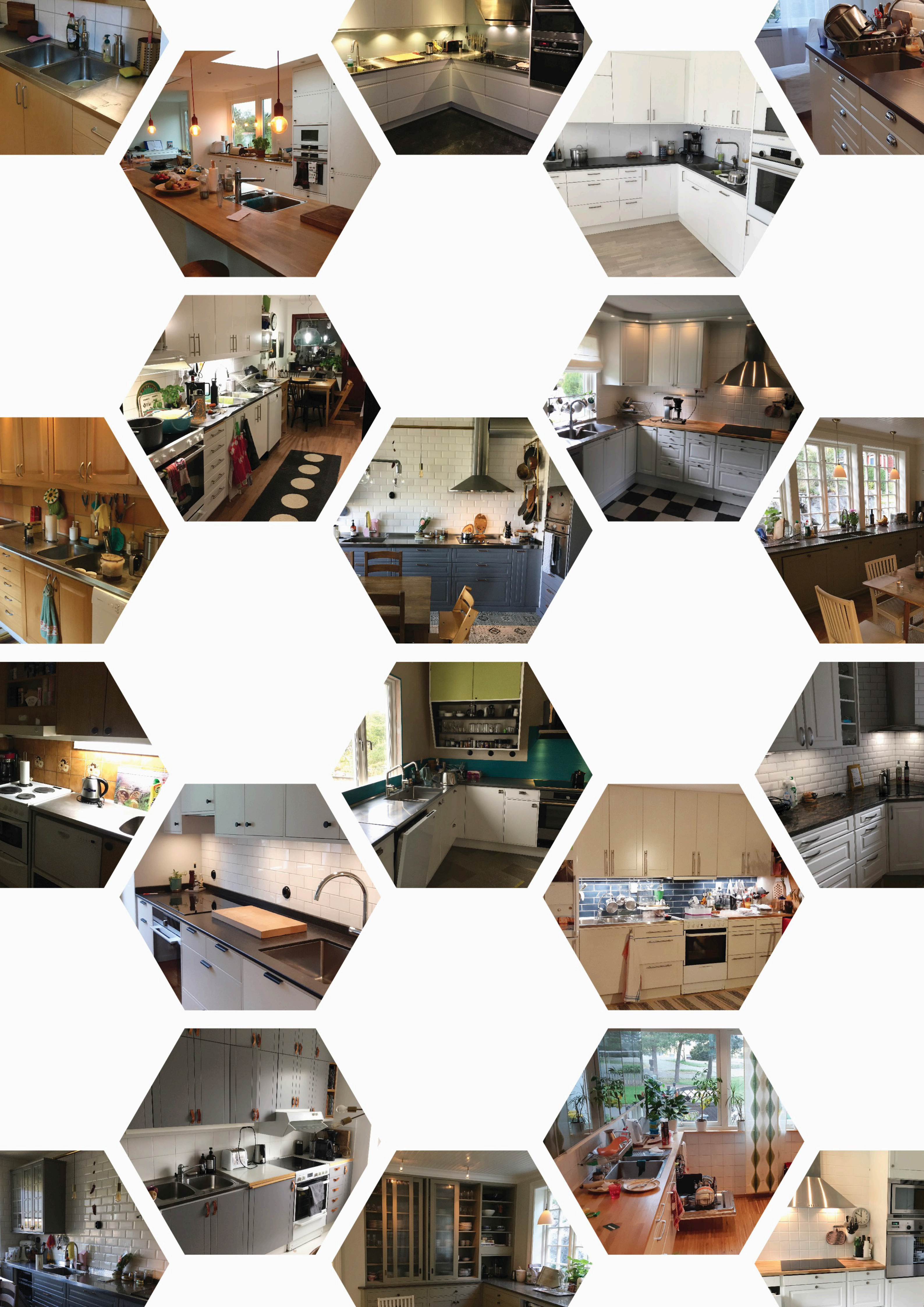
"analytical generalisation" (Collingridge & Gantt, 2019), the research has strived for transparency in the way the studies have been carried out, compared findings with existing literature, and discussed similarities and differences between different contexts, to allow readers to make their own judgment of whether the findings are applicable in other situations.

4.4.4 Ethical considerations

In the sampling procedures for the studies, the aim has been to include participants of varying demographics. However, participation has been voluntary and has therefore depended on people's interest to take part. In Studies A and C, a small compensation in the form of movie tickets was provided to the participants but is unlikely to have had much influence on the final sample. Even though a variety of household characteristics has been sought, it has been impossible to represent all different groups in society. Factors such as financial assets and housing type greatly determine people's possibilities to make changes to their living environment and associated practices. As discussed earlier, the possibilities to generalise findings are therefore limited.

In all studies, participants have been informed about the purpose of the study, the procedures for storing data, and that the collected data will only be used for research purposes. General Data Protection Regulation (GDPR) forms, including this information, were signed by the participants at the start of each study. Similarly, participants needed to agree to audio or video being recorded as part of the data collection.

Considerations have been given not to collect sensitive data or more personal data than needed for the context of each study. However, people may still feel exposed when sharing information about their daily life and practices at home. In Study A, the interviews often took place in people's homes, which may be something that not everyone feels comfortable with. Again, this was voluntary, and, in a few cases, the interviews were held via phone or video meeting instead. Study C, which was centred around heating and demand-side management, may have been perceived as more exposing in terms of the home environment being affected. However, the load control schedule was planned to be used regardless of whether the study was to be carried out or not. In Study D, data about the participants' energy consumption and use of Ero 2.0 was collected but finally not used in the analysis because it was not considered to contribute much to the findings from the other data collection methods.



Participant kitchens of Study A.
Photos by Sofie Hagejärd and Anita Ollár.

5

TOWARDS CIRCULAR KITCHENS

This chapter summarises findings from Studies A and B, both focusing on the circularity of domestic kitchens. The findings (primarily of Study A) have been revisited and analysed a second time, with a stronger connection to social practice theory. Study A is centred on the use and renewal of kitchens in relation to their design. Section 5.1 summarises findings about the daily use of kitchens. A summary of the findings focusing on kitchen renewal is presented in Section 5.2. These findings were then used to identify design opportunities for improving the circularity of kitchens, presented in Section 5.3. However, only applying circular design strategies is not enough to transition to a circular economy of kitchens. Therefore, Study B focused on the potential for introducing more circular business models for kitchens by exploring the perspectives of potential consumers on circular value propositions for kitchen furniture and appliances. These findings are summarised in Section 5.4. The chapter ends with a discussion about different approaches to circularity for the kitchen, Section 5.5. Parts of this chapter have been adapted from my licentiate thesis (Hagejärd, 2020).

5.1 Daily kitchen use

This section centres on daily kitchen use and presents households' perceptions of resource use in connection with their kitchen practices, based on findings from Study A. In the focus group, participants discussed how they felt unaware of how much energy and water they were using in the kitchen and that there was a lack of incentive to reduce their consumption. It was also apparent that energy savings were generally of low priority in daily kitchen practices, as illustrated by the following quote:

> *No, it's not like it's my highest priority when I'm cooking to save energy – it is that I'm hungry [laughing]. Then I want energy! […] It's not like I'm thinking while I use the kitchen that 'now I should time it so that I turn on the oven at exactly the right minute to make it fit', I don't. (I-4)*

Avoiding food waste seemed to be given high priority by most participants. At the same time, this was seen as a complex task that was sometimes difficult to fulfil. Fruit and vegetables were given particular mention as examples of food that sometimes spoil before being used. This problem was given several explanations: lack of space in the fridge, resulting in vegetables being stored too tightly, the

temperature in the fridge being too low, lack of time to cook, or simply forgetting about it. Two focus group participants discussed a feature that they missed from previous dwellings: a naturally cooled pantry in the kitchen with a valve that lets in fresh air from the outside and located against a north-facing wall. They explained that this provided a suitable environment for storing root crops, fruit, and vegetables. To prevent food waste, several households had adopted the strategy of going shopping more often and buying smaller amounts of food.

Sometimes other types of groceries also ended up as waste. Regarding the storage space in cabinets, one interviewee explained that:

> *You don't see what you have at home, so you buy a lot of food you already have. I think that is not very sustainable. In the end, you have four packages of the same thing at home just because they always end up at the back. (I-5)*

The different levels of priority given to avoiding food waste versus saving energy and water seemed to originate in various elements of kitchen-related practices. First, the action of throwing away food was expressed as more serious than wasting energy and water. The prevention of food waste also seemed to be perceived as more straightforward than saving energy and water. In other words, competences differed, in terms of both knowledge regarding how to minimise resource waste as well as in social norms regarding what is appropriate.

Second, the meanings differed in that wasting food seemed to generate stronger negative emotions than wasting energy and water. One interviewee explained: *"I sometimes have a bad conscience about things being thrown away"* (I-20). Another thought that *"throwing away food is completely insane"* (I-18).

Third, materials in the kitchen also played a role in the prevention of energy, water, and food wastage. Food waste needs to be taken care of by separating it from other categories of waste and either composting it yourself or having it collected, while the amounts of energy and water used in the kitchen are generally much less visible. Something that was mentioned as a contributing factor to using more water than necessary was the slow change from warm to cold and cold to warm water. One interviewee gave an example of an appliance feature intended to improve energy efficiency but which, instead, gave the opposite effect – a fridge door that was very difficult to open if you had already opened it shortly before. This resulted in the fridge door sometimes being left open to avoid the inconvenience of not being able to open it again. Furthermore, one interviewee who did not have a dishwasher in her kitchen stated this as a drawback since she believed she used more water and energy by hand-washing the dishes.

In discussions about cooking, one interviewee mentioned that vegetarian cooking demands more workspace because *"it's a lot of chopping"* (I-3). Regarding packaging waste, a general opinion among the participants was that the space dedicated to sorting kitchen waste is insufficient. For many participants, waste-sorting had spread to rooms other than the kitchen, such as the hallway, the laundry room, or the basement. However, as one interviewee stated, *"most of the waste occurs in the kitchen, so it's reasonable to have it close"* (I-19). Another interview opined:

Many times, the reason to why we are very poor at recycling is because we don't have a natural place to put [the waste]. After all, we have filled up what we have there […] Since recycling has grown faster over time than the sink [cabinet], I think we should soon go up one module [in size] as standard (I-3)

5.2 Kitchen renewal

This section is focused on the practice of renovating the kitchen, based on findings in Study A. An overview of the households' completed changes in the kitchen is shown in Table 5.1. The practice of renovating the kitchen showed a variety of performances in the different cases of the participating households. The configuration of elements and their links thus varied from case to case. A summary of the practice-as-entity, or many performances, of renovating the kitchen is shown in Figure 5.1, including all elements identified from the interviews (but no links, as this would make the figure too complex). Figure 5.1 shows that many different meanings were connected to kitchen renovations. Together with the materials and competences present in each case, this determined the purpose and extent of the renovation. Competences needed to perform the kitchen renovation varied among the households and renovation cases, for instance, in terms of architectural planning and assembly and installation of the kitchen furniture and appliances. Thus, the extent to which households planned and performed the renovation by themselves varied.

Furthermore, the practice of renovating the kitchen was shaped by other practices connected to the kitchen and home environment. For families, the kitchen played a central role in a variety of practices, which in many cases were bundled together. For instance, practices of preparing food or tidying up after a meal were connected to practices of looking after the children. In general, the kitchen was perceived as a social space where a large part of a household's conversations take place, also with guests. The kitchen was also mentioned as a place for working. The practice of cooking was performed differently in different households depending on life situation, interest, and cooking skills. Managing and storing waste from grocery packaging was sometimes performed in the kitchen and sometimes in other rooms, such as the laundry room. In some cases, the household performed other renovations in the home, which affected the kitchen to varying degrees. All these practices had some influence on the practice of renovating the kitchen, in terms of motivating the kitchen renovation, planning the space, when the renovation was performed, and so on.

Table 5.1. Overview of renovations carried out in the kitchens of the participating households in Study A.

Case	Replaced appliances	Replaced cabinets	Replaced cabinet fronts	Replaced countertop	Replaced flooring	Painted/wallpapered/tiled walls	Added/replaced ceiling	Expanded the kitchen [1]	Removed cabinet	Moved cabinet	Removed wall [2]	Added wall [2]	Other changes
I-1	X	X	X	X	X	X		X	X	X			
I-2	X			X	X	X			X				X
I-3	X	X	X	X	X	X	X	X			X		
I-4	X	X	X	X	X	X		X	X				
I-5	X		X			X			X				X
I-6													
I-7	X	X	X	X	X	X		X	X	X	X		X
I-8	X	X	X	X	X	X		X	X	X			
I-9	X	X	X	X	X	X	X	X	X	X	X	X	
I-10	X	X	X	X	X	X	X	X	X	X	X		
I-11													X
I-12	X												
I-13	X	X	X	X	X	X	X	X	X				
I-14	X	X	X	X	X	X	X	X	X	X	X		
I-15													
I-16													
I-17													
I-18													
I-19	X		X	X	X	X							
I-20	X	X	X	X		X		X					

[1] added cabinet(s) or kitchen island, [2] between the kitchen and another room.

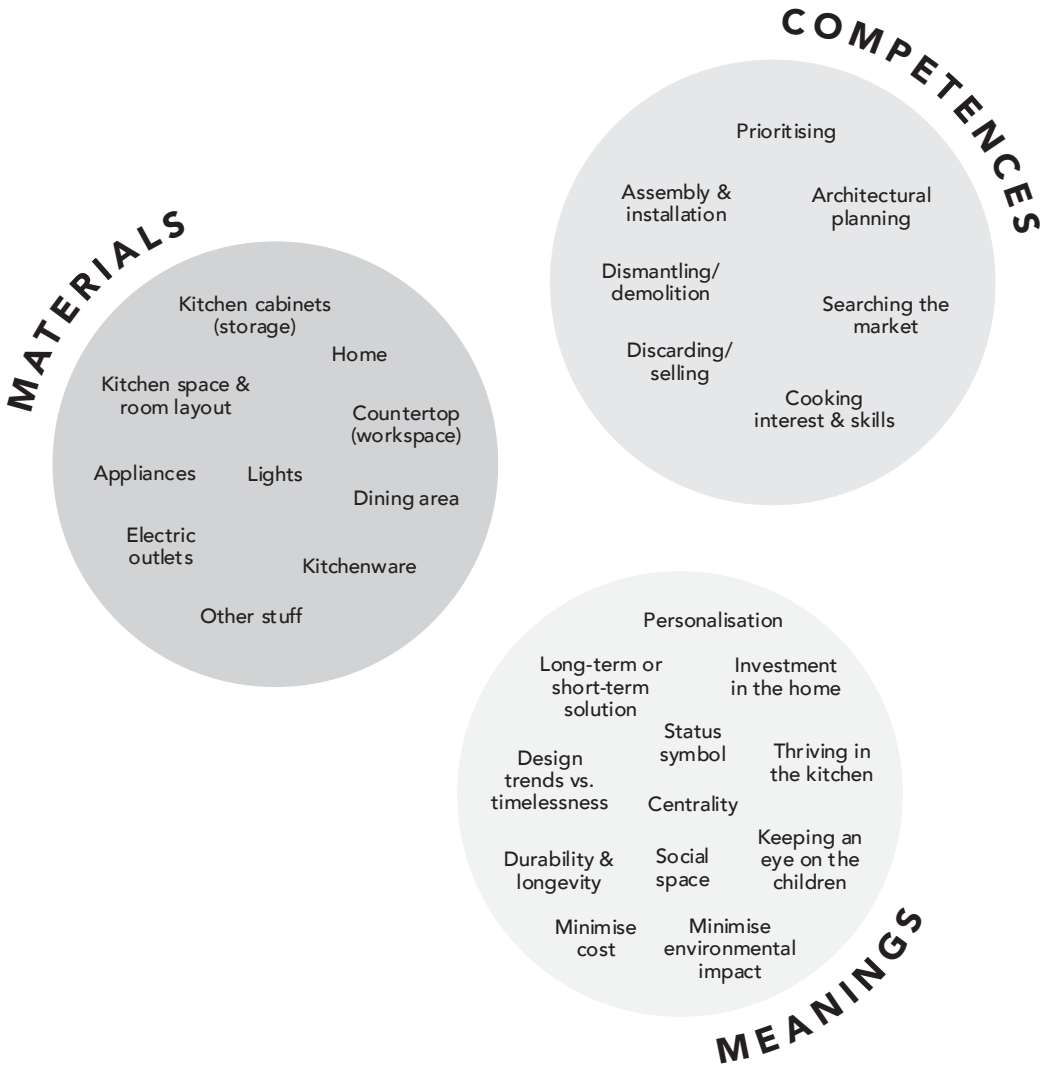


Figure 5.1. Identified practice elements in kitchen renovations from all interviews.

Two different examples of kitchen renovations as practice-as-performances are shown in Figures 5.2 and 5.3. Figure 5.2 shows a case (I-2 in Tables 4.2 and 5.1) where the kitchen was perceived to be in relatively good condition but with an appearance that the household disliked. The household found the kitchen layout to be functional in relation to their needs, and since they expected to live in the same house only a few years more, they wanted to keep down the costs for the renovation. They were also motivated to preserve parts of the kitchen and make a more sustainability-oriented renovation. Instead of replacing the whole kitchen, they therefore searched for other alternatives for renewing the kitchen. In the end, they decided to repaint the kitchen and only replace some of the appliances, the countertop, flooring, and some other components. To make better use of the storage space available, they also got rid of some kitchenware and small appliances.

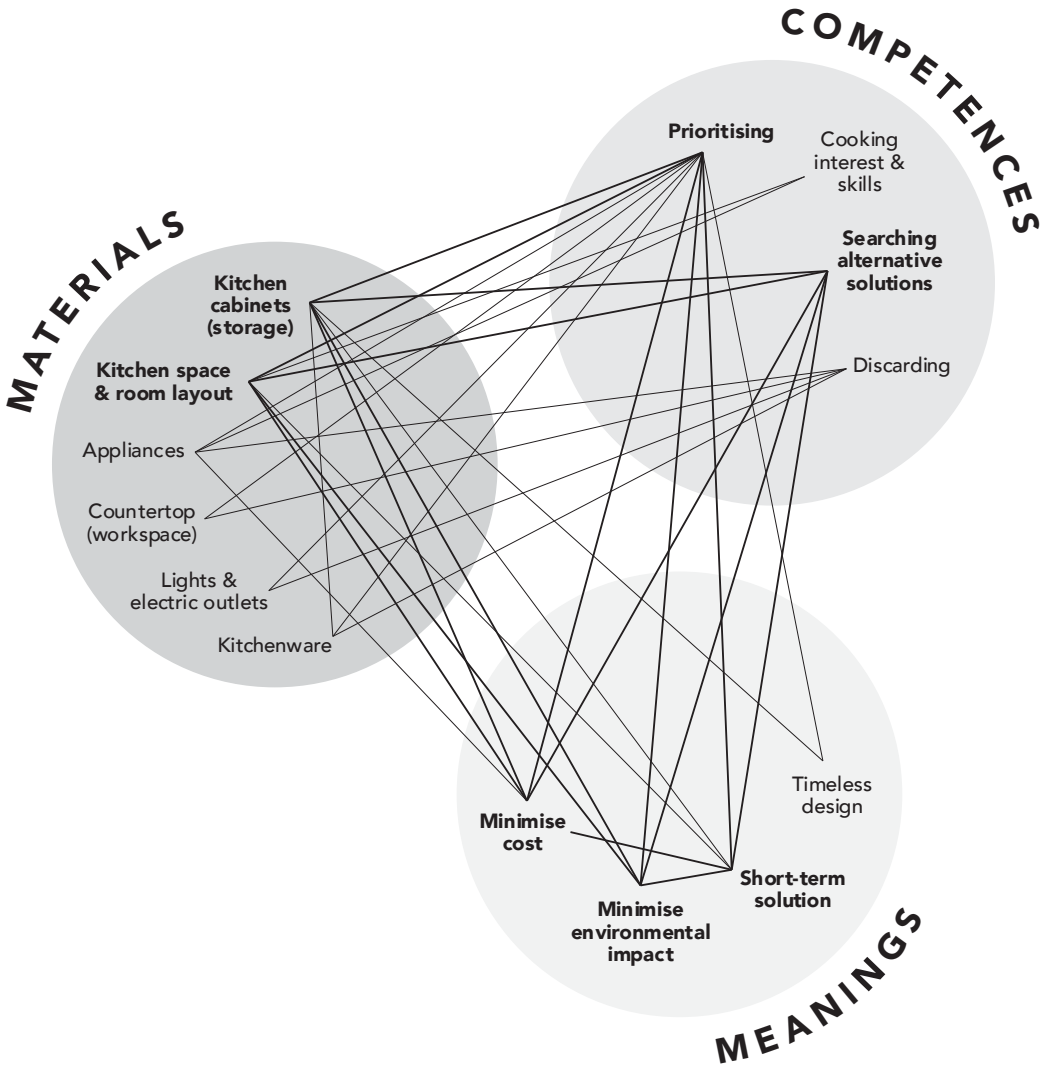


Figure 5.2. Identified elements in the kitchen renovation of case I-2, where only parts of the kitchen were replaced or updated. The meanings of minimising costs and environmental impact both had a strong influence on the extent of the renovation. The competence of searching for alternative solutions was strongly connected to the aforementioned meanings, as well as the material aspects of the room layout and the functionality and condition of the current kitchen cabinets. Bold text in the figure indicates strong elements and thick lines indicate strong links between elements.

Figure 5.3 shows an example of another case (I-3 in Tables 4.2 and 5.1) where the household decided to do a more extensive renovation. The couple initially had split opinions about the original kitchen, which was a closed, U-shaped kitchen. However, when they had children, they both agreed that a more open layout of the kitchen would allow a better overview and make it possible to keep an eye on the children when doing things in the kitchen. They also disliked the style and appearance of the original kitchen. They planned the kitchen renovation to follow another home renovation, in which they replaced the floor joists of the whole bottom floor of their terraced house. Being an architect in the profession, one of the household members made the drawings for the new kitchen himself. In the new

kitchen, they prioritised storage spaces and workspaces that would better fit their needs. One example is that instead of installing one large fridge and one large freezer, they chose two combined fridge-freezer columns so that they could set one of the fridges at a higher temperature. This was to create an optimal storage space for fruits and vegetables and consequently avoid food waste. They also aimed for a timeless design and durable materials that would contribute to the longevity of the kitchen. The renovation was seen as an investment in the home and choosing a design that would make the home "saleable" was therefore prioritised. The old kitchen was dismantled by the household itself and sold on a secondary market.

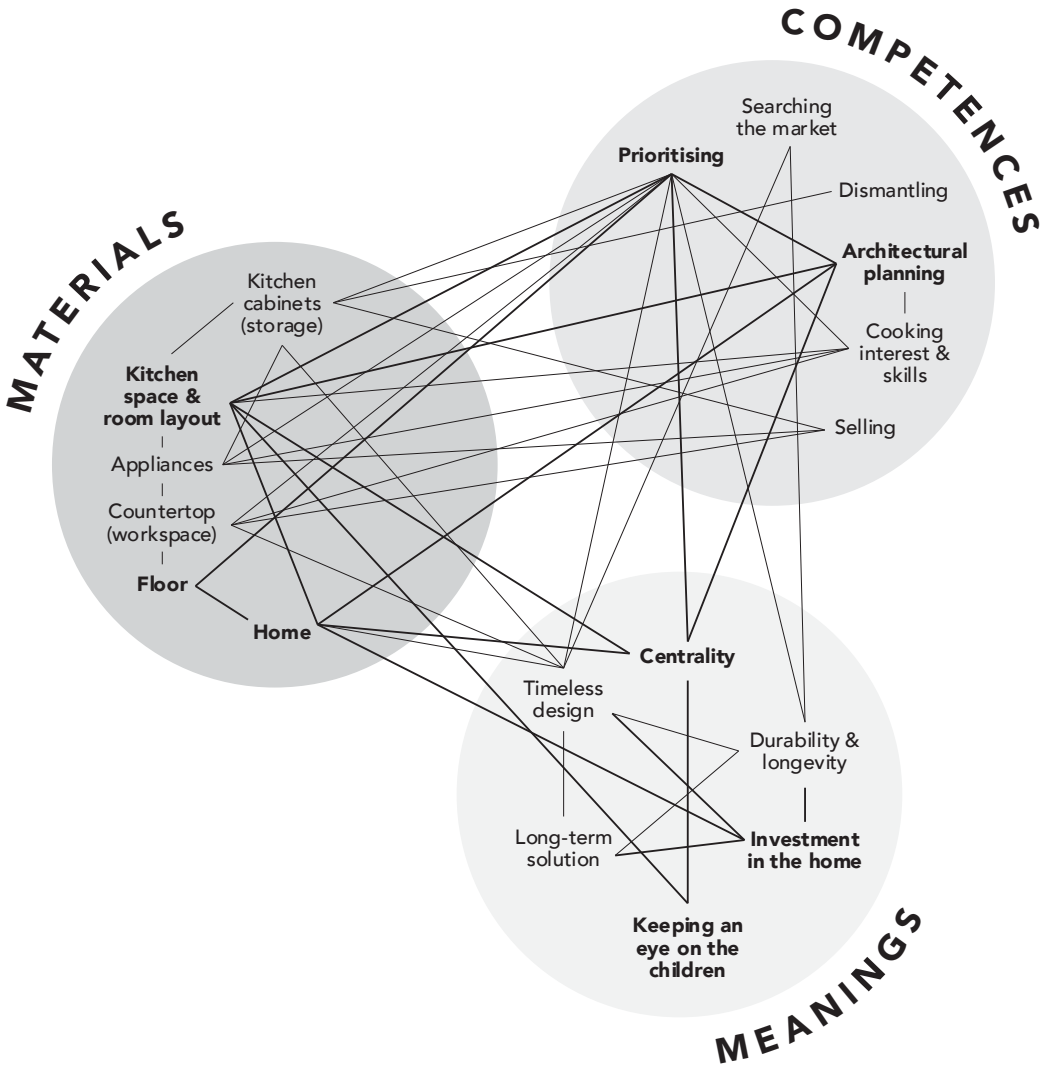


Figure 5.3. Identified elements in an extensive kitchen renovation, case I-3, which completely changed the room layout and replaced the whole kitchen. The meaning of having the kitchen as a central space in the home from which you could keep an eye on the children was a strong motivation behind the renovation and strongly linked to the material aspect of room layout as well as the competence of architectural planning. The kitchen renovation was seen as an investment in the home and had a strong connection to another renovation: replacing the floor. Bold text in the figure indicates strong elements and thick lines indicate strong links between elements.

The two above examples give some insight into how the practice of renovating the kitchen can look very different depending on the configuration of elements present in the specific situation. Further information about other renovations performed by the interviewed households is given in Paper A (Hagejärd et al., 2020).

To summarise, the identified motivations behind kitchen renovations could be grouped into: (1) functional demands and changing needs, (2) aesthetic demands and changing trends, (3) obsolescence due to wear, and (4) linkage to another home renovation. When the motivation for the kitchen renovation is aesthetic demands and changing trends, it seems that there is potential to perform a less extensive renovation. In cases where one or several of the other motivations were present, the households either performed or planned for completely renewing the kitchen.

5.3 Design opportunities for improving the circularity of kitchens

The participants discussed a variety of opportunities for increasing the circularity of kitchens. These can be summarised as: (1) improved technical and functional quality, (2) timeless design, (3) acknowledging emotional values, (4) allowing aesthetical upgrades, (5) allowing functional upgrades and repair, (6) systemic changes and new business models, and (7) increased awareness of environmental impacts connected to kitchen renewal. The first three categories were often described as being dependent on each other, as highlighted in the following two quotes:

> *It's important to do something so good and so timeless that you understand that this is a treasure, it's an inheritance (…) But that requires a completely different authenticity in materials and an ability to withstand both wear from the eye and the hand (I-11)*

> *In my experience, doing something that has some kind of emotional value is often overlooked. If we do something and we strive for it to be beautiful, functional, made of good materials and so on, then I think there's a desire to care for it differently (…) So I think we should try to get people to appreciate how things can age and how they can do so beautifully (I-4)*

Categories 4 and 5 were discussed as strategies to ensure that needs and preferences are met over time. Allowing aesthetic upgrades of the kitchen was described as one way to enable personalisation of the kitchen without doing a complete renovation. Some participants liked the idea of having durable, high-quality cabinet frames that last many years with fronts that can easily be replaced or repainted: *"If you have the frames in good quality, then it's relatively easy to do a face-lift on a kitchen"* (I-13). However, it was also mentioned that allowing aesthetic upgrades is not solely a matter of advantages; it might risk making kitchen interiors even more trend-sensitive than they already are.

When new needs arise in the kitchen (for instance when the family grows or the residence changes owner), a functional upgrade may be preferred. Functional upgrades set the bar for modular design even higher, as it may be necessary to move

cabinets or change cabinet interiors. To better support both functional and aesthetic upgrades, some participants thought that there should be an even higher level of standardisation and collaboration between different kitchen producers.

Some participants also discussed the need for changes on a systemic level, for instance through a more secure secondary market for kitchen furniture and appliances. Finally, several participants also discussed the need for a change of mindset and increased awareness of the environmental impact connected to kitchen renovations. One interviewee reflected: *"You develop something that should be replaced quickly, and people think it's trendy to replace it and keep up with the latest kitchen trends, so I think it's a big societal issue that needs to be discussed"* (I-8).

5.4 Perspectives on circular value propositions for kitchens

Paper B (Hagejärd et al., forthcoming) presents different aspects identified in the workshop discussions regarding scenarios about circular value propositions for kitchen furniture and appliances. Because the scenarios did not describe practices, there were limited possibilities to analyse the findings from a social practice theory perspective. Still, applying a practice lens when revisiting the findings contributed to the identification of meanings and sometimes competences associated with the scenarios. The connection to the material context of the dwelling was also discussed.

5.4.1 Evaluation of scenarios for kitchen furniture

Table 5.2 shows an overview of the workshop scenarios focusing on kitchen furniture. The following sections discuss one scenario at a time, followed by an evaluation of the scenarios in relation to the motivations for and barriers to circular consumption found in previous literature.

Table 5.2. Workshop scenarios 1 – 3 for kitchen furniture

	S1 Pre-used kitchen	S2 New kitchen	S3 Kitchen leasing
Product	Modular kitchen furniture in durable materials with a long technical lifetime	Modular kitchen furniture in durable materials with a long technical lifetime	Modular kitchen furniture in durable materials with a long technical lifetime
Payment	Buy from kitchen manufacturer	Buy from kitchen manufacturer	Lease monthly from kitchen manufacturer
Condition	Used, in good condition	New	Either new or used, in good condition
Service	Installation included + 5-year warranty	Installation included + 20-year warranty	Installation, repairs, and replacement of broken products included
After use	The manufacturer can buy the kitchen back for a minor amount, depending on condition	The manufacturer can buy the kitchen back for a minor amount, depending on condition	Upon cancellation of the subscription, the kitchen is returned to the manufacturer
Upgrades			For an extra fee, the kitchen design and functionality can be upgraded

Scenario 1: Pre-used kitchen

Overall, this scenario gave rise to split opinions. Some of the participants expressed a strong reluctance towards buying a pre-used kitchen, rooted in meanings about it being unhygienic, a source of pests, or in worse condition than expected. On the other hand, participants who favoured this scenario imagined meanings such as being environmentally conscious, economic, and being able to afford a high-quality kitchen with a confirmation that it has aged well during previous use. They also discussed the convenience of this scenario compared to buying a used kitchen on the conventional secondary market, due to the services and sell-back option included.

However, the expected work and competences involved when buying a pre-used kitchen also contributed to the reluctance towards this scenario. Apart from needing to sell or discard the current kitchen, some participants also expected more work connected to finding a used kitchen that would fit the existing kitchen space and room layout, as well as evaluating its condition, compared to buying a new one.

The type of dwelling also seemed to be an important factor in the evaluation of the scenario, for instance, the extent to which you are allowed to make changes at home and how large an investment you would be willing to make. Other factors that were discussed were the life situation and financial conditions of the household.

Scenario 2: New kitchen

Among the three scenarios for kitchen furniture, this was the most preferred option. This was explained by meanings such as the "feeling of new", investing in a high-quality kitchen with a sustainability profile, convenience, and the expectancy of higher flexibility and adaptability compared to buying a pre-used kitchen. However, it was also discussed that few customers would be willing to pay the higher price for this kitchen, compared to a conventional kitchen in chipboard and MDF, when they could get another more luxurious kitchen for the money.

Overall, the participants expected less work connected to buying a new kitchen than a used one, but the type of dwelling and the time expected to live in the same dwelling were discussed as important factors in determining if you would be willing to make the investment. Again, life situation and financial conditions were discussed as important factors as well.

Scenario 3: Kitchen leasing

This was the least preferred option among the three kitchen furniture scenarios. The reluctance towards this scenario was rooted in several meanings. First, since there is currently no corresponding business model on the market for kitchen furniture in Sweden, the participants were unfamiliar with this concept and perceived it as strange. Second, although not demanding the consumer to make a large investment initially, the model of leasing the kitchen was expected to become expensive in the long run and eventually turn into a debt trap for those who are financially vulnerable. It was therefore seen as a temporary solution for specific life situations. Third, not owning the kitchen was expected to contribute to a lower sense of responsibility and care for the kitchen. Fourth, the high degree of flexibility and adaptability connected to this scenario was discussed to possibly trigger even more frequent kitchen renewals and thereby a higher environmental impact in the end. The positive meanings connected to this scenario were convenience, ensured quality and functionality of the kitchen during the subscription period, and the opportunity for more people to have access to a good kitchen.

Some participants expected more work connected to leasing a kitchen than buying a new one. Life situation and financial conditions were considered particularly important in this scenario.

Motivations and barriers connected to the kitchen furniture scenarios

In Paper B (Hagejärd et al., forthcoming), a review of previous literature studying motivations and barriers for participating in circular consumption is summarised. Tables 5.3 and 5.4 list the motivations and barriers identified from the review in relation to the three scenarios for kitchen furniture. These categories are not based on social practice theory. A grading from low to high indicates how strongly the motivations and barriers seemed to be associated with the scenarios. This is a

subjective grading performed by the authors of the paper and based on the workshop group discussions.

Table 5.3. Motivations for circular consumption identified in previous literature and graded for each scenario by the authors based on workshop group discussions. Uniqueness was not mentioned as a motivation in the workshops and is left blank.

Motivations	S1 Pre-used kitchen	S2 New kitchen	S3 Kitchen leasing
Economic reasons	High	Low	Medium
Environmental reasons	High	Medium	Medium
Quality	Medium	High	High
Uniqueness			
Product features	Medium	Medium	Medium
Flexibility	Medium	High	High
Convenience	Medium	High	High
Emotional values	Low	Medium	Medium

Table 5.4. Barriers to circular consumption identified in previous literature and graded for each scenario by the authors based on workshop group discussions. Some barriers were not discussed or relevant and are left blank.

Barriers	S1 Pre-used kitchen	S2 New kitchen	S3 Kitchen leasing
Contamination	High	Low	Low
Uncertainty	Medium	Medium	High
Financial concern	Medium	High	High
Desire for new products	High		
Quality and performance	High	Low	Low
Lack of availability	Medium	Low	Low
Desire to own			High
Consumption work	Medium	Low	Medium
Not meeting needs and expectations	Medium	Medium	Medium
Environmental concern	Low	Low	Medium
Practical feasibility	Medium	Low	High

5.4.2 Evaluation of scenarios for kitchen appliances

Table 5.5 shows an overview of the workshop scenarios focusing on kitchen appliances. The following sections present findings from the workshop group discussions around these scenarios, followed by an evaluation of the scenarios in relation to motivations and barriers for circular consumption.

Table 5.5. Workshop scenarios 4 – 6 for kitchen appliances

	S4 Pre-used appliance	S5 Appliance leasing	S6 Pay-per-use
Product	Kitchen appliances (with focus on the dishwasher)	Kitchen appliances (with focus on the dishwasher)	Kitchen appliances (with focus on the dishwasher)
Payment	Buy from appliance manufacturer	Lease monthly from appliance manufacturer	Pay-per-use
Condition	Used, in good condition and fully functioning	Either new or used, in good condition and fully functioning	Either new or used, in good condition and fully functioning
Service	Installation included + 3-year warranty	Installation, repairs, and replacement of broken products included	Installation, repairs, and replacement of broken products included
After use	The manufacturer can buy the appliance back for a minor amount, depending on condition	Upon cancellation of the subscription, the appliance is returned to the manufacturer	Upon cancellation of the subscription, the appliance is returned to the manufacturer
Upgrades		For an extra fee, the appliance can be replaced with another model	For an extra fee, the appliance can be replaced with another model

Scenario 4: Pre-used appliance

Similar to the discussions around *S1 Pre-used kitchen*, some participants expressed reluctance towards buying a used appliance. This seemed to be rooted in meanings such as expecting appliances in general to have a short lifespan and thereby having to deal with problems early on. Furthermore, it was discussed that you do not stay up to date with technical developments if you buy a used appliance. On the other hand, it was mentioned that you might be able to afford a more advanced appliance if you buy it second-hand. Again, it was considered more convenient and safer to buy a used appliance with a warranty and sell-back option included than buying one on the ordinary secondary market. Overall, *S4 Pre-used appliance* was considered an economical and environmentally conscious choice.

Scenario 5: Appliance leasing

Among the scenarios for kitchen appliances, this was the least preferred scenario. Similar to *S3 Kitchen leasing*, this scenario was perceived as expensive in the long run and therefore a temporary solution in specific cases. However, it seemed that the concept of leasing an appliance was slightly more accepted than leasing a kitchen. Among the positive meanings connected to the scenario was the opportunity to gain access to advanced appliances and stay up to date with the latest technology, without having to make a large investment initially. It was also considered convenient to

always have functioning appliances and have the possibility to change or upgrade an appliance. Still, some expected leasing appliances to bring more work than buying new ones.

Scenario 6: Pay-per-use

This scenario was discussed to increase awareness and contribute to more sustainable use of appliances but was at the same time considered to bring economic stress. Furthermore, some participants felt reluctant to have their use of appliances monitored by a company and expected that using the appliance might become a source of conflict between household members.

This scenario introduced new competences specific to this scenario, such as keeping track of costs and planning use, linked to meanings of frugality and economic stress. The type of dwelling was considered strongly influential on the relevance of the scenario and strongly linked to the meaning of being a temporary solution.

Motivations and barriers connected to the kitchen appliance scenarios

Tables 5.6 and 5.7 list the motivations and barriers identified in previous research in relation to the three kitchen appliance scenarios. The grading was performed by the authors of Paper B and is a subjective grading based on the workshop group discussions.

Table 5.6. *Motivations for circular consumption identified in previous literature and graded for each scenario by the authors based on workshop group discussions. Uniqueness was not mentioned as a motivation in the workshops and is left blank.*

Motivations	S4 Pre-used appliance	S5 Appliance leasing	S6 Pay-per-use
Economic reasons	High	Medium	Medium
Environmental reasons	High	Low	High
Quality	Low	Medium	Medium
Uniqueness			
Product features	Medium	Medium	Medium
Flexibility	Medium	High	High
Convenience	Medium	High	Medium
Emotional values	Low	Medium	Low

Table 5.7. Barriers to circular consumption identified in previous literature and graded for each scenario by the authors based on workshop group discussions. Some barriers were not discussed or relevant and are left blank.

Barriers	S4 Pre-used appliance	S5 Appliance leasing	S6 Pay-per-use
Contamination	High	Low	Low
Uncertainty	Medium	High	High
Financial concern	Medium	High	High
Desire for new products	High		
Quality and performance	High	Low	Low
Lack of availability	Low	Low	Low
Desire to own		High	High
Consumption work	Medium	Medium	High
Not meeting needs and expectations	Medium	Medium	High
Environmental concern	Low	Medium	Medium
Practical feasibility	Medium	High	High

5.5 Discussion

This chapter has elaborated on the circularity of domestic kitchens, focusing on kitchen renewal practices, circular design opportunities, and the potential for applying circular business models to kitchen furniture and appliances from a user perspective. This section will discuss the findings in relation to different types of housing and user groups.

From the findings of both Studies A and B, it becomes clear that circular kitchen designs and business models need to be developed with a diversity of user needs, aspirations, and life situations in mind. Thus, there are several pathways towards the future circularity of kitchens. These pathways involve different design approaches in terms of durability and longevity on one hand and flexibility and modularity on the other. These different approaches will require different business models to support the circularity in the best way for each design. Furthermore, each approach comes with different limitations and risks, which need to be addressed to avoid rebound effects and unnecessary high environmental impact. Figure 5.4 illustrates different circular design approaches for the kitchen and highlights risks to be considered for each case. Of course, there are many other design strategies that will influence the final circularity and sustainability as well, such as the use of timeless design, avoiding the use of hazardous chemicals, etc. There are also middle grounds between the different approaches, not visible in this illustration. This should, therefore, be seen as a simplified categorisation to aid the discussion about different pathways. Also, note that the "conventional kitchen" does not represent a circular approach but is included as a baseline example. The relevance of these approaches for different user

groups and housing types, combined with different kinds of circular business models, will be discussed in the following.

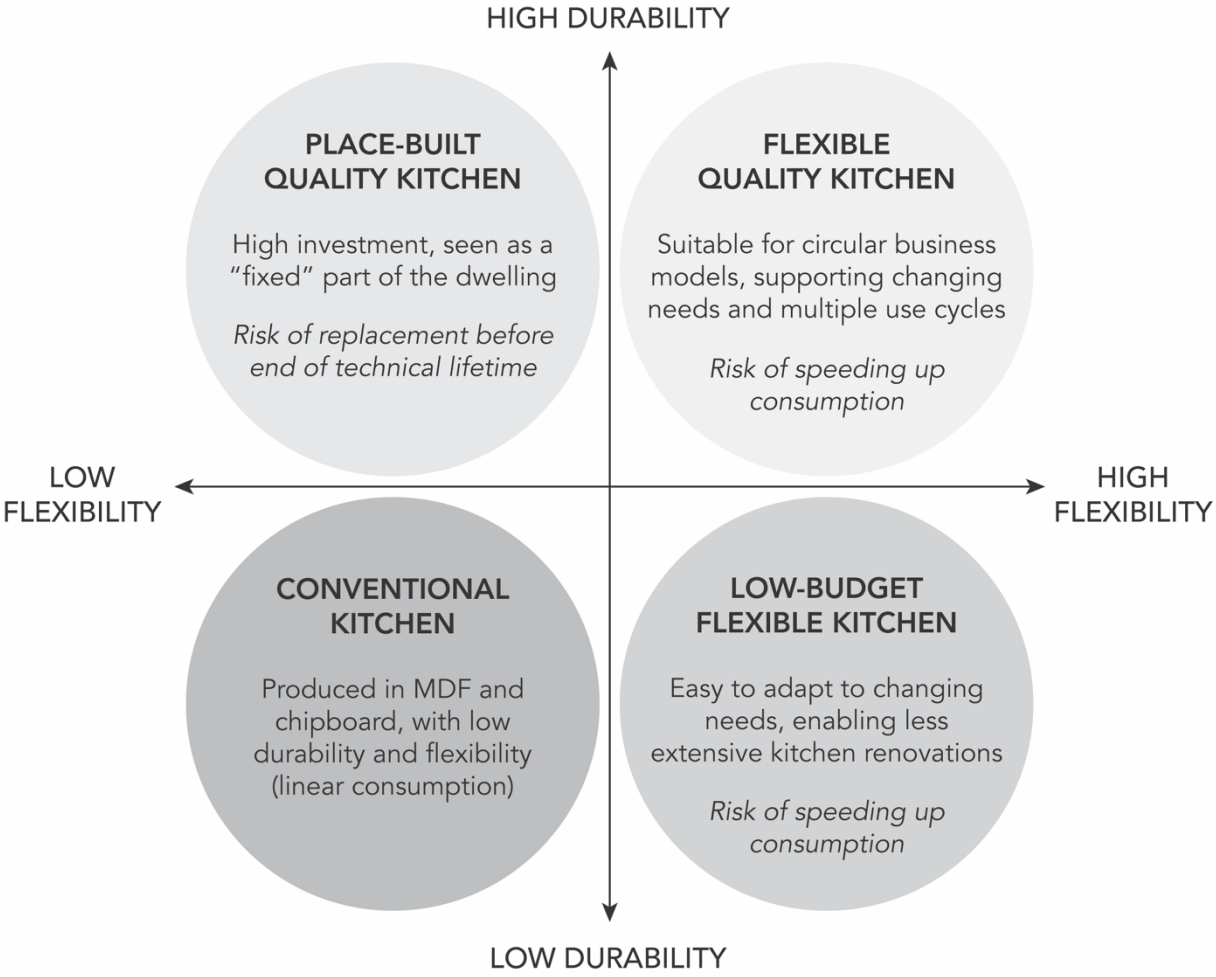


Figure 5.4. Different approaches towards circular kitchen design.

A *conventional kitchen*, produced in MDF and chipboard, mainly follows a linear consumption model due to limitations in both durability and flexibility. This restricts the possibilities for a long lifetime and multiple use cycles of the kitchen. It also complicates recycling at the end of life. This baseline approach is placed in the lower left quadrant of Figure 5.4.

A *place-built quality kitchen*, placed in the higher left quadrant of Figure 5.4, is expected to have a long lifetime due to its use of materials with high durability. The use of such materials combined with a lack of mass production will contribute to making this an expensive option. The kitchen furniture also becomes a more fixed part of the dwelling. The fact that it is place-built provides freedom to adapt the kitchen furniture to the specific kitchen space but limits the possibilities to adapt the kitchen over time. This makes it a relevant option for homeowners who want to invest in a kitchen they expect to keep for a long time. However, as discussed in the workshops of Study B, trying to future-proof the kitchen is challenging given the technological development of appliances and changes on a societal level regarding

lifestyles and, consequently, how we use kitchens. The household that chooses to install the kitchen might also experience life changes resulting in, for instance, changed needs or a move from the dwelling sooner than expected. Then, the new household may have completely different needs or preferences connected to the kitchen. Consequently, the risk is that the kitchen will be replaced before the end of its functional lifespan, despite good intentions of keeping it for as long as possible.

This approach towards circular design shows a low relevance for access-based consumption models due to its limited flexibility. It should rather be combined with product-oriented services (Tukker, 2004) such as repair. Flexibility can be somewhat improved by allowing smaller upgrades such as replacing handles, repainting, or exchanging fronts. Take-back management can then be relevant on a component level rather than for the whole kitchen.

Overall, the place-built quality kitchen may have higher relevance for households living in a house than in an owner-occupied apartment, as kitchens are often renovated on a more frequent basis in owner-occupied apartments (Femenías et al., 2018). Still, households living in owner-occupied apartments can be considered part of the target group. The economic aspect of this approach makes it an exclusive option for a limited group of people. However, the place-built quality kitchen may also be a relevant option for rental apartments, given its long technical lifetime and a reduced need for landlords to renovate the kitchen over time. Thus, targeting rental apartments could contribute to achieving a wider diffusion of this circular kitchen approach, but other approaches are needed as well.

A different approach is presented in the very opposite quadrant of Figure 5.4, to the lower right. The *low-budget flexible kitchen* addresses the problems connected to conventional kitchens going through extensive renovations before the end of their functional life due to limited possibilities and incentives to replace only parts of the kitchen. The focus of this approach is on improving the flexibility of the kitchen without increasing the price to a level that excludes a considerable part of the potential target group. However, flexibility, to some extent, also requires a certain level of quality and durability to allow for replacements and upgrades without damaging the furniture. Therefore, this approach might, in some ways, be a hypothetical scenario that is difficult to implement in practice. Still, in the last years, there have been some incremental innovations of improved flexibility developed by kitchen producers for conventional MDF and chipboard kitchens, which suggests that this approach holds some potential for improved circularity. However, as discussed in the workshops of Study B, improved flexibility and adaptability bring both opportunities and risks. Although offering the potential to extend the lifetime of the kitchen, increased flexibility may also speed up consumption rates by triggering more frequent upgrades.

Again, the target group for this approach would primarily be homeowners, either living in houses or owner-occupied apartments. It also has some relevance for rental apartments. By installing kitchens of higher flexibility, landlords could provide greater possibilities for tenants to adapt the kitchen to different needs and preferences through less extensive renovations. However, to withstand multiple use

cycles over many years, the kitchen furniture should preferably have higher durability as well.

The final approach, *flexible quality kitchen*, is found in the upper right quadrant of Figure 5.4. It combines high durability with high flexibility and thereby provides the highest potential for achieving circularity, at least in theory. The prototype kitchens developed in the CIK project have aimed to combine both durability and flexibility in their design. This has the potential to support changing needs over time while also enabling a long lifetime and multiple use cycles of the kitchen. Compared to place-built kitchens, this approach shows a higher potential for mass production. Still, due to the use of high-quality materials, the price will be higher than for a conventional kitchen in MDF and chipboard. To make this option relevant for a wider group in society, it may, therefore, be combined with access-based consumption models such as leasing. This reduces the need to make a large investment from the start. For landlords, it is of economic relevance to use kitchens with a long technical lifetime to reduce renovation costs over time, and offering flexibility in the kitchen design may be attractive to tenants. Through this approach, the role of landlords could become more central in offering circular alternatives to tenants. Leasing contracts for kitchen furniture and appliances could be included as part of the apartment rent, offering different price levels from a basic kitchen to a more advanced or larger kitchen (to the extent possible for the available kitchen space in the apartment).

In owner-occupied apartments, the flexible quality kitchen has the potential to enable less extensive renovations while supporting the current practice of frequently renewing the kitchen. It can, of course, be discussed if the practice of frequently updating the kitchen should be supported at all. However, because a change of mindsets on a societal level regarding keeping our kitchens for longer is difficult to achieve, this approach could at least lower the environmental impact connected to the renovations. Thus, the practice of renovating the kitchen could change in terms of the material elements included. Still, my standpoint is that meanings and competences connected to the practice of renovating the kitchen should change over time as well, in terms of social norms and knowledge about how kitchen renovations impact our environment. How to achieve that is a topic for future research.

Implementing an access-based consumption model in owner-occupied apartments or houses is complicated due to the current Swedish building regulations requiring a kitchen to be installed in the dwelling. If a leasing contract for the kitchen would be implemented, it would therefore need to be passed on to the next household if the dwelling would be sold. Another topic for future research could be to evaluate current building regulations in terms of how well they support circularity, among other aspects, and if a change is motivated.

The flexible quality kitchen approach could also be combined with a business model including take-back management. However, as discussed in the workshops of Study B, a major part of the households who decide to renovate the kitchen are those who have bought a dwelling where the previous owner has chosen the kitchen, while a household who chooses the kitchen themselves are more likely to keep their kitchen for longer. Thus, the possibility to sell back kitchen furniture to the

manufacturer may be more relevant for the buyer of a dwelling than the buyer of a kitchen. Overall, how to improve the relevance of circular business models in the context of the kitchen is an area that needs further research.

6

TOWARDS SUSTAINABLE ENERGY USE AT HOME

This chapter summarises findings from Study C (Hagejärd et al., 2021) and Study D (Hagejärd et al., 2023), both focusing on opportunities for supporting households' energy demand flexibility for a more sustainable energy system. Section 6.1 focuses on flexibility in heating demand and summarises findings from Study C. Section 6.2 is focused on flexibility in electricity demand and summarises findings from Study D. Section 6.3 then discusses the findings from both studies in relation to previous research.

6.1 Flexibility in heating demand

The practice of managing the indoor climate at home involves different meanings, competences, and materials depending on the carrier of the practice. From the perspective of the energy provider, the overall aim is to optimise energy use according to the energy system while maintaining an acceptable indoor climate for residents. From the landlords' perspective, the overall aim is to optimise energy costs while maintaining an acceptable indoor climate for residents. Here, I will focus on the perspective of residents in the context where demand-side management is applied to space heating in rental apartments.

In this case, when carried by the resident, the practice of managing indoor climate at home involves many different materials that can be utilised in connection to the competences of adjusting space heating, ventilation, or body heating and cooling. These materials and competences are further connected to meanings such as having a pleasant or unpleasant indoor climate, feeling too cold or too warm, feeling in control, saving energy, and being prepared for and aware of upcoming load shifts. These may also include saving money, but in this case, heating was included in the rent. The material elements are a mix of infrastructures and technologies connected to the building, such as radiators, floor heating, ventilation systems, and windows, as well as the apartment in terms of its position within the building and its different rooms. The material elements also involve the bodies of the household members, guests, and any pets present in the apartment. One participant reported:

"Since I'm frozen, I wear double socks. The outermost pair are thermal socks. I also have a large dog who generates heat next to me which, I think, makes me feel warm enough at the moment" (woman, group C)

Finally, this category contains different products within the home that can be used as a means to improve the perception of the indoor climate. For instance, using additional or less clothing, taking a hot or cold shower, eating or drinking something warm or cold, or using the phone to contact the landlord about the indoor climate. These elements are illustrated in Figure 6.1, but without any links between them as this would make the figure too complex.

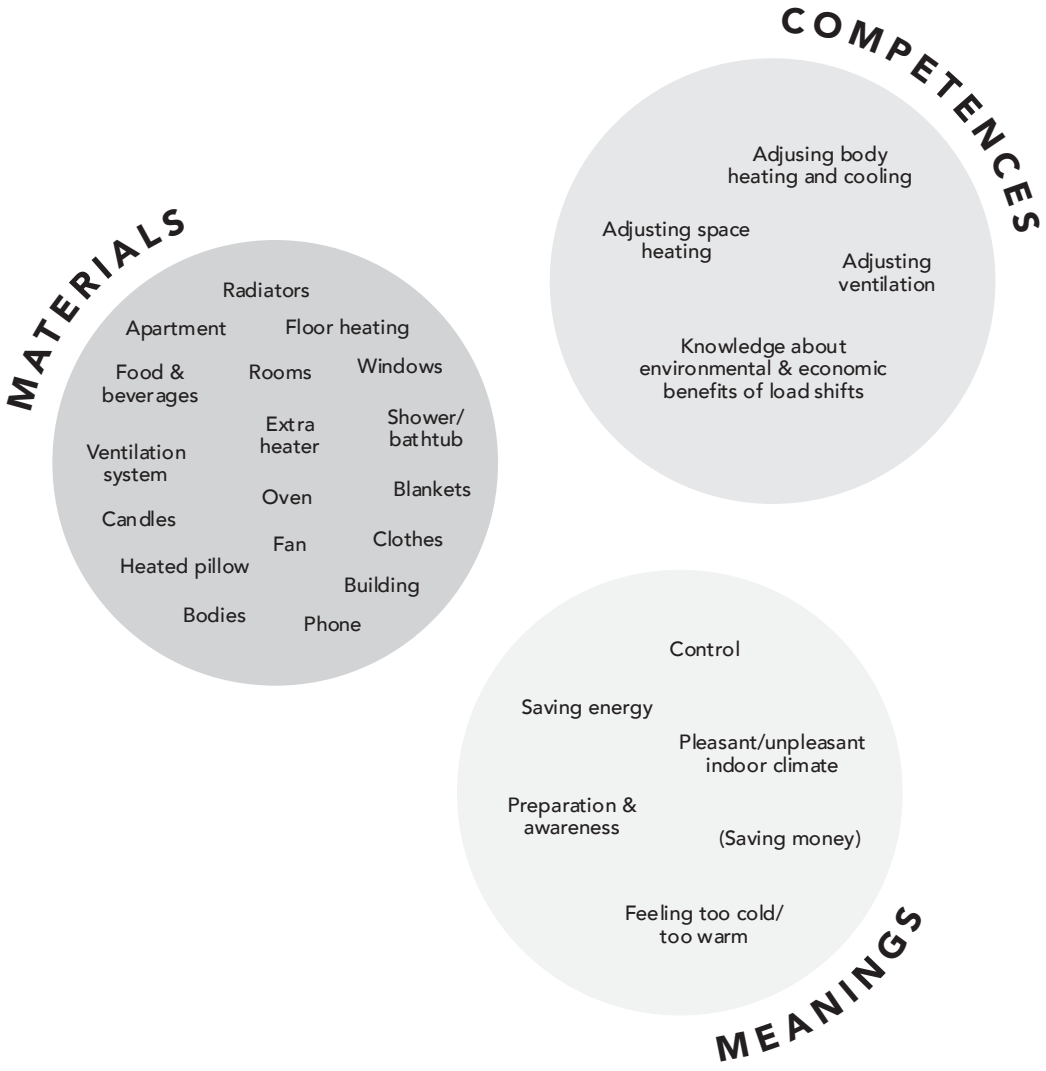


Figure 6.1. Configuration of elements within the practice of managing indoor climate at home when carried by the resident in the context where demand-side management by the energy provider is applied to space heating in rental apartments.

The practice of managing the indoor climate at home is connected to many other practices, which influence how the indoor climate is perceived and consequently the configuration of elements within this practice. Practices carried out at different times

of the day and in different rooms of the apartment shape this practice over time and in space. The practice of sleeping during the night brings certain meanings about what is an appropriate climate in the bedroom and consequently different actions such as opening windows to air out the room, adjusting radiators in the bedroom, or using extra blankets to keep warm. This study indicated varied experiences of and preferences for room temperature during the night.

Following practices of getting up in the morning, having breakfast and getting ready for the day brings new meanings about the climate in different rooms of the apartment. In this study, both surveys indicated that mornings were perceived as significantly colder than other times of the day. Furthermore, the living room was perceived as statistically significantly colder than other rooms in the apartment.

Overall, the study recorded higher dissatisfaction due to experiencing the apartment as too cold rather than too warm. When comparing days with and without load shifts in the two groups where this was applied, no statistically significant difference was detected in thermal perception. However, the final survey indicated a lower willingness to accept larger temperature variations to save energy after the trial than before.

From the findings, it is suggested that the acceptance of demand-side management depends on four main factors: (1) baseline indoor climate conditions, (2) timing and magnitude of the load shifts, (3) individual control, and (4) communication. First, if the residents already perceive the indoor climate as unpleasant, they are not likely to be willing to accept further compromises on their comfort. Therefore, building-related problems that have a negative impact on indoor climate perception should first of all be resolved, for instance, by making sure that the building is properly insulated with sufficient ventilation. One participant explained:

> *I care very much about the environment and save electricity in every way I can, but it doesn't feel worth freezing every day throughout the winter. I think the landlord wants to save money and that has nothing to do with the environment at all. (Woman, group C)*

Second, the timing and magnitude of load shifts are of central importance to support acceptance. Since mornings were generally perceived as slightly colder than other times of the day, this may lower the acceptance for load shifts during mornings. However, mornings are often the target for load shifts due to peaks in hot water demand during this time (Kensby et al., 2015). The challenge, therefore, becomes to plan load shifts in a way that mitigates temperature reductions during mornings, for instance, by increasing heating slightly in the transition between night and morning, then reducing it again to avoid the "morning peak".

Third, a majority of the participants perceived a lack of control over their indoor climate. The perceived control over the indoor climate was positively correlated with the willingness to accept larger temperature variations. This highlights the importance of improving the residents' experienced control to raise acceptance towards load shifting. Of course, providing higher individual control of the indoor climate may counteract the effectiveness of load shifts. Therefore, it is relevant for

future research to explore how the experienced control can be improved while also supporting flexibility in the heating demand.

Fourth, communication plays a central role in shaping meanings such as making residents feel aware of and prepared for upcoming load shifts. It can also contribute to raising competences and knowledge about the environmental and economic benefits related to load shifts. One participant explained:

> *On some nights, I've felt that you've raised or lowered the heat. Then I've added an extra blanket or removed one. It's ok that it's colder during the night, if I know in advance. Of course, it's nice to have it a little warmer during the morning and evening. (Woman, group A)*

6.2 Flexibility in electricity demand

The introduction of the HEMS prototype Ero 2.0 influenced the practice of managing electricity and hot water use at home in different ways. The focus here will be on electricity. Figure 6.2 illustrates the identified elements and links of this practice. Hereafter, Ero 2.0 will simply be referred to as Ero.

Besides the app, Ero also introduced other material elements, such as smart plugs and, in some cases, a borrowed iPhone or iPad. Furthermore, it created new links to other material elements already present, such as appliances and devices, other smart home technologies, and the apartment in terms of its layout and size. In terms of competences, Ero both introduced new ones and contributed to strengthening some competences. This included awareness of electricity use (in total as well as specifically per device), awareness of water use, confirming that a device is turned on or off, knowledge about the energy mix, and the variability of the energy supply. Increased awareness of electricity and water use was reported by a majority of the participants.

The electricity threshold in the app introduced the competence of setting and interpreting the electricity threshold and also the meaning of staying below the threshold. Other meanings identified were to save money, reduce the environmental impact connected to energy use, comfort, and have a tidy and noise-free home.

To some extent, Ero contributed to changes in different energy-reliant practices at home. The most common changes seemed to be to reduce the use of the floor heating and tumble dryer.

> *[…] in the beginning, before I got this app, I had the floor heating on at all times, but then I saw the consumption and thought "that's a lot actually, consumed on the floor heating". That's why it's generally turned off right now (15-M)*

> *I don't do a lot of cooking. The electricity I use is hard to minimise and my washing – I need to do that. So, the only thing I could change was the dryer because I can dry clothes on the balcony and in the bathroom. That was the only hack for me (19-M)*

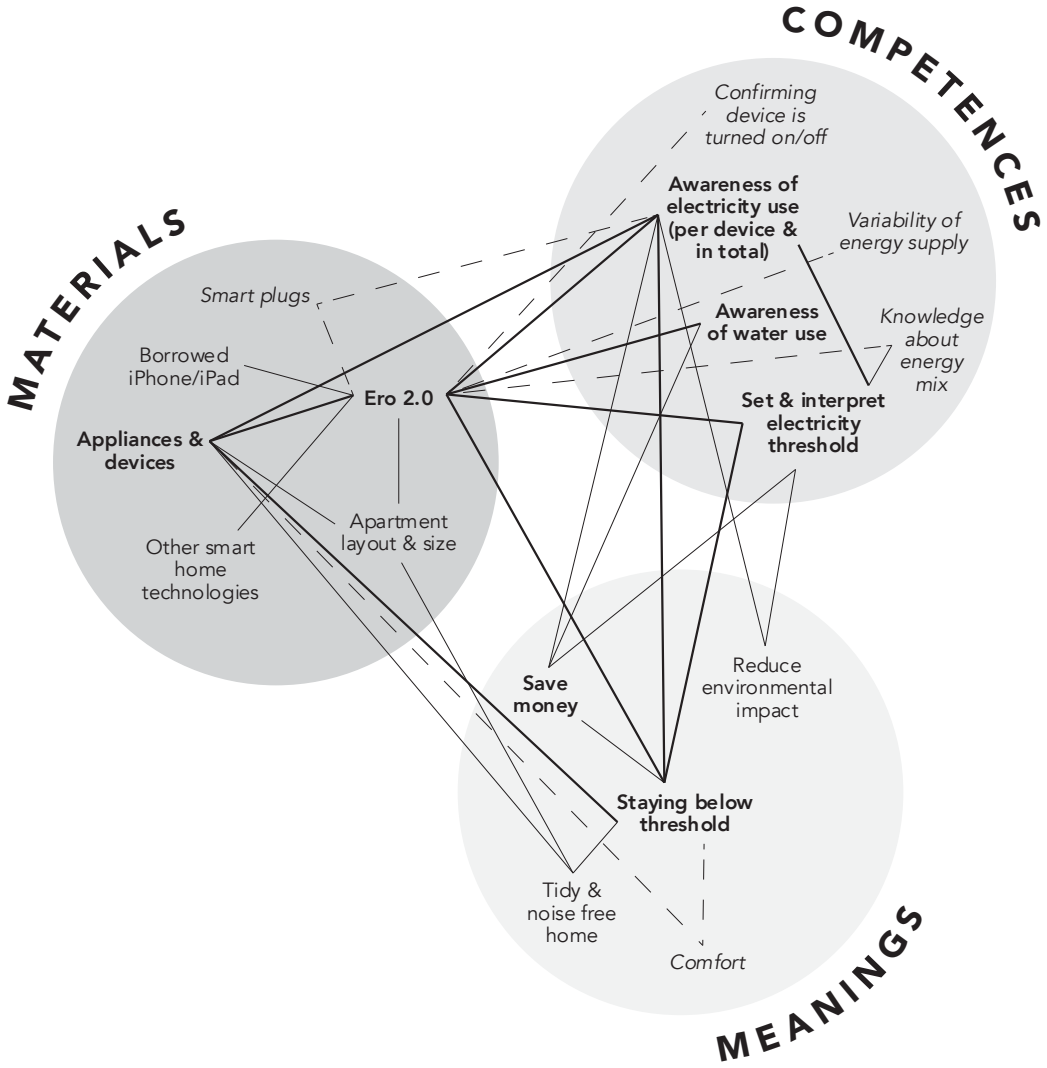


Figure 6.2. Configuration of elements within the practice of managing electricity (and hot water) use at home based on findings in Study D. Bold text indicates central elements and thick lines indicate strong links between elements. Italic text indicates weak elements, and dashed lines are weak links. Mapping inspired by Christensen et al. (2020).

Shifting practices in time to use energy when the availability was higher according to the personal electricity threshold seemed less common. Still, a few participants reported that they had used the threshold to plan when they use different appliances, the most common being the dishwasher and the tumble dryer. Other changes in practices were reported as well, such as only running the dishwasher or washing machine when full or using eco-programs to a greater extent. However, in many cases, Ero did not contribute to any changes in energy-reliant practices.

Several difficulties were identified in connection to changing energy-reliant practices. These could be summarised into five categories: (1) lack of flexibility in everyday life, (2) limitations in size and layout of the dwelling, (3) lack of incentives and perceived impact, (4) lack of guidance, and (5) lack of possibilities to control devices through the interface.

First, life situations were in some cases mentioned to restrict the flexibility to change practices, particularly in the case of having a baby: *"[…] when you have a baby, and you need to do the laundry… yeah then you need to do it"* (15-M). Another factor mentioned was the work situation. Second, some explained being restricted by the compact and open layout in the apartment, causing disturbances from the dishwasher in the rest of the living area, limiting possibilities of running longer washing programs or shifting it in time. Another mentioned the space to limit the possibilities of hanging laundry instead of using the tumble dryer.

> *Personally, for me, it's most difficult to let go of the tumble dryer, partly because I don't have the space to hang [the clothes] and air dry and partly because it's not the weather outside to hang it out. I grew up in a house where I lived with my family and then we always hung clothes outdoors. I don't have the same possibility here, and I find it difficult to break – I haven't come up with any idea how I can do otherwise. (10-F)*

Third, the incentives for changing energy-reliant practices were perceived as low, with a lack of communication on both economic and environmental benefits connected to staying below the personal electricity threshold:

> *What does it mean if you plan up when you do laundry and wash dishes and how much electricity and money can you save in a year? So you can see a little more clearly what impact it has (29-M)*

Fourth, regardless of the participants' knowledge levels regarding smart technologies and the energy system, there seemed to be a general lack of guidance in Ero about how to adapt electricity use to the personal electricity threshold:

> *[…] I think the way it was, it was always telling me that I'm using too much, so you get a little bit frustrated because I… It doesn't help me change that, so it just tells me "Hey you're an idiot" [laughter] and then I, you know can't really, can't really change anything so… (26-M)*

This was related to difficulties in interpreting the personal electricity threshold and a lack of concrete, personalised advice. Not understanding why the electricity threshold was exceeded caused frustration and a lack of engagement in using Ero: *"[…] so the only time I see it is when my threshold is above. Maybe I'm below on times when I'm not opening the app […] I always see it when I'm the bad guy"* (26-M). It also became clear that different participants requested different kinds of guidance.

Finally, control possibilities of devices were limited to the bathroom floor heating, which could be turned on and off through Ero, and consumption data was limited to only a few appliances. Some participants described this as a factor limiting their possibilities to become more flexible in their electricity use and requested more control, both in terms of receiving more data and having the possibility to schedule devices:

> *If I'm going to save electricity on something, maybe it's all these devices that are on standby […] I would like to measure that whole package to see, because I suspect that they draw*

almost as much power in standby as they do when they are on […] So if I were to save power, I would sort of have the option of turning them off when I'm not at home. (31-M)

6.3 Discussion

In both studies it is evident that people have different preconditions to contribute to energy demand flexibility. This involves many different factors, of which all have probably not been identified in these two studies alone. I will here build further on the concept of "flexibility capital" (Fjellså et al., 2021; Powells & Fell, 2019) and use social practice theory to explain the varying possibilities of households to provide flexibility in energy demand.

Material elements involve financial resources and the availability of smart home technologies to support load shifting and reductions in energy use, as previously identified as part of a household's flexibility capital (Fjellså et al., 2021; Powells & Fell, 2019). However, this category includes a much broader range of elements. Dwelling characteristics were in both studies identified as important in this aspect. The size and layout of an apartment play an important role in allowing changes in practices, such as providing space for hanging laundry or limiting disturbances from appliances in the home environment if their use is to be shifted in time. Building properties such as insulation, home infrastructures such as ventilation, and the location of an apartment within a multi-residential building largely affect the baseline indoor climate and a household's overall perception of and satisfaction with their home environment, and, consequently, the acceptance of heat load shifts. Furthermore, a household's potential to change the above-mentioned factors depends on tenure, with homeowners having greater flexibility in adjusting their home environment than tenants.

A household's demand flexibility is also affected by individual and collective temporal rhythms (Southerton, 2012). For instance, individual temporal rhythms may change drastically if the family expands and collective temporal rhythms such as work hours determine the period that people are at home and can perform homely practices. Previous research has already identified the limited flexibility of families with children to time-shift energy-reliant practices to avoid contributing to peaks in energy demand, both due to individual and collective temporal rhythms (Nicholls & Strengers, 2015; Nyborg & Røpke, 2013).

Both Studies C and D indicate the importance of meanings on a household's flexibility capital. Mental images of a cosy home environment connected with warm indoor temperatures may contribute to a reluctance to allow temperature reductions. Negative emotions connected to the use of HEMS, such as always feeling like "the bad guy" when checking the status of one's electricity use, may contribute to a loss of engagement in using the HEMS and trying to adapt energy-reliant practices. Furthermore, if meanings connected to saving money or contributing to a sustainable energy system are not communicated effectively, users may perceive a lack of motivation to adapt as well.

A household's flexibility capital is also determined by their competences, as suggested by Fjellså et al. (2021). As Study D showed, varying knowledge levels regarding energy use, technology, and the energy system require different kinds of guidance to support households in changing energy-reliant practices. The participants also had varying interests in being able to use a HEMS for automation of devices. Figure 6.3 illustrates different approaches towards energy demand flexibility supported by HEMS, acknowledging varying levels of knowledge and preferences for automation or manual control of devices among users.

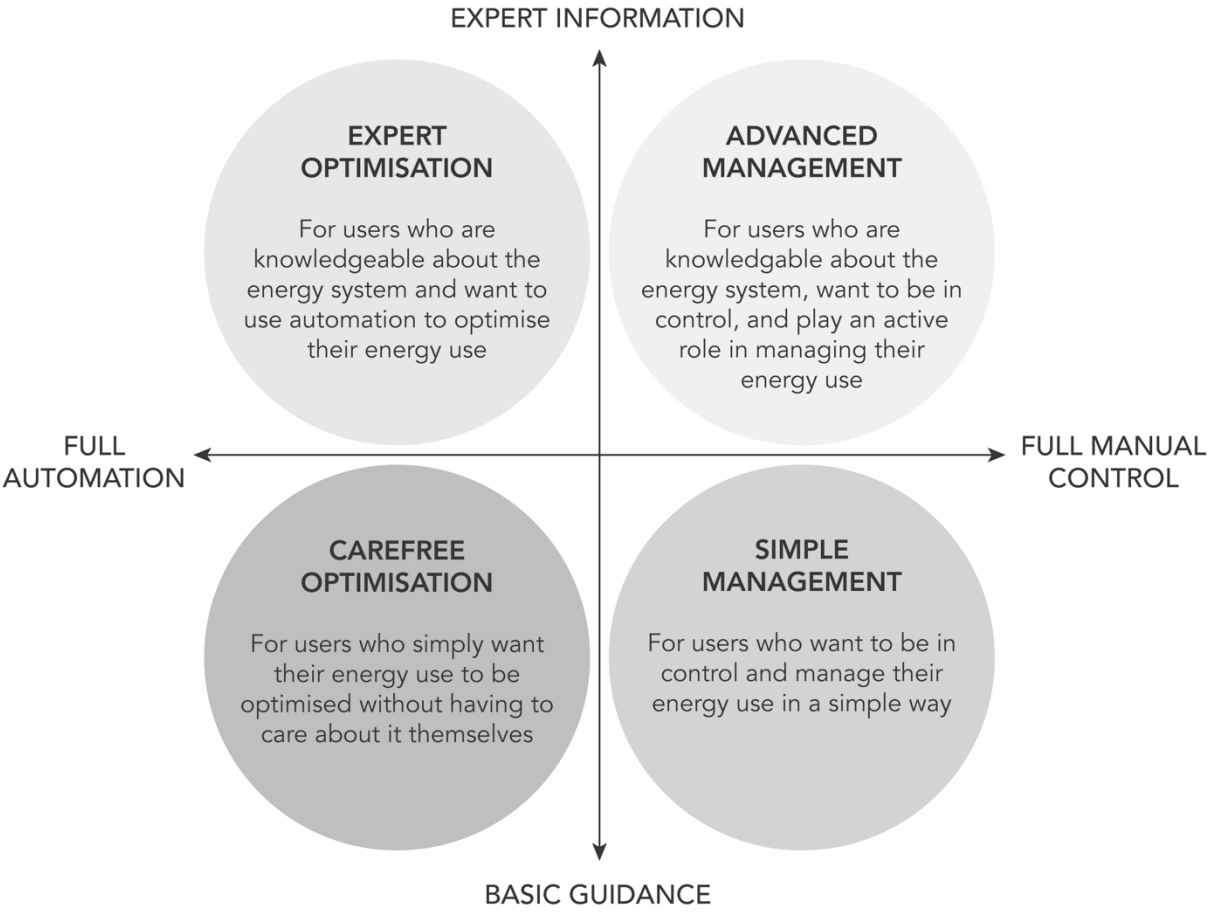


Figure 6.3. Different approaches towards energy demand flexibility, aimed at varying knowledge levels and preferences for automation versus manual control of devices.

The four approaches in Figure 6.3 should be interpreted as simplified categorisations that overlap in some respects. Users may identify with several approaches or somewhere in between them, depending on the context. The *carefree optimisation* approach is aimed at users who prefer not having to interact with the energy system themselves. They are not interested in changing practices according to the availability of energy but could accept some home functionalities to be managed automatically, such as indoor heating, electric vehicle charging, or the fridge and freezer. However, the perception of control may be improved through

communication about how the system operates. This category shares similarities with the category of "reception", described by Renström (2019a).

The *simple management* approach is aimed at users who are interested in making some adaptations to their everyday practices to save money or contribute to lowering the environmental impact connected to their energy use. They are reluctant to have their home functionalities operated automatically. At the same time, their knowledge of how the energy system operates is limited, and they, therefore, need guidance adapted to their knowledge level and specific context. Providing too much or too advanced information poses the risk that users feel overwhelmed and lose interest in interacting with the system, as previously suggested by Christensen et al. (2020).

The *advanced management* approach is intended for users with greater knowledge of the energy system and an interest in actively monitoring their energy use and making adaptations to their everyday practices accordingly. In other words, this would be the approach preferred by "Resource Man" (Strengers, 2014), although few users may, in reality, have the capacity to take on this role.

The final approach, *expert optimisation*, is intended for users who are knowledgeable about smart technologies and the energy system but are not that interested in making adaptations to their everyday practices. They would prefer having some home functionalities controlled automatically rather than having to actively monitor their energy use. In contrast to the carefree optimisation category, they do however wish to take part in adapting the automatic control according to their specific context, for instance by scheduling devices to automatically turn off when they are not at home. Thus, this approach requires slightly more engagement and allows more control from users than the carefree optimisation approach.

The studies indicated that the perception of control may positively influence a household's perceived possibilities for becoming more flexible in their energy demand. The perception of being in control might mean different things to different people. A central question that arises from both studies is how to improve households' feeling of control over their energy use in relation to the home environment without undermining demand flexibility. In Study C, perceived control over indoor climate was positively correlated to participants' willingness to allow load shifts, and in Study D, added control of the bathroom floor heating through Ero contributed to the use of this function being reduced the most among different devices representing considerable energy consumption in the home. Furthermore, Larsen et al. (2023) have previously suggested that when residents feel out of control of their space heating, they may reevaluate their expectations of comfort and create their own workarounds in relation to automated load shifting to maintain comfort, possibly leading to higher energy consumption in the end. However, it has also been found that higher levels of control provided by smart home technologies may result in higher levels of energy use (Larsen & Johra, 2019).

The level of actual control that can be provided to residents in terms of their indoor climate and remote control of appliances is largely affected by home infrastructures. For instance, in multi-residential buildings, temperature is often controlled at a building level, although the different locations of apartments within

the building cause temperature variations. Yet, needs and preferences regarding indoor temperature are likely to vary among the residents, with some groups being more vulnerable and, therefore, entitled to place higher demands on their indoor climate.

7

DISCUSSION

This chapter discusses the findings of the studies in relation to the research questions, followed by a reflection on the research scope and the relation between the two focus areas of this thesis. The chapter ends with a discussion of the limitations of the research.

7.1 Design opportunities for sustainable home-related consumption

RQ1: How could the design of products and services support home-related sustainable consumption, focusing on circularity and smart energy use?

For sustainability-oriented products and services to be effective in lowering households' environmental impact, they need to acknowledge the diversity of households, their life situation, and their capacity to change practices as well as their home environment. Starting with the kitchen, circular design strategies and business models need to be combined in ways that facilitate circular consumption in different types of housing while striving to avoid risks such as speeding up consumption or the kitchen being replaced before the end of its functional life. Aiming for the highest circularity, in theory, may not result in the highest sustainability effects in reality because such a solution may not be available for the wide population and may result in unintended effects. For instance, the "flexible quality kitchen" approach described in Section 5.5 is likely to become unaffordable for most households, and the improved flexibility could potentially speed up consumption by allowing households to update their kitchens more frequently. Yet, improving the quality and modularity of kitchens are both central strategies to enable lifetime extension and the closing of resource loops. Circular business models involving take-back management, consumption of pre-used products, or access-based consumption may further facilitate the circular consumption of kitchen furniture and appliances but need to adapt to the specific context and building regulations. An overview of design opportunities to improve the circularity of kitchens is presented in Table 7.1, based on the different approaches presented earlier in Figure 5.4.

Table 7.1. Design opportunities to improve the circularity of kitchens, referring to some of the circular design strategies suggested by Bocken et al. (2016).

	Main circular design strategies	Target groups	Circular business models
Low-budget flexible kitchen	• Design for upgradeability and adaptability • Design for standardisation and compatibility	• Owner-occupied homes • Rental apartments	• Purchase with take-back management • Consumption of pre-used products
Place-built quality kitchen	• Design for attachment and trust • Design for reliability and durability	• Owner-occupied homes (particularly houses) • Rental apartments	• Purchase with take-back management of some components
Flexible quality kitchen	• Design for reliability and durability • Design for upgradeability and adaptability • Design for standardisation and compatibility	• Rental apartments • Owner-occupied homes (particularly apartments)	• Access-based consumption • Purchase with take-back management • Consumption of pre-used products
All	• Design for ease of maintenance and repair • Design for dis- and reassembly • Design for a technological cycle • Avoid use of hazardous chemicals • Use of materials and energy sources with low environmental impact in the production • Provide smart storage solutions		

For the place-built quality kitchen, applying circular business models becomes less important than for the other two approaches, because it focuses primarily on extending the lifetime of the kitchen in one single home rather than enabling multiple use cycles in different homes. The high quality of the materials may enable the kitchen to be reused in a different setting, but the limited focus on flexibility may complicate the adaptation of the kitchen to a different space.

In the CIK project, a circular design approach similar to the flexible quality kitchen was applied in the development of the kitchen prototypes CIK 1.0 and 2.0. In the development of CIK 3.0, the approach was instead steered towards the low-budget flexible kitchen to increase the potential for a wider diffusion on the market due to the lower price.

The circular design approaches suggested for the kitchen are also relevant to other categories of furniture in the home. Some furniture categories are, like the kitchen, seen as rather fixed parts of the dwelling, for instance, wardrobes and bathroom cabinets. For these categories, all three approaches are relevant. However, many furniture categories are more flexible to be moved around or replaced, such as tables and bureaus, which makes the approaches focused on flexibility highly relevant. Still, the design strategies listed for the place-built quality kitchen approach

are relevant for these furniture categories as well because they focus on designing long-life products. For furniture that contains soft materials, such as sofas or beds, it may be important to implement different levels of durability and flexibility to different components, making it easy to wash and replace soft materials while the frames can remain the same. Combining different circular design strategies and using different levels of durability and flexibility is also relevant for the kitchen, with the cabinet frames designed to last for longer than the cabinet fronts, which may be updated to give the kitchen a new expression. For home appliances, it is important to implement circular design strategies from all dimensions of slowing, closing, and narrowing resource loops. The higher need for maintenance and repair, as well as the higher environmental impact of appliances compared to furniture, makes appliances even more relevant for access-based consumption and other circular business models.

Focusing on energy demand flexibility, HEMS could play a part in raising households' competences connected to their consumption, in terms of knowledge but also through offering improved control of their home environment. Combining different forms of consumption, such as electricity, heating, and water, as well as the household's own electricity production and storage, if applicable, may contribute to higher engagement in time-shifting energy consumption, in line with findings from previous research (Gram-Hanssen et al., 2020). Furthermore, the information should be personalised and meaningful to the user (Geelen et al., 2019), showing disaggregated consumption data for different appliances (Agarwal et al., 2023; Kendel et al., 2017), and adapt to the competence level of different users (Cockbill et al., 2020; Reisinger et al., 2022).

A list of design opportunities for future HEMS is shown in Table 7.2, categorised according to different knowledge levels among users and preferences for automation or manual control, as previously illustrated in Figure 6.3. The categories overlap and most users may end up somewhere between the categories, but the table can be used as a guide to consider the variety of people who might be using HEMS in the future. Still, HEMS is not likely to bring about major changes in households' practices on their own.

The installation of HEMS changes the material elements of the home, which may lead to changes in energy-reliant practices. However, a reconfiguration of practices could also be achieved through changes in other material arrangements of the home, meanings and competences, or relations with other practices. Other material arrangements could include appliances that facilitate time-shifting of practices by minimising disturbances through reduced noise levels. It could also involve floor plans that separate the kitchen from the living room to a larger extent and isolating walls within the apartment to a higher degree to reduce noise disturbances. However, such changes may bring other consequences which are not desired. For instance, a separate kitchen may be less space efficient and give less support to practices of socialising or keeping an eye on children.

Table 7.2. Design opportunities to improve households' energy demand flexibility through Home Energy Management Systems (HEMS).

	Design implications for HEMS
Simple management	• Provide information that is meaningful and easy to relate to everyday practices • Highlight functions that contribute to high energy use • Focus on the current situation and future • Include a personal energy threshold based on a predefined recommendation or simple settings for raising or lowering the threshold, explaining how this impacts price and environmental footprint
Carefree optimisation	• Optimisation of energy demand flexibility operates in the background, for instance allowing a third party to operate load shifts of functions such as heating, electric vehicle charging, or the fridge and freezer • Allow users to access simple information of how the system operates and to reject load shifts
Expert optimisation	• Allow scheduling of home functionalities • Enable grouping different functions and creating different modes, according to temporal rhythms and routines such as work hours, dinner time, or night mode • Facilitate combinations of different smart home technologies in one system
Advanced management	• Allow analysis of energy consumption and production data historically, to highlight trends and changes in consumption • Allow advanced analysis of the consumption of specific devices • Include a personal energy threshold based on individual preferences regarding energy sources, price, or CO_2 intensity
All	• Focus on positive achievements and avoid blaming the user • Include electricity, heating, water consumption data, and the household's own electricity production and storage, if applicable • Allow users to influence the frequency of receiving notifications • Allow different interface versions for different users within the same household

Many sustainability-oriented innovations are expensive and only available for the affluent part of society. To achieve a broad transition to more sustainable use of resources, people from all parts of society need to be considered, both in terms of having access to sustainable options and being protected from negative consequences, such as health issues due to energy poverty. The type of housing greatly determines the extent to which a household can make changes to their home environment, to improve possibilities for energy demand flexibility and sustainable use of resources. Focusing on the kitchen area, tenants' everyday kitchen practices may not be supported by the configuration and design of the kitchen. For instance, storage solutions may not be well adapted to the household's need to store groceries, waste, and equipment for cooking and eating. Focusing on indoor climate, insufficient insulation, ventilation, shading, and control of the temperature in different rooms may result in an unpleasant environment for tenants, who need to come up with their own solutions for improving their comfort and wellbeing at home. In Sweden, it is common for heating to be included in the rent. Thus, there may be no economic incentive for tenants to save energy by turning down radiators (to the extent possible) or avoiding airing the apartment. Electricity is usually paid

for by the tenants themselves. However, they have little influence over which appliances that are included in the apartment. In many rental apartment buildings in Sweden, washing machines, tumble dryers, and drying cabinets are placed in common laundry rooms rather than in the apartments. This complicates the time-shifting of laundry practices. As mentioned, the size and layout of the apartment may also limit the extent to which energy-reliant practices are shifted in time.

7.2 User perspectives on sustainability-oriented solutions for the home

RQ2: How do people perceive and evaluate products and services aimed at reducing the environmental impact of home-related consumption?

People's openness towards and integration of sustainability-oriented solutions into everyday life at home depend on many different factors, such as life situations, interests, previous experiences, and preconditions connected to tenure and the home environment. This research does not aim to create a representative image of how different groups of people perceive such products and services but rather to illustrate examples and highlight some aspects that may shape people's perceptions.

Study B showed that people imagine different motivations and barriers concerning circular value propositions for kitchen furniture and appliances. For some, the thought of buying pre-used products was strongly associated with feelings of disgust, in line with previous research (Bovea et al., 2017; Gullstrand Edbring et al., 2016). There were also concerns about the additional effort needed or that it would not be worth the money, similar to findings by Van Weelden et al. (2016). Similarly, access-based consumption models for kitchen furniture and appliances were met with strong scepticism connected to financial concerns (Cherry & Pidgeon, 2018; Muylaert et al., 2022), a desire to own (Gullstrand Edbring et al., 2016; Tunn et al., 2021), unfamiliarity with the concept (Borg et al., 2020), and impact on everyday life (Rexfelt & Hiort Af Ornäs, 2009). Some of these barriers may be lowered as circular consumption models become more mainstream in society. To support such a shift, it is important to both focus on the motivations and lower the barriers to participating in circular consumption. Convenience and environmental benefits are often promoted in connection to access-based consumption (Bardhi & Eckhardt, 2012; Borg et al., 2020). However, in line with findings by Gullstrand Edbring et al. (2016), Study B showed that people may distrust how sustainable such consumption models are. Similarly, the added convenience may be outweighed by additional efforts needed in other ways. For instance, leasing a kitchen was by some participants expected to bring more work than buying a new one. Therefore, giving more focus to other motivations or lowering the barriers that conflict with these motivations may be a way forward. From the findings, it seems that financial concerns, uncertainties, and practical feasibility are important barriers for most of the scenarios included. In the case of rental apartments, landlords could play an

important role in lowering these barriers for tenants. However, as illustrated in previous research, kitchens are more frequently renovated in owner-occupied homes (Femenías et al., 2018), which suggests an even higher potential to achieve positive environmental effects by focusing on this group of households.

In the case of demand flexibility in residential space heating, Study C showed that when satisfaction with the indoor climate is already low, the acceptance for implementing load shifts will be low as well. Therefore, as a first step, building-related problems such as poor insulation or insufficient ventilation need to be resolved to prevent negative experiences of the indoor climate.

Study C also stressed the importance of timing and magnitude of load shifts. However, balancing residents' preferences with the goal of reducing peak demand is complicated due to several factors. First, indoor climate preferences and needs among residents vary, which makes it impossible to make everyone satisfied. Second, Study C indicated that mornings were generally perceived as colder, which complicates peak shaving during the morning hours, where the highest heating demand often takes place (Kensby et al., 2015). Third, practices such as airing the bedroom during nighttime contribute to lowering the temperature more than intended if load shifts are applied during early morning hours. Previous research has suggested that heat losses connected to the practice of having windows open in the bedroom may be prevented by better opportunities to control indoor temperature separately for different rooms (Madsen & Gram-Hanssen, 2017).

Study C showed that communication about load shifts is important to prepare residents and make load shifts more acceptable. Previous research has suggested that communication plays a central role in motivating participation in demand response programs, by explaining benefits as well as giving advice on how to maintain comfort (Christensen et al., 2022; Sweetnam et al., 2019). It is also important that residents feel in control over their home environment. Being aware of when and for how long the load shifts will operate is a first step in improving the feeling of control, but it could also be improved further by giving residents the possibility to slightly influence the time window in which they can accept load shifts to take place. Furthermore, the feeling of control over indoor temperature may be improved through alternative material rearrangements of the home, such as products aimed at heating the body rather than the living space, which has been the focus of other studies (Renström et al., 2017; Van Moeseke et al., 2024).

In the case of Ero, Study D discovered a broad variation in interest and competence levels regarding both smart technologies and the energy system. For technologically advanced users, Ero became a disappointment as they expected to be able to do more with the app, such as scheduling devices to turn on and off automatically, retrieve consumption data over longer periods, or combine it with other smart technologies they already had installed at home. For others, Ero (and the study itself) became an eye-opener as they learned about the varying energy supply and that it matters when they use energy. If the study had been performed today, it is less likely that this would have been new knowledge for the participants as the energy crisis has put light on energy availability and significantly impacted

energy prices, with hour-based tariffs becoming more common also in Sweden (Tidningen Energi, 2022).

In Study D, many participants reported becoming more aware of their electricity and water use, highlighting some practices contributing to significant consumption levels, such as using the bathroom floor heating and the tumble dryer. However, mirroring findings from previous research (Skjølsvold et al., 2017; Verkade & Höffken, 2017), the interest and engagement in using Ero generally decreased over time.

7.3 Changes in everyday practices

RQ3: How are everyday practices shaped by the introduction of products and services aimed at reducing the environmental impact of home-related consumption?

The research in this thesis has indicated that the introduction of sustainability-oriented solutions may contribute to both intended and unintended changes in practices. Unintended practice changes can be either positive or negative from an environmental point of view.

Although Study A did not focus on practice changes from interventions, the interviews revealed some practices that changed due to reconfigurations of material elements through the kitchen renovation. For instance, some households mentioned getting rid of their kettle when they installed an induction hob, as the hob was perceived to be equally efficient. Thus, the practice of boiling water changed. From a circular economy perspective, these households applied the "refuse" strategy (Potting et al., 2017), through which the shift from a less efficient hob to an induction hob made the kettle redundant. Another material reconfiguration detected in one of the households was the shift from a separate fridge and a freezer to two combined fridge and freezer columns, with different temperature settings for the fridges. This shift was explained to improve the household's possibilities for storing vegetables and keeping them fresh for longer, possibly affecting practices such as grocery shopping, cooking, and eating.

Study A also detected some practice changes that were desired by the household and which motivated certain changes in the kitchen. For instance, keeping an eye on and interacting with the children seemed to be bundled with practices of preparing food or cleaning up in the kitchen. One household wished to improve the possibilities for performing these practices simultaneously and, therefore, opened their kitchen to the living room area. Several households wished to simplify waste handling and implemented larger or more efficient storage space for waste in their kitchens.

Like Study A, Study B did not study actual practice changes resulting from interventions but elaborated on the potential consequences of participating in hypothetical scenarios of circular consumption. In the pay-per-use scenario,

participants could imagine several consequences for everyday practices, such as running the dishwasher less frequently or handwashing to a greater extent. They could also imagine the pay-per-use scenario as a source of stress and conflict at home. In the scenarios for pre-used kitchen furniture and appliances, some participants expected consequences such as having to replace them again soon or deal with reparations, similar to findings by Van Weelden et al. (2016). Thus, participating in circular consumption models may bring new meanings and require new competences, in daily use and in the obtainment and riddance of the products, compared to more conventional forms of consumption (buying new products). New meanings could involve negative emotions related to worrying about costs, the products being contaminated from previous use, or having the use of products monitored by a company (in the case of pay-per-use). It may also involve positive emotions related to feeling thrifty, making an environmentally conscious choice, or the fun experience of trying something new. New competences could be needed in terms of searching the market for alternative options, evaluating the condition of pre-used products, or planning the use and keeping track of costs (in the case of pay-per-use).

Although access-based consumption has become more mainstream in society in recent years, consumption practices related to home furniture and appliances mostly follow traditional consumption models based on individual ownership. With time, access-based consumption models may become more common also in the context of the home. The likeliness of households participating in circular consumption practices, such as leasing a dishwasher or kitchen furniture, may increase with a growing number of such options being available on the market, in line with suggestions from previous research (Christensen, Halkier, et al., 2024). It may also be positively influenced by social influence from friends, neighbours, colleagues, and others who already participate in circular consumption models. Previous research has demonstrated peer effects such as buying electric vehicles and installing solar panels as a result of social influence (Wolske et al., 2020).

Study C showed varied strategies for maintaining or improving thermal comfort and satisfaction with the indoor climate, no matter if it was affected by load shifts or not. From the limited data, it is not possible to conclude whether such practices changed due to the introduction of heat load shifting. However, the findings suggest that dissatisfaction with the indoor climate may result in various practices using little or no direct energy, such as using additional clothing or extra blankets, practices that use considerable amounts of energy, such as using extra radiators or heating fans, or practices that waste energy, such as airing out warm air through windows. Therefore, if introducing interventions to reduce the environmental impact connected to space heating, it is important to also promote practices of low or no energy use to the residents to achieve environmental benefits while ensuring their wellbeing. Thus, new competences may need to be introduced to prevent environmental benefits from heat load control from being counteracted by energy-intensive practices. For instance, for load shifting or peak shaving during mornings to be effective, residents should avoid lowering temperatures or airing during nighttime (Christensen et al.,

2022), alternatively limiting such practices to bedroom areas only. Improving competences regarding the environmental and economic benefits of heat load control may also be helpful, as suggested in previous research (Christensen et al., 2022; Christensen & Petersen, 2023; Sweetnam et al., 2019). Furthermore, implementing load control in space heating could involve new meanings regarding control of the indoor climate, what is an acceptable temperature range, awareness of temperature variations, saving money, using cleaner energy, or solidarity (contributing to the functioning of the energy system to benefit all).

Changes in the material context, such as renovations to improve the energy efficiency of the building, could support heat load shifting by making the load shifts less noticeable. For rental apartments, this decision is up to the landlord, while tenants have limited possibilities to change their material context. The reconfigurations in material elements that tenants can implement themselves are limited to products that can be used in their apartments. Recent research has studied how products focused on heating the body rather than the living space may support lower indoor temperatures (Renström et al., 2017; Van Moeseke et al., 2024).

As found in Study D, the impact on everyday practices, as a result of introducing a HEMS, varied greatly, from no significant changes to entirely changing some energy-intensive practices, such as using a drying rack instead of using the tumble dryer. Previous research has suggested that the potential for changing practices increases with a higher visibility of practices (Christensen, Halkier, et al., 2024). Through Ero, some energy-intensive practices became more visible, which motivated practice changes in some households. Especially floor heating became visible through Ero, both in terms of highlighting the relatively high energy consumption compared to other connected appliances and by making it easy to turn it on or off.

Focusing on time-shifting, Ero mainly contributed to participants shifting the time of performing cleaning practices, such as dishwashing, which is in line with findings from previous research (Friis & Christensen, 2016; Gram-Hanssen et al., 2020; Nicholls & Strengers, 2015; Nyborg & Røpke, 2013; Smale et al., 2017; Verkade & Höffken, 2017). Furthermore, some practices were reconfigured with smaller changes, for instance using eco-programs on the dishwasher and washing machine to a greater extent. The practice of checking Ero was introduced, sometimes connected to receiving notifications or during a specific part of the day. This can be referred to as an energy management practice (Naus et al., 2015). However, as already discussed, this practice often decreased over time and did generally not become part of the participants' daily routines. Thus, the use of Ero generally stayed in the appropriation phase and did not reach the routinisation phase, as described by Rabiu & Jaeger-Erben (2022). As discussed by some participants, the practice of checking Ero was seen as just another thing competing for their time. In line with previous research (Geelen et al., 2019; Verkade & Höffken, 2017), Ero primarily became a tool supporting awareness around energy use rather than a tool for time-shifting energy-reliant practices.

As indicated in Figure 6.2, Ero introduced new elements within all three categories (materials, meanings, and competences). The lack of resulting practice changes may be explained by the inability of Ero to break existing links, both within and between practices. For some, meanings such as being comfortable or having a tidy and noise-free home were strongly linked to the use of certain appliances or functions, which made rearrangements difficult. Some meanings, such as saving money or reducing environmental impacts, were not linked strongly enough to Ero or to competences of evaluating the household's electricity use in relation to the electricity threshold. Furthermore, work hours and household composition shape the time available and the temporal rhythms of everyday practices.

Despite increasing the visibility of energy-intensive practices, Ero did not provide a greater variability in options to perform the practices differently. Previous research has suggested that a high variation in ways of carrying out practices contributes to better potential for changing existing practices (Christensen, Halkier, et al., 2024). It has also been suggested that a high level of social interaction could make practice changes more likely (Christensen, Halkier, et al., 2024; Christensen & Røpke, 2010). In its current form, Ero did not directly support social interaction around energy-intensive practices. However, social interaction could be supported between households by using Ero to create a local energy community for the neighbourhood. To support social interaction around energy use within households, there may be better options than having household members individually use an app on their phones. One possibility could be to include energy feedback in the appliances themselves to make the information easily available to all members of the household and more integrated into the practices of using them.

7.4 Reflection on research scope and focus areas

The two themes included in this thesis share the overall aim of contributing to more sustainable consumption related to the home environment and represent different pathways within the wider sustainability transition. There are several synergies between these two pathways. Both the transition to a circular economy and sustainable energy systems strive to break free from our dependency on fossil fuels and instead use "clean", renewable energy. Reducing the use of energy is also an important part of both concepts. Overall, both tracks seek to avoid resource depletion and environmental degradation. However, in some respects, the two tracks differ in their view on and strategy for reaching sustainable consumption. Smart home technologies are widely seen as a prerequisite to achieving a transition to sustainable energy systems. While a circular economy aims to slow, close, and narrow resource loops (Bocken et al., 2016), a smart energy system requires advanced technologies with complex designs, including a wide range of materials, which complicates strategies for narrowing and closing loops. Furthermore, these technologies need to be up to date to support the function of digital services, which

complicates strategies of slowing resource loops and keeping products for a long time.

This brings us back to the question of what "smart" energy use stands for and if the technological aspect of smart needs to be reconsidered. As found in Study D, HEMS may contribute to engaging some people in their energy use and changing energy-reliant practices, but for others, HEMS do not seem to be the solution. For them, other strategies may be more effective in supporting a sustainable energy transition.

Researchers are now starting to question the "technologically deterministic approach" widely adopted in smart energy research agendas (Robison et al., 2023). Instead of viewing smart technologies as inevitable, Robison et al. (2023) suggest the need for a more critical exploration of potential negative and unintended consequences of smart technologies, as well as how smart technologies may be used to promote alternative pathways towards sustainable energy systems, integrating concepts such as sufficiency and degrowth. Building on ideas of planetary boundaries (Rockström et al., 2023) and the doughnut economy representing a "safe and just space for humanity" (Raworth, 2017), Darby and Fawcett (2018) define energy sufficiency as "a state in which people's basic needs for energy services are met equitably and ecological limits are respected" (p. 8). Instead of focusing mainly on technological development, the sufficiency concept questions what is enough to live a good life, recognising the equality of all people (Christensen, Aagaard, et al., 2024; Hasselqvist et al., 2022).

In some ways, participants of both Studies C and D adopted principles of energy sufficiency. In Study C, residents had limited control over the space heating, and those who considered their apartments too cold even when the radiators were set at the maximum level had to find other strategies to maintain their comfort. These strategies could include using energy in other ways, such as taking a hot shower, drinking or eating something warm, or using extra blankets. Some strategies may consume no direct energy at all, while other strategies may consume even more energy than if the space was heated enough. Only lowering indoor temperatures may, therefore, cause rebound effects and may furthermore expose vulnerable individuals to health risks. However, in a project focused on heating people rather than buildings, Van Moeseke et al. (2024) observed heating consumption to decrease by 50% without additional electricity use through the adoption of personal heating systems such as heating blankets, heated chairs, and infrared panels, in combination with more clothing.

In Study D, some participants ceased using the tumble dryer or the bathroom floor heating as a result of using Ero. This suggests that HEMS may be used to support principles not only of energy demand flexibility but also energy sufficiency. Still, such energy savings need to be compared with the environmental impacts connected to the production of the HEMS technologies themselves (Tippe et al., 2025).

Sufficiency is also a relevant concept to explore in the context of the kitchen. From this point of view, it is relevant to question how large the kitchen needs to be

and how large appliances need to be installed to support the household's everyday practices in the kitchen. For instance, the most common type of dishwasher in Swedish kitchens is a 60 cm wide dishwasher, but for smaller households, it may be enough with a smaller alternative. If an access-based consumption model for kitchen furniture and appliances was implemented in rental apartments, with larger kitchens and appliances resulting in higher apartment rent, tenants could be motivated not to have a larger kitchen than needed.

If smart home technologies are to be used to a broad extent, they should, as far as possible, be designed based on circular strategies and combined with circular business models. A cheaper alternative to buying a HEMS could be to rent it for a limited period to learn about the energy consumption of different appliances at home, trends in the household's consumption over the 24 hours of the day and week in relation to trends in energy supply, and get personalised recommendations for how to change the household's consumption to support a sustainable energy system. To make HEMS even more available to the wider society, there could be public libraries from which people could borrow HEMS for free during a certain period.

By providing access rather than ownership of HEMS, resource loops could be narrowed (using HEMS more efficiently as one HEMS is used by several households), slowed (supporting multiple use cycles of HEMS and repairing or upgrading it between use cycles), and closed (as the service provider is responsible for taking care of the HEMS after the end of use).

In both the circular economy transition and the sustainable energy transition, a central question that emerges is how to ensure justice and equal possibilities to participate in sustainable consumption. As discussed in Section 5.4, a circular kitchen designed with high-quality materials and modular construction is going to be more expensive than a conventional MDF and chipboard kitchen. Similarly, advanced smart home technologies are currently not affordable for everyone. Access-based consumption models are therefore relevant to apply both in the context of circular kitchens and smart home technologies to reduce initial investment costs. However, to make access-based consumption models more financially attractive in a longer perspective, the possibility of buying out products over time may be important.

Another potential conflict between the circular economy pathway and the sustainable energy systems pathway concerns the additional energy needed to transport and sometimes repair, refurbish, or remanufacture products to enable lifetime extension and recirculation of products. Additionally, the energy efficiency of home appliances has improved significantly in the last decades (APPliA, 2023), which means that there is a limit to how many years an appliance should be used before it becomes better to buy a new appliance with better energy performance. Further analysis of the environmental impact over the whole lifetime of both circular kitchen furniture, appliances, and smart home technologies is therefore needed.

To support lifestyles within a circular economy and sustainable energy systems, it will not be enough to focus only on the integration of new material elements into practices, such as smart technologies and products based on circular economy principles, but a similar focus must be given to the meanings and competences

connected to practices of high environmental impact. For instance, the practice of renovating the kitchen, even though it has not reached the end of its technical lifespan, has become a normal thing to do, and there is little discussion on a societal level about the environmental impact connected to kitchen renovations. Similar to the way that media has highlighted the environmental impact of different transportation modes and dietary choices, there should also be attention given to the impact of home renovations, products we buy for our homes, indoor temperatures, and the size of the living space.

7.5 Limitations

This section summarises the overall limitations of the research. A more detailed discussion of methodological limitations is provided in Section 4.4.

First, the research in this thesis was conducted in a Swedish context, with a focus on urban areas. This limits the extent to which the findings may be transferred and generalised to other geographical areas. Still, many of the findings hold relevance for other Western countries as well.

Second, the focus of this thesis has been on sustainable home-related consumption from a household point of view. Investigating the perspectives of other actors relevant to the topic, such as energy companies and housing companies, was beyond the scope of this thesis. Still, understanding multiple perspectives is vital to achieving a societal transition towards more sustainable consumption.

Third, consumption levels and resulting environmental impacts have not been quantified in the studies. Rather, the focus was on exploring and illuminating some interesting aspects of home-related consumption and identifying opportunities for change.

8

CONCLUSIONS AND FUTURE WORK

This final chapter concludes with the contributions to research and practice from the studies included in the thesis. Recommendations for further research are then outlined, discussing future research directions and important questions requiring deeper or broader investigation.

8.1 Research contribution

This research has contributed to an improved understanding of households' perspectives on sustainable consumption in relation to their home environment. A deep insight into households' current practices and how they perceive their possibilities of making adaptations in everyday life is important to identify opportunities for more sustainable use of resources. A lack of understanding of households' perspectives may steer the technical development in directions not fostering significant improvements but may instead contribute to rebound effects and increased environmental impact overall. Thus, households play a central role in sustainability transitions, as concluded in previous research (Dubois et al., 2019; Schot et al., 2016).

The studies included in this thesis illuminate different aspects of sustainable consumption within the two themes, focusing on the circularity of kitchens and sustainable energy use at home. A summary of the research contribution and practical implications of the studies are listed in Table 8.1. The combined findings from the studies lead to the following conclusions:

- Households have varied preconditions for participating in sustainable consumption. This is connected to various factors including financial conditions, tenure and characteristics of the dwelling, household composition, and life situation. Furthermore, knowledge, interest, and previous experiences of related products and services shape the acceptance and adoption of offerings aimed at enabling sustainable resource use. Sustainability-oriented research and development must consider these variations to enable wide participation in the sustainability transition. It will not be enough to target the affluent part of society with "green" products and service offerings. Low-income households or those with limited possibilities

to adapt their home environment need to be included and not punished economically or through sacrifices in health.

- The material context of the home, including building properties and infrastructures, configuration of the living space, and products available within the home, greatly influence daily practices and investment decisions. The studies have indicated that perceived limitations or shortcomings of the home environment may result in extensive renovations (Study A), alternative ways of maintaining thermal comfort and satisfaction with the indoor climate (Study C), or a dependency on energy-intensive appliances, such as the tumble-dryer (Study D). In some cases, renovations may be necessary to ensure functionality and energy efficiency, as well as the wellbeing of people within the household. Then, there must be offerings available on the market that support a lower environmental impact in the long run. Similarly, reducing the environmental impact of space heating requires that there are alternative low-energy solutions available for households to ensure their health and wellbeing. Households cannot alone be responsible for lowering their environmental impact but need to be supported by smart and flexible product and dwelling designs as well as circular service offerings.

- Considering ways of meeting households' needs and preferences is important, but in order to achieve radical changes and enable the transition to a circular economy and sustainable energy systems, current consumption practices and mindsets need to be challenged on a societal level. The limited resources of the planet will not be able to support a wide demand for completely new products and unlimited access to energy whenever required. Both the circular economy transition and sustainable energy transition need to integrate aspects of sufficiency.

Finally, this research represents a methodological contribution through the variety of research designs applied in the studies. Different methods were used to collect both qualitative and quantitative data momentarily, retrospectively, and longitudinally. This contributed to a nuanced understanding of the phenomena under study and the quality of the research. The different research designs may be used as inspiration for future studies.

8.2 Implications for practice

This thesis brings practical implications of relevance for actors who, in different ways, are connected to the home. First, it presents design implications for companies involved in kitchen furniture, home appliances, and energy management, striving to offer more sustainable and circular solutions for households. The uptake and effect of sustainability-oriented solutions are largely determined by their ability to meet

households' needs and preferences, fit into the life situation, and contribute to overcoming everyday challenges. The design implications presented in this thesis are based on insights into the perspectives of a variety of households and grouped according to different approaches towards circularity and energy demand flexibility because there will not be a single solution that fits all. In the case of kitchen furniture and appliances, opportunities to apply circular business models are discussed as well. The different approaches should be viewed as overlapping and not as distinct categories, and other approaches may need to be considered as well. Furthermore, gaining insight into household perspectives is a continuous process as technology and society evolve at a rapid pace.

Second, this thesis highlights the role of landlords in supporting households in both circularity and sustainable energy use. In the intersection between households, building companies, energy companies, and kitchen and appliance producers, landlords play an important role in making sustainability-oriented solutions available to households and facilitating their operation and use.

Third, energy providers are advised to develop communication strategies in connection with demand-side management systems. This is important to get households on board, understand the benefits, be aware of load shifts, and know how to adapt to maintain their comfort.

Fourth, architects and designers shape preconditions for sustainable consumption in the home environment by making practices of low environmental impact possible to perform as an alternative to more resource-intensive practices.

Finally, households need to be supported by policies that aim to make options for more sustainable consumption easily available and affordable. A summary of the practical implications of the different studies is presented in the right-most column of Table 8.1.

Table 8.1. Contributions to research and practice from the included studies.

	Research contribution	Implications for practice
Study A	• Contributes to an improved understanding of how everyday kitchen use is affected by the kitchen design. • Contributes to an improved understanding of households' motivations behind kitchen renovations and how these impact the extent of kitchen renovations.	• The "conventional kitchen design" including chipboard and MDF does not support smaller changes to be made to meet the changing needs and preferences of households, either because of changes in life situation or a change of owner/tenant. • Highlights circular design strategies of relevance for kitchen producers to support lifetime extension of the kitchen.

Table 8.1. Continued.

	Research contribution	Implications for practice
Study B	• Presents a novel exploration of people's perspectives on circular value propositions for kitchen furniture and appliances through scenarios of circular consumption models that to date have reached little or no diffusion in the context of Swedish kitchens. • Identifies motivations and barriers for participating in circular consumption models in the context of the kitchen, in relation to previous literature. • Conceptualisation of circular consumption models in relation to circular strategies.	• Identifies different approaches towards circular kitchens, acknowledging the varied preconditions of households to participate in circular consumption. Different circular design strategies and business models need to be combined in ways that enable circularity in different contexts. • Suggests a central role of landlords in supporting circularity in the case of rental apartments. • Suggests further consideration of Swedish building regulations to facilitate circular consumption of kitchen furniture and appliances.
Study C	• Contributes to an improved understanding of residents' perceptions of indoor climate and thermal comfort, both in general and in relation to heat load shifting. • Highlights some strategies which residents may use to maintain their thermal comfort. • Contributes with reflections on the research methodology, which may be refined and applied in larger studies.	• Stresses the importance of landlords to ensure an acceptable baseline level of indoor climate to support the acceptance of heat load shifts. This involves adaptation on building level, such as providing sufficient insulation and ventilation. • To the extent possible, landlords should offer the possibility for residents to control the indoor temperature at room level. • Stresses the importance of energy providers to communicate with residents regarding the time and duration of planned heat load shifts and motivate the relevance of applying heat load shifts. To the extent possible, the energy company should consider residents' preferences regarding the time and duration of load shifts.
Study D	• Presents findings from households' testing and evaluation of a new HEMS prototype, including the concept of a personal electricity threshold to support both energy savings and time-shifting of energy-reliant practices. • Contributes to an improved understanding of households' potential to provide energy demand flexibility and highlights barriers to changing practices in everyday life.	• Suggests design implications for future HEMS. • Highlights the importance of considering alternative or complementary approaches to support households' energy demand flexibility, such as designing dwellings and appliances in a way that minimises disturbances connected to time-shifting practices or allowing low/non-energy practices to substitute energy intensive practices.

8.3 Directions for future work

From the analysis of the studies, several topics have emerged that deserve further exploration in future studies. First, based on the varying possibilities for households to participate in sustainable consumption, future research needs to investigate strategies to promote equity among people in society and enable everyone to somehow take part in sustainability transitions without being punished economically or make sacrifices related to health and wellbeing. Further research should consider how to make sustainability-oriented products and services available for the many. This would involve improving the knowledge about people's perspectives on sustainable consumption and the home environment, including participants of different household constellations, tenures, financial conditions, cultures, ages, gender, urban or rural areas, and vulnerable groups in society.

Focusing on energy, an investigation would be needed regarding households' ability and interest in using smart technologies, engaging with local power production, or taking part in energy communities. Furthermore, household views on their roles in future sustainable energy systems should be explored, centred around questions regarding active or more passive participation in energy management. As discussed in relation to Studies C and D, further exploration of how to improve residents' feeling of control over their home environment without causing increases in energy use seems central to achieving energy demand flexibility.

Focusing on circular economy, further investigation of how to make circular consumption available to a wider group in society and the roles of different actors to enable this should receive further attention. It is obvious that the responsibility cannot be carried by a single actor alone, but collaboration will be central, which suggests a need for further research on how to enable collaborations for fostering circular consumption. Furthermore, motivations and barriers to participating in circular consumption need further investigation to improve the understanding of how they impact households' perception and adoption of circular consumption models, either consciously or unconsciously. The importance of different motivations and barriers may vary depending on the product category, which suggests that a broad exploration of consumption areas is needed.

Second, further experiments with introducing interventions to change energy-reliant practices are also needed. In contrast to Study D, focusing on one practice at a time might feel less overwhelming as a task while keeping a system's perspective of the home and being attentive to how changes in one practice may impact other practices. Furthermore, a deeper understanding of how everyday practices at home are affected by the installation of smart home technologies, PV panels, and energy storage solutions is of relevance.

Third, this research has indicated that the transition to circular economy and sustainable energy systems need to be combined with the concept of sufficiency. How to promote lifestyles based on sufficiency principles therefore demands further attention (Mont & Lehner, 2023). Previous research on 1.5-degree lifestyles (Cap et al., 2024; Koide et al., 2021; Richter et al., 2024; Vadovics et al., 2024) is relevant

here and specific focus should be given to how to combine different concepts, while avoiding rebound effects in other areas of household consumption.

Finally, further research that examines the environmental impact of products and services aimed at enabling circularity and sustainable energy use at home is needed. This, to make sure that positive impacts outweigh negative impacts when considering the whole life cycle of introduced products.

REFERENCES

Aagaard, L. K. (2022). When Smart Technologies Enter Household Practices: The Gendered Implications of Digital Housekeeping. *Housing, Theory and Society*, *00*(00), 1–18. https://doi.org/10.1080/14036096.2022.2094460

Adams, S., Kuch, D., Diamond, L., Fröhlich, P., Henriksen, I. M., Katzeff, C., Ryghaug, M., & Yilmaz, S. (2021). Social license to automate: A critical review of emerging approaches to electricity demand management. *Energy Research and Social Science*, *80*(January). https://doi.org/10.1016/j.erss.2021.102210

Agarwal, R., Garg, M., Tejaswini, D., Garg, V., Srivastava, P., Mathur, J., & Gupta, R. (2023). A review of residential energy feedback studies. *Energy and Buildings*, *290*(April), 113071. https://doi.org/10.1016/j.enbuild.2023.113071

Akenji, L., Bengtsson, M., Toivio, V., Lettenmeier, M., Fawcett, T., Parag, Y., Saheb, Y., Coote, A., Spangenberg, J. H., Capstick, S., Gore, T., Coscieme, L., Wackernagel, M., & Kenner, D. (2021). *1.5-Degree Lifestyles: Towards A Fair Consumption Space for All*. https://hotorcool.org/1-5-degree-lifestyles-report/

Andersen, P. V. K., Georg, S., Gram-Hanssen, K., Heiselberg, P. K., Horsbol, A., Johansen, K., Johra, H., Marszal-Pomianowska, A., & Moller, E. S. (2019). Using residential buildings to manage flexibility in the district heating network: Perspectives and future visions from sector professionals. *IOP Conference Series: Earth and Environmental Science*, *352*. https://doi.org/10.1088/1755-1315/352/1/012032

APPliA. (2023). *The home appliance Industry in Europe 2022-2023*. http://applia-europe.eu/

Bakker, C., Wang, F., Huisman, J., & den Hollander, M. (2014). Products that go round: Exploring product life extension through design. *Journal of Cleaner Production*, *69*, 10–16. https://doi.org/10.1016/j.jclepro.2014.01.028

Baldé, A. C. P., Kuehr, R., Yamamoto, T., Mcdonald, R., D'Angelo, E., Althaf, S., Bel, G., Deubzer, O., Fernandez-Cubillo, E., Forti, V., Gray, V., Herat, S., Honda, S., Iattoni, G., Deepali, S. K., di Cortemiglia, V. L., Lobuntsova, Y., Nnorom, I., Pralat, N., & Wagner, M. (2024). *The global e-waste monitor 2024*. https://ewastemonitor.info/the-global-e-waste-monitor-2024/

Bardhi, F., & Eckhardt, G. M. (2012). Access-Based Consumption: The Case of Car Sharing. *Journal of Consumer Research*, *39*, 881–898. https://doi.org/10.1086/ 666376

Blomsma, F., & Brennan, G. (2017). The Emergence of Circular Economy: A New Framing Around Prolonging Resource Productivity. *Journal of Industrial Ecology*, *21*(3), 603–614. https://doi.org/10.1111/jiec.12603

Bocken, N. M. P., de Pauw, I., Bakker, C., & van der Grinten, B. (2016). Product design and business model strategies for a circular economy. *Journal of Industrial and Production Engineering*, *33*(5), 308–320. https://doi.org/10.1080/21681015.2016.1172124

Bocken, N. M. P., Mugge, R., Bom, C. A., & Lemstra, H. J. (2018). Pay-per-use business models as a driver for sustainable consumption: Evidence from the case of HOMIE. *Journal of Cleaner Production*, *198*, 498–510. https://doi.org/10.1016/j.jclepro.2018.07.043

Bocken, N. M. P., Weissbrod, I., & Antikainen, M. (2021). Business Model Experimentation for the Circular Economy: Definition and Approaches. *Circular Economy and Sustainability*, *1*(1), 49–81. https://doi.org/10.1007/s43615-021-00026-z

Bolger, N., Davis, A., & Rafaeli, E. (2003). Diary Methods: Capturing Life as it is Lived. *Annual Review of Psychology*, *54*, 579–616. https://doi.org/10.1146/annurev.psych.54.101601.145030

Borg, D., Mont, O., & Schoonover, H. (2020). Consumer acceptance and value in use-oriented product-service systems: Lessons from Swedish consumer goods companies. *Sustainability (Switzerland)*, *12*(19), 1–19. https://doi.org/10.3390/su12198079

Bovea, M. D., Pérez-Belis, V., & Quemades-Beltrán, P. (2017). Attitude of the stakeholders involved in the repair and second-hand sale of small household electrical and electronic equipment: Case study in Spain. *Journal of Environmental Management*, *196*, 91–99. https://doi.org/10.1016/j.jenvman.2017.02.069

Boverket. (2024). *Inredning och utrustning för matlagning*. https://www.boverket.se/sv/PBL-kunskapsbanken/regler-om-byggande/boverkets-byggregler/bostadsutformning/inredning-och-utrustning-for-matlagning/

Bressanelli, G., Saccani, N., Perona, M., & Baccanelli, I. (2020). Towards circular economy in the household appliance industry: An overview of cases. *Resources*, *9*(11), 1–23. https://doi.org/10.3390/resources9110128

Breyer, C., Khalili, S., Bogdanov, D., Ram, M., Oyewo, A. S., Aghahosseini, A., Gulagi, A., Solomon, A. A., Keiner, D., Lopez, G., Ostergaard, P. A., Lund, H., Mathiesen, B. V., Jacobson, M. Z., Victoria, M., Teske, S., Pregger, T., Fthenakis, V., Raugei, M., … Sovacool, B. K. (2022). On the History and Future of 100% Renewable Energy Systems Research. *IEEE Access*, *10*(June), 78176–78218. https://doi.org/10.1109/ACCESS.2022.3193402

Browne, A. L. (2016). Can people talk together about their practices? Focus groups, humour and the sensitive dynamics of everyday life. *Area*, *48*(2), 198–205. https://doi.org/10.1111/area.12250

Browne, A., Medd, W., Anderson, B., & Pullinger, M. (2014). Method as intervention: Intervening in practice through quantitative and mixed methodologies. *Social Practices, Intervention and Sustainability: Beyond Behaviour Change*, 179–195. https://doi.org/10.4324/9781315816494

Bueger, C. (2014). Pathways to practice: Praxiography and international politics. *European Political Science Review*, *6*(3), 383–406. https://doi.org/10.1017/S1755773913000167

Camacho-Otero, J., Boks, C., & Pettersen, I. N. (2018). Consumption in the circular economy: A literature review. *Sustainability (Switzerland)*, *10*(8). https://doi.org/10.3390/su10082758

Cap, S., de Koning, A., Tukker, A., & Scherer, L. (2024). (In)Sufficiency of industrial decarbonization to reduce household carbon footprints to 1.5°C-compatible levels. *Sustainable Production and Consumption*, *45*(December 2023), 216–227. https://doi.org/10.1016/j.spc.2023.12.031

Cherry, C. E., & Pidgeon, N. F. (2018). Why is ownership an issue? Exploring factors that determine public acceptance of product-service systems. *Sustainability (Switzerland)*, *10*(7). https://doi.org/10.3390/su10072289

Christensen, L. R. L., Broholt, T. H., Barthelmes, V. M., Khovalyg, D., & Petersen, S. (2022). A mixed-methods case study on resident thermal comfort and attitude towards peak shifting of space heating. *Energy and Buildings*, *276*, 112501. https://doi.org/10.1016/j.enbuild.2022.112501

Christensen, L. R. L., & Petersen, S. (2023). Mixed-methods case studies on residents' acceptance of temperature fluctuations from model predictive control. *Energy and Buildings*, *297*(May), 113405. https://doi.org/10.1016/j.enbuild.2023.113405

Christensen, T. H., Aagaard, L. K., Juvik, A. K., Samson, C., & Gram-hanssen, K. (2024). Promoting practices of sufficiency: reprogramming resource-intensive material arrangements. *Buildings and Cities*, *5*(1). https://doi.org/10.5334/bc.436

Christensen, T. H., Friis, F., Bettin, S., Throndsen, W., Ornetzeder, M., Skjølsvold, T. M., & Ryghaug, M. (2020). The role of competences, engagement, and devices in configuring the impact of prices in energy demand response: Findings from three smart energy pilots with households. *Energy Policy*, *137*(July 2019). https://doi.org/10.1016/j.enpol.2019.111142

Christensen, T. H., Halkier, B., Gram-Hanssen, K., Freudendal-Pedersen, M., & Krog Juvik, A. (2024). Exploring routinization and reflexivity in change and reproduction of consumption towards lower climate impact. *Journal of Consumer Culture*, *24*(1), 211–229. https://doi.org/10.1177/14695405231207599

Christensen, T. H., & Røpke, I. (2010). Can Practice Theory Inspire Studies of ICTs in Everyday Life? In B. Bräuchler & J. Postill (Eds.), *Theorising Media and Practice* (pp. 233–256). Berghahn Books. https://doi.org/10.1515/9781845458546-014

Circle Economy Foundation. (2024). *Circularity Gap Report*. 1–85. www.deloitte.com.

Cockbill, S. A., Mitchell, V., & May, A. J. (2020). Householders as designers? Generating future energy services with United Kingdom home occupiers. *Energy Research and Social Science*, *69*(June), 101615. https://doi.org/10.1016/j.erss.2020.101615

Collingridge, D. S., & Gantt, E. E. (2019). The Quality of Qualitative Research*. *American Journal of Medical Quality*, *34*(5), 439–445. https://doi.org/10.1177/1062860619873187

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (4th ed.). SAGE Publications, Inc.
Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and Conducting Mixed Methods Research* (2nd ed.). SAGE Publications, Inc.
Cross, N. (2006). *Designerly Ways of Knowing*. Springer.
Darby, S. and Fawcett, T. (2018). Energy sufficiency: an introduction (concept paper). In *European Council for an Energy Efficient Economy (ECEEE)*. https://www.energysufficiency.org/static/media/uploads/site-8/library/papers/sufficiency-introduction-final-oct2018.pdf
Darby, S. J. (2018). Smart technology in the home: time for more clarity. *Building Research and Information*, *46*(1), 140–147. https://doi.org/10.1080/09613218.2017.1301707
De Jong, A., Önnevall, E., Reitsma, L., & Wessmann, S. (2016). Challenging the role of design(ing) in the sustainability field - Towards a "humble" design approach. *ACM International Conference Proceeding Series, 23-27-October, 2016 Gothenburg*. https://doi.org/10.1145/2971485.2987671
De los Rios, I. C., & Charnley, F. J. S. (2017). Skills and capabilities for a sustainable and circular economy: The changing role of design. *Journal of Cleaner Production*, *160*, 109–122. https://doi.org/10.1016/j.jclepro.2016.10.130
Delmas, M. A., Fischlein, M., & Asensio, O. I. (2013). Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. *Energy Policy*, *61*, 729–739. https://doi.org/10.1016/j.enpol.2013.05.109
den Hollander, M. C., Bakker, C. A., & Hultink, E. J. (2017). Product Design in a Circular Economy: Development of a Typology of Key Concepts and Terms. *Journal of Industrial Ecology*, *21*(3), 517–525. https://doi.org/10.1111/jiec.12610
Dokter, G. (2023). *Circular design through co-creation: Exploring perspectives and future directions for design in a circular economy* [Chalmers University of Technology]. https://research.chalmers.se/publication/538160
Donatello, S., Caldas, M. G., & Wolf, O. (2017). *Revision of the EU Green Public Procurement (GPP) criteria for Furniture*. https://doi.org/10.2760/14246
Dubois, G., Sovacool, B., Aall, C., Nilsson, M., Barbier, C., Herrmann, A., Bruyère, S., Andersson, C., Skold, B., Nadaud, F., Dorner, F., Moberg, K. R., Ceron, J. P., Fischer, H., Amelung, D., Baltruszewicz, M., Fischer, J., Benevise, F., Louis, V. R., & Sauerborn, R. (2019). It starts at home? Climate policies targeting household consumption and behavioral decisions are key to low-carbon futures. *Energy Research and Social Science*, *52*(September 2018), 144–158. https://doi.org/10.1016/j.erss.2019.02.001
Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550. https://doi.org/10.2307/258557
Ellen MacArthur Foundation. (2015). *Towards a Circular Economy: Business Rationale for an Accelerated Transition*. https://doi.org/2012-04-03
Energiföretagen. (2023). *Elproduktion*. https://www.energiforetagen.se/energifakta/elsystemet/produktion/

Energiföretagen. (2024). *Fjärrvärme*. https://www.energiforetagen.se/energifakta/fjarrvarme/
European Commission. (2020). *Circular economy action plan: For a cleaner and more competitive Europe*. https://op.europa.eu/en/publication-detail/-/publication/0b83467b-a23a-11ef-85f0-01aa75ed71a1/language-en
European Commission. (2025). *Renewable Energy Directive*. https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en
Eurostat. (2022). *Energy consumption in households*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_consumption_in_households
Femenías, P., Holmström, C., & Jönsson, H. (2018). *Framtidens klimatsmarta och hållbara bostad*.
Fjellså, I. F., Silvast, A., & Skjølsvold, T. M. (2021). Justice aspects of flexible household electricity consumption in future smart energy systems. *Environmental Innovation and Societal Transitions*, *38*(December 2020), 98–109. https://doi.org/10.1016/j.eist.2020.11.002
Flick, U. (2018). *An introduction to qualitative research* (6th ed.). Sage Publications Limited.
Forlizzi, J., Stolterman, E., & Zimmerman, J. (2009). From Design Research to Theory: Evidence of a Maturing Field. *Proceedings of IASDR*, *9*, 2889–2898.
Forrest, A., Hilton, M., Ballinger, A., & Whittaker, D. (2017). Circular Economy Opportunities in the Furniture Sector. In *European Environmental Bureau (EEB)*. file:///C:/Users/giuli/Desktop/Circular-Economy-in-the-Furniture-Sector.pdf
Friis, F., & Christensen, T. H. (2016). The challenge of time shifting energy demand practices: Insights from Denmark. *Energy Research and Social Science*, *19*, 124–133. https://doi.org/10.1016/j.erss.2016.05.017
Geelen, D., Mugge, R., & Silvester, S. (2019). The use of apps to promote energy saving: a study of smart meter–related feedback in the Netherlands. *Energy Efficiency*, *12*, 1635–1660.
Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8
Geissdoerfer, M., Pieroni, M. P. P., Pigosso, D. C. A., & Soufani, K. (2020). Circular business models: A review. *Journal of Cleaner Production*, *277*, 123741. https://doi.org/10.1016/j.jclepro.2020.123741
Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
Ghisellini, P., Cialani, C., & Ulgiati, S. (2016). A review on circular economy: The expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, *114*, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Goulden, M., Spence, A., Wardman, J., & Leygue, C. (2018). Differentiating 'the user' in DSR: Developing demand side response in advanced economies. *Energy Policy*, *122*(June), 176–185. https://doi.org/10.1016/j.enpol.2018.07.013

Gram-Hanssen, K. (2011). Understanding change and continuity in residential energy consumption. *Journal of Consumer Culture*, *11*(1), 61–78. https://doi.org/10.1177/1469540510391725

Gram-Hanssen, K., & Darby, S. J. (2018). "Home is where the smart is"? Evaluating smart home research and approaches against the concept of home. *Energy Research and Social Science*, *37*(September 2017), 94–101. https://doi.org/10.1016/j.erss.2017.09.037

Gram-Hanssen, K., Hansen, A. R., & Mechlenborg, M. (2020). Danish PV prosumers' time-shifting of energy-consuming everyday practices. *Sustainability (Switzerland)*, *12*(10). https://doi.org/10.3390/su12104121

Groat, L. N., & Wang, D. (2013). *Architectural Research Methods* (2nd ed.). John Wiley & Sons, Incorporated.

Grunewald, P., & Diakonova, M. (2018). Flexibility, dynamism and diversity in energy supply and demand: A critical review. *Energy Research and Social Science*, *38*(January), 58–66. https://doi.org/10.1016/j.erss.2018.01.014

Guasselli, F., Vavouris, A., Stankovic, L., Stankovic, V., Didierjean, S., & Gram-Hanssen, K. (2024). Smart energy technologies for the collective: Time-shifting, demand reduction and household practices in a Positive Energy Neighbourhood in Norway. *Energy Research and Social Science*, *110*(August 2023). https://doi.org/10.1016/j.erss.2024.103436

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In *Handbook of qualitative research,* (pp. 163–194).

Gullstrand Edbring, E., Lehner, M., & Mont, O. (2016). Exploring consumer attitudes to alternative models of consumption: Motivations and barriers. *Journal of Cleaner Production*, *123*, 5–15. https://doi.org/10.1016/j.jclepro.2015.10.107

Hagejärd, S. (2020). *Towards a Circular Home: Exploring opportunities for design to support households in sustainable resource use* [Thesis for the degree of licentiate]. Chalmers University of Technology.

Hagejärd, S., Dokter, G., Rahe, U., & Femenías, P. (2021). My apartment is cold! Household perceptions of indoor climate and demand-side management in Sweden. *Energy Research and Social Science*, *73*. https://doi.org/10.1016/j.erss.2021.101948

Hagejärd, S., Dokter, G., Rahe, U., & Femenías, P. (2023). "It's never telling me that I'm good!" Household experiences of testing a smart home energy management system with a personal threshold on energy use in Sweden. *Energy Research & Social Science*, *98*(103004). https://doi.org/10.1016/j.erss.2023.103004

Hagejärd, S., Ollár, A., Femenías, P., & Rahe, U. (2020). Designing for Circularity—Addressing Product Design, Consumption Practices and Resource Flows in Domestic Kitchens. *Sustainability (Switzerland)*, *12*(3). https://doi.org/10.3390/su12031006

Hargreaves, T. (2018). Beyond energy feedback. *Building Research and Information*, *46*(3), 332–342. https://doi.org/10.1080/09613218.2017.1356140

Hargreaves, T., Wilson, C., & Hauxwell-Baldwin, R. (2018). Learning to live in a smart home. *Building Research and Information*, *46*(1), 127–139. https://doi.org/10.1080/09613218.2017.1286882

Hasselqvist, H., Renström, S., Strömberg, H., & Håkansson, M. (2022). Household energy resilience: Shifting perspectives to reveal opportunities for renewable energy futures in affluent contexts. *Energy Research and Social Science*, *88*, 102498. https://doi.org/10.1016/j.erss.2022.102498

Herrero, S. T., Nicholls, L., & Strengers, Y. (2018). Smart home technologies in everyday life: do they address key energy challenges in households? *Current Opinion in Environmental Sustainability*, *31*, 65–70. https://doi.org/10.1016/j.cosust.2017.12.001

Hitchings, R. (2012). People can talk about their practices. *Area*, *44*(1), 61–67. https://doi.org/10.1111/j.1475-4762.2011.01060.x

Hoolohan, C., & Browne, A. L. (2020). Design thinking for practice-based intervention: Co-producing the change points toolkit to unlock (un)sustainable practices. *Design Studies*, *67*, 102–132. https://doi.org/10.1016/j.destud.2019.12.002

IEA. (2023). *Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach*. https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach

IPCC. (2022). Climate Change 2022 - Mitigation of Climate Change. In *Cambridge University Press*.

Ivanova, D., Stadler, K., Steen-Olsen, K., Wood, R., Vita, G., Tukker, A., & Hertwich, E. G. (2016). Environmental Impact Assessment of Household Consumption. *Journal of Industrial Ecology*, *20*(3), 526–536. https://doi.org/10.1111/jiec.12371

Jansen, B. (2024). *The Circular Kitchen: Perspectives for Design and Implementation* [Delft University of Technology]. https://doi.org/10.7480/abe.2024.14

Jensen, R. H., Strengers, Y., Kjeldskov, J., Nicholls, L., & Skov, M. B. (2018). Designing the desirable smart home: A study of household experiences and energy consumption impacts. *Conference on Human Factors in Computing Systems - Proceedings*, *2018-April*, 1–14. https://doi.org/10.1145/3173574.3173578

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher*, *33*(7), 14–26. https://doi.org/10.3102/0013189X033007014

Karjalainen, S. (2013). Should it be automatic or manual - The occupant's perspective on the design of domestic control systems. *Energy and Buildings*, *65*, 119–126. https://doi.org/10.1016/j.enbuild.2013.05.043

Kendel, A., Lazaric, N., & Maréchal, K. (2017). What do people 'learn by looking' at direct feedback on their energy consumption? Results of a field study in Southern France. *Energy Policy*, *108*(February), 593–605. https://doi.org/10.1016/j.enpol.2017.06.020

Kensby, J., Trüschel, A., & Dalenbäck, J. O. (2015). Potential of residential buildings as thermal energy storage in district heating systems - Results from a pilot test. *Applied Energy*, *137*, 773–781. https://doi.org/10.1016/j.apenergy.2014.07.026

Keskin, D., Wever, R., & Brezet, H. (2020). Product innovation processes in sustainability-oriented ventures: A study of effectuation and causation. *Journal of Cleaner Production*, *263*, 121210. https://doi.org/10.1016/j.jclepro.2020.121210

Kirchherr, J., Yang, N. H. N., Schulze-Spüntrup, F., Heerink, M. J., & Hartley, K. (2023). Conceptualizing the Circular Economy (Revisited): An Analysis of 221 Definitions. *Resources, Conservation and Recycling*, *194*(April), 107001. https://doi.org/10.1016/j.resconrec.2023.107001

Kitzinger, J. (1995). Introducing Focus Groups. *British Medical Journal*, *311*(7000), 299–302.

Kivunja, C., & Kuyini, A. B. (2017). Understanding and Applying Research Paradigms in Educational Contexts. *International Journal of Higher Education*, *6*(5), 26. https://doi.org/10.5430/ijhe.v6n5p26

Koide, R., Lettenmeier, M., Akenji, L., Toivio, V., Amellina, A., Khodke, A., Watabe, A., & Kojima, S. (2021). Lifestyle carbon footprints and changes in lifestyles to limit global warming to 1.5 °C, and ways forward for related research. *Sustainability Science*, *16*(6), 2087–2099. https://doi.org/10.1007/s11625-021-01018-6

Korhonen, J., Honkasalo, A., & Seppälä, J. (2018). Circular Economy: The Concept and its Limitations. *Ecological Economics*, *143*, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041

Krych, K., & Pettersen, J. B. (2024). Long-term lifetime trends of large appliances since the introduction in Norwegian households. *Journal of Industrial Ecology*, 1–15. https://doi.org/10.1111/jiec.13608

Kuijer, L. (2014). *Implications of Social Practice Theory for Sustainable Design* [Thesis for the degree of Doctor of Philosophy]. Delft University of Technology.

Kuijer, L., & Bakker, C. (2015). Of chalk and cheese: behaviour change and practice theory in sustainable design. *International Journal of Sustainable Engineering*, *8*(3), 219–230. https://doi.org/10.1080/19397038.2015.1011729

Kvale, S. (1995). The Social Construction of Validity. *Qualitative Inquiry*, *1*(1), 19–40.

Larsen, S. P., Gram-Hanssen, K., & Madsen, L. V. (2023). In Control or Being Controlled? Investigating the Control of Space Heating in Smart Homes. *Sustainability*, *15*(9489). https://doi.org/10.3390/su15129489

Larsen, S. P., & Johra, H. (2019). User engagement with smart home technology for enabling building energy flexibility in a district heating system. *IOP*

Conference Series: Earth and Environmental Science, *352*(1). https://doi.org/10.1088/1755-1315/352/1/012002
Linder, M., & Williander, M. (2017). Circular Business Model Innovation: Inherent Uncertainties. *Business Strategy and the Environment*, *26*(2), 182–196. https://doi.org/10.1002/bse.1906
Liu, Y., Qu, Y., Lei, Z., & Jia, H. (2017). Understanding the Evolution of Sustainable Consumption Research. *Sustainable Development*, *25*(5), 414–430. https://doi.org/10.1002/sd.1671
Lorek, S., & Fuchs, D. (2013). Strong sustainable consumption governance - Precondition for a degrowth path? *Journal of Cleaner Production*, *38*, 36–43. https://doi.org/10.1016/j.jclepro.2011.08.008
Lorek, S., & Spangenberg, J. H. (2014). Sustainable consumption within a sustainable economy - Beyond green growth and green economies. *Journal of Cleaner Production*, *63*, 33–44. https://doi.org/10.1016/j.jclepro.2013.08.045
Lüdeke-Freund, F., Gold, S., & Bocken, N. M. P. (2019). A Review and Typology of Circular Economy Business Model Patterns. *Journal of Industrial Ecology*, *23*(1), 36–61. https://doi.org/10.1111/jiec.12763
Lund, H., Østergaard, P. A., Connolly, D., & Mathiesen, B. V. (2017). Smart energy and smart energy systems. *Energy*, *137*, 556–565. https://doi.org/10.1016/j.energy.2017.05.123
Madsen, L. V., & Gram-Hanssen, K. (2017). Understanding comfort and senses in social practice theory: Insights from a Danish field study. *Energy Research and Social Science*, *29*, 86–94. https://doi.org/10.1016/j.erss.2017.05.013
Maréchal, K. (2010). Not irrational but habitual: The importance of "behavioural lock-in" in energy consumption. *Ecological Economics*, *69*(5), 1104–1114. https://doi.org/10.1016/j.ecolecon.2009.12.004
Martin, R., & Strengers, Y. (2024). Non-energy feedback: The unseen impacts of sensory, social, material and systemic feedback on household energy demand. *Energy Research and Social Science*, *113*(March), 103560. https://doi.org/10.1016/j.erss.2024.103560
Mathiesen, B. V, Lund, H., Connolly, D., Wenzel, H., Østergaard, P. A., Möller, B., Nielsen, S., Ridjan, I., Karnøe, P., Sperling, K., & Hvelplund, F. K. (2015). Smart Energy Systems for coherent 100% renewable energy and transport solutions. *Applied Energy*, *145*, 139–154. https://doi.org/10.1016/j.apenergy.2015.01.075
McIlvennie, C., Sanguinetti, A., & Pritoni, M. (2020). Of impacts, agents, and functions: An interdisciplinary meta-review of smart home energy management systems research. *Energy Research and Social Science*, *68*, 101555. https://doi.org/10.1016/j.erss.2020.101555
Mennicken, S., & Huang, E. M. (2012). Hacking the Natural Habitat: An In-the-Wild Study of Smart Homes, Their Development, and the People Who Live in Them. *10th International Conference on Pervasive Computing*, 143–160.

Mont, O., & Lehner, M. (2023). From sufficiency to sustainable abundance: dispelling a myth. *Paper Presented at 5th SCORAI, 21st ERSCP, and Wageningen University Conference, Wageningen, Netherlands*, 1–10. https://osf.io/79asj

Moreno, M., De los Rios, C., Rowe, Z., & Charnley, F. (2016). A conceptual framework for circular design. *Sustainability (Switzerland)*, *8*(9). https://doi.org/10.3390/su8090937

Morgan, D. L. (2014). Pragmatism as a Paradigm for Social Research. *Qualitative Inquiry*, *20*(8), 1045–1053. https://doi.org/10.1177/1077800413513733

Muylaert, C., Thiry, G., Roman, P., Ruwet, C., De Hoe, R., & Maréchal, K. (2022). Consumer perception of product-service systems: Depicting sector-specific barriers in the mobility, clothing and tooling sectors. *Frontiers in Environmental Science*, *10*(November), 1–16. https://doi.org/10.3389/fenvs.2022.1048554

Naturskyddsföreningen. (2023). *Bästa bohaget: Miljövinsten med begagnat*. https://www.naturskyddsforeningen.se/artiklar/basta-bohaget/

Naus, J., Van Vliet, B. J. M., & Hendriksen, A. (2015). Households as change agents in a Dutch smart energy transition: On power, privacy and participation. *Energy Research and Social Science*, *9*, 125–136. https://doi.org/10.1016/j.erss.2015.08.025

Nicholls, L., & Strengers, Y. (2015). Peak demand and the 'family peak' period in Australia: Understanding practice (in)flexibility in households with children. *Energy Research & Social Science*, *9*, 116–124. https://doi.org/10.1016/j.erss.2015.08.018

Nicolini, D. (2009). Articulating practice through the interview to the double. *Management Learning*, *40*(2), 195–212. https://doi.org/10.1177/1350507608101230

Nicolini, D. (2017). Practice Theory as a Package of Theory, Method and Vocabulary: Affordances and Limitations. In M. Jonas, B. Littig, & A. Wroblewski (Eds.), *Methodological Reflections on Practice Oriented Theories* (pp. 1–261). Springer International Publishing AG. https://doi.org/10.1007/978-3-319-52897-7

Noy, C. (2008). Sampling knowledge: The hermeneutics of snowball sampling in qualitative research. *International Journal of Social Research Methodology*, *11*(4), 327–344. https://doi.org/10.1080/13645570701401305

Nußholz, J. L. K. (2017). Circular business models: Defining a concept and framing an emerging research field. *Sustainability (Switzerland)*, *9*(10), 14–17. https://doi.org/10.3390/su9101810

Nyborg, S. (2015a). Pilot users and their families: Inventing flexible practices in the smart grid. *Science and Technology Studies*, *28*(3), 54–80.

Nyborg, S. (2015b). Pilot Users and Their Families: Inventing Flexible Practices in the Smart Grid. *Science & Technology Studies*, *28*(3), 54–80. https://doi.org/https://doi.org/10.23987/sts.55342

Nyborg, S., & Røpke, I. (2013). Constructing users in the smart grid—insights from the Danish eFlex project. *Energy Efficiency*, *6*(4), 655–670. https://doi.org/10.1007/s12053-013-9210-1

Nyström, S., Börjesson Rivera, M., & Katzeff, C. (2024). Households as part of the solution - Examining Swedish policy expectations on demand response in households. *Energy Policy*, *189*(March). https://doi.org/10.1016/j.enpol.2024.114118

Nyström, S., Katzeff, C., & Rivera, M. B. (2024). Home-personas meet energy narratives of demand response: Uncovering mismatches between Swedish stakeholder expectations and everyday life. *Futures*, *161*(June). https://doi.org/10.1016/j.futures.2024.103410

Öhrlund, I., Linné, Å., & Bartusch, C. (2019). Convenience before coins: Household responses to dual dynamic price signals and energy feedback in Sweden. *Energy Research and Social Science*, *52*(February), 236–246. https://doi.org/10.1016/j.erss.2019.02.008

Ollár, A. (2024). *Spatial Design for Circularity in Residential Buildings: Exploring the Case of the Kitchen* [Chalmers University of Technology]. https://research.chalmers.se/publication/541775

Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation*. John Wiley & Sons.

Pantzar, M., & Shove, E. (2010). Understanding innovation in practice: a discussion of the production and re-production of nordic walking. *Technology Analysis and Strategic Management*, *22*(4), 447–461. https://doi.org/10.1080/09537321003714402

Parker, A., & Tritter, J. (2006). Focus group method and methodology: Current practice and recent debate. *International Journal of Research and Method in Education*, *29*(1), 23–37. https://doi.org/10.1080/01406720500537304

Pettersen, I. N. (2013). *Changing Practices: The Role of Design in Supporting the Sustainability of Everyday Life*. Norwegian University of Science and Technology (NTNU).

Pettersen, I. N. (2015). Towards practice-oriented design for sustainability: The compatibility with selected design fields. *International Journal of Sustainable Engineering*, *8*(3), 206–218. https://doi.org/10.1080/19397038.2014.1001468

Pettersen, I. N. (2016). Fostering absolute reductions in resource use: the potential role and feasibility of practice-oriented design. *Journal of Cleaner Production*, *132*, 252–265. https://doi.org/10.1016/j.jclepro.2015.02.005

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). Circular economy: Measuring innovation in the product chain. *PBL Netherlands Environmental Assessment Agency*, *2544*, 42.

Powells, G., & Fell, M. J. (2019). Flexibility capital and flexibility justice in smart energy systems. *Energy Research and Social Science*, *54*(March), 56–59. https://doi.org/10.1016/j.erss.2019.03.015

Quoquab, F., & Mohammad, J. (2020). A Review of Sustainable Consumption (2000 to 2020): What We Know and What We Need to Know. *Journal of Global Marketing*, *33*(5), 305–334. https://doi.org/10.1080/08911762.2020.1811441

Rabiu, M. K., & Jaeger-Erben, M. (2022). Appropriation and routinisation of circular consumer practices: A review of current knowledge in the circular

economy literature. *Cleaner and Responsible Consumption*, *7*(September 2021). https://doi.org/10.1016/j.clrc.2022.100081
Raworth, K. (2017). *Doughnut economics: Seven ways to think like a 21st-Century economist*. Random House Business Books.
Reckwitz, A. (2002). Toward a Theory of Social Practices: A Development in Culturalist Theorizing. *European Journal of Social Theory*, *5*(2), 243–263. https://doi.org/10.1177/13684310222225432
Regeringskansliet. (2020). *Cirkulär ekonomi - strategi för omställningen i Sverige*. https://www.regeringen.se/4a3baa/contentassets/619d1bb3588446deb6dac198f2fe4120/200814_ce_webb.pdf
Reisch, L. A., & Thøgersen, J. (2015). Research on sustainable consumption: Introduction and overview. In *Handbook of Research on Sustainable Consumption* (pp. 1–17). Edward Elgar Publishing Limited.
Reisinger, M. R., Prost, S., Schrammel, J., & Fröhlich, P. (2022). User requirements for the design of smart homes: dimensions and goals. *Journal of Ambient Intelligence and Humanized Computing*, *0123456789*. https://doi.org/10.1007/s12652-021-03651-6
Renström, S. (2019a). *Participating in Energy Systems through Everyday Designs: Exploring roles for households in a more sustainable energy future*. Chalmers University of Technology.
Renström, S. (2019b). Supporting diverse roles for people in smart energy systems. *Energy Research & Social Science*, *53*(July 2018), 98–109. https://doi.org/10.1016/j.erss.2019.02.018
Renström, S., Andersson, S., Jonasson, A., Rahe, U., Merl, K., & Sundgren, M. (2019). Limit My Energy Use! An In-Situ Exploration of a Smart Home System Featuring an Adaptive Energy Threshold. *19th Conference of the European Roundtable on Sustainable Consumption and Production (ERSCP): Circular Europe for Sustainability – Design, Production and Consumption*.
Renström, S., Strömberg, H., & Rahe, U. (2017). Design for alternative ways of doing – explorations in the context of thermal comfort. *Journal of Design Research*, *15*(3–4), 153–173. https://doi.org/10.1504/JDR.2017.089911
Rexfelt, O., & Hiort Af Ornäs, V. (2009). Consumer acceptance of product-service systems: Designing for relative advantages and uncertainty reductions. *Journal of Manufacturing Technology Management*, *20*(5), 674–699. https://doi.org/10.1108/17410380910961055
Reynders, G., Amaral Lopes, R., Marszal-Pomianowska, A., Aelenei, D., Martins, J., & Saelens, D. (2018). Energy flexible buildings: An evaluation of definitions and quantification methodologies applied to thermal storage. *Energy and Buildings*, *166*, 372–390. https://doi.org/10.1016/j.enbuild.2018.02.040
Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., … Rockström, J. (2023). Earth beyond six of nine

planetary boundaries. *Science Advances*, *9*(37), 1–16. https://doi.org/10.1126/sciadv.adh2458
Richter, J. L., Lehner, M., Elfström, A., Henman, J., Vadovics, E., Brizga, J., Plepys, A., & Mont, O. (2024). 1.5° lifestyle changes: Exploring consequences for individuals and households. *Sustainable Production and Consumption*, *50*(March), 511–525. https://doi.org/10.1016/j.spc.2024.07.018
Rittel, H. W. J., & Webber, M. M. (2017). Dilemmas in a general theory of planning. *Foundations of the Planning Enterprise: Critical Essays in Planning Theory: Volume 1*, *4*(December 1969), 67–169. https://doi.org/10.4324/9781315255101-12
Robison, R., Skjølsvold, T. M., Hargreaves, T., Renström, S., Wolsink, M., Judson, E., Pechancová, V., Demirbağ-Kaplan, M., March, H., Lehne, J., Foulds, C., Bharucha, Z., Bilous, L., Büscher, C., Carrus, G., Darby, S., Douzou, S., Drevenšek, M., Frantál, B., … Wyckmans, A. (2023). Shifts in the smart research agenda? 100 priority questions to accelerate sustainable energy futures. *Journal of Cleaner Production*, *419*(July). https://doi.org/10.1016/j.jclepro.2023.137946
Rockström, J., Gupta, J., Qin, D., Lade, S. J., Abrams, J. F., Andersen, L. S., Armstrong McKay, D. I., Bai, X., Bala, G., Bunn, S. E., Ciobanu, D., DeClerck, F., Ebi, K., Gifford, L., Gordon, C., Hasan, S., Kanie, N., Lenton, T. M., Loriani, S., … Zhang, X. (2023). Safe and just Earth system boundaries. *Nature*, *619*(7968), 102–111. https://doi.org/10.1038/s41586-023-06083-8
Sandberg, M. (2021). Sufficiency transitions: A review of consumption changes for environmental sustainability. *Journal of Cleaner Production*, *293*, 126097. https://doi.org/10.1016/j.jclepro.2021.126097
SCB. (2023). *Boende i Sverige*. https://www.scb.se/hitta-statistik/sverige-i-siffror/manniskorna-i-sverige/boende-i-sverige/
Schatzki, T. R. (2002). *The Site of the Social: A Philosophical Account of the Constitution of Social Life and Change*. Pennsylvania State University Press.
Schot, J., Kanger, L., & Verbong, G. (2016). The roles of users in shaping transitions to new energy systems. *Nature Energy*, *1*(May). https://doi.org/10.1038/nenergy.2016.54
Scott, K., Bakker, C., & Quist, J. (2012). Designing change by living change. *Design Studies*, *33*(3), 279–297. https://doi.org/10.1016/j.destud.2011.08.002
Selvefors, A., Rexfelt, O., Renström, S., & Strömberg, H. (2019). Use to use – A user perspective on product circularity. *Journal of Cleaner Production*, *223*, 1014–1028. https://doi.org/10.1016/j.jclepro.2019.03.117
Sheridan, T. B., & Verplank, W. L. (1978). *Human and Computer Control of Undersea Teleoperators*. MIT Man-Machine Laboratory.
Shove, E., Pantzar, M., & Watson, M. (2012). *The Dynamics of Social Practice: Everyday Life and how it Changes*. SAGE Publications Ltd.
Sigüenza, C. P., Cucurachi, S., & Tukker, A. (2021). Circular business models of washing machines in the Netherlands: Material and climate change

implications toward 2050. *Sustainable Production and Consumption*, *26*, 1084–1098. https://doi.org/10.1016/j.spc.2021.01.011

Skjølsvold, T. M., Jørgensen, S., & Ryghaug, M. (2017). Users, design and the role of feedback technologies in the Norwegian energy transition: An empirical study and some radical challenges. *Energy Research and Social Science*, *25*, 1–8. https://doi.org/10.1016/j.erss.2016.11.005

Smale, R., van Vliet, B., & Spaargaren, G. (2017). When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands. *Energy Research and Social Science*, *34*, 132–140. https://doi.org/10.1016/j.erss.2017.06.037

Soergel, B., Rauner, S., Daioglou, V., Weindl, I., Mastrucci, A., Carrer, F., Kikstra, J., Ambrósio, G., Aguiar, A. P. D., Baumstark, L., Bodirsky, B. L., Bos, A., Dietrich, J. P., Dirnaichner, A., Doelman, J. C., Hasse, R., Hernandez, A., Hoppe, J., Humpenöder, F., … Kriegler, E. (2024). Multiple pathways towards sustainable development goals and climate targets. *Environmental Research Letters* , *19*(12). https://doi.org/10.1088/1748-9326/ad80af

Southerton, D. (2012). Habits, routines and temporalities of consumption: From individual behaviours to the reproduction of everyday practices. *Time & Society*, *22*(3), 335–355. https://doi.org/10.1177/0961463X12464228

Sovacool, B. K., & Furszyfer Del Rio, D. D. (2020). Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies. *Renewable and Sustainable Energy Reviews*, *120*(May 2019), 109663. https://doi.org/10.1016/j.rser.2019.109663

Spengler, L. (2016). Two types of 'enough': sufficiency as minimum and maximum. *Environmental Politics*, *25*(5), 921–940. https://doi.org/10.1080/09644016.2016.1164355

Stappers, P. J. (2007). Doing Design as a Part of Doing Research. In R. Michel (Ed.), *Design Research Now* (pp. 81–91). Birkhäuser Basel. https://doi.org/10.1007/978-3-7643-8472-2_6

Stappers, P. J., & Giaccardi, E. (2017). Research through Design. In M. Soegaard & R. Friis-Dam (Eds.), *The Encyclopedia of Human-Computer Interaction* (2nd editio). https://www.interaction-design.org/literature/book/the-encyclopedia-of-human-computer-interaction-2nd-ed/research-through-design

Strengers, Y. (2013). *Smart energy technologies in everyday life: Smart Utopia?* Palgrave Macmillan.

Strengers, Y. (2014). Smart energy in everyday life: Are You Designing for Resource Man? *Interactions*, *21*(4), 24–31. https://doi.org/10.1145/2621931

Strengers, Y., Hazas, M., Nicholls, L., Kjeldskov, J., & Skov, M. B. (2020). Pursuing pleasance: Interrogating energy-intensive visions for the smart home. *International Journal of Human Computer Studies*, *136*, 102379. https://doi.org/10.1016/j.ijhcs.2019.102379

Sumter, D., de Koning, J., Bakker, C., & Balkenende, R. (2020). Circular economy competencies for design. *Sustainability (Switzerland)*, *12*(4), 1–16. https://doi.org/10.3390/su12041561

Suski, P., Palzkill, A., & Speck, M. (2023). Sufficiency in social practices: An underestimated potential for the transformation to a circular economy. *Frontiers in Sustainability*, *3*. https://doi.org/10.3389/frsus.2022.1008165

Svenska Kraftnät. (2024). *Om olika energikällor*. https://www.svk.se/om-kraftsystemet/om-olika-energikallor/

Sweetnam, T., Spataru, C., Barrett, M., & Carter, E. (2019). Domestic demand-side response on district heating networks. *Building Research and Information*, *47*(4), 330–343. https://doi.org/10.1080/09613218.2018.1426314

Teece, D. J. (2010). Business models, business strategy and innovation. *Long Range Planning*, *43*(2–3), 172–194. https://doi.org/10.1016/j.lrp.2009.07.003

Tidningen Energi. (2022). *Allt fler elkunder väljer timavtal*. https://www.energi.se/artiklar/2022/augusti-2022/allt-fler-elkunder-valjer-timavtal/

Tippe, M., Wigger, H., Brand-Daniels, U., & Vogt, T. (2025). Operationalising user behaviour: a study on the life cycle assessment of smart home technologies. *Energy, Sustainability and Society*, *15*(1). https://doi.org/10.1186/s13705-024-00506-8

Tracy, S. J. (2010). Qualitative quality: Eight a"big-tent" criteria for excellent qualitative research. *Qualitative Inquiry*, *16*(10), 837–851. https://doi.org/10.1177/1077800410383121

Tukker, A. (2004). Eight types of product-service system: eight ways to sustainability? Experiences from Suspronet. *Business Strategy and the Environment*, *13*, 246–260. https://doi.org/10.1002/bse.414

Tukker, A. (2015). Product services for a resource-efficient and circular economy - a review. *Journal of Cleaner Production*, *97*, 76–91. https://doi.org/10.1016/j.jclepro.2013.11.049

Tunn, V. S. C., Van den Hende, E. A., Bocken, N. M. P., & Schoormans, J. P. L. (2021). Consumer adoption of access-based product-service systems: The influence of duration of use and type of product. *Business Strategy and the Environment*, *30*(6), 2796–2813. https://doi.org/10.1002/bse.2894

United Nations Environment Programme. (2024). *Global Resources Outlook 2024: Bend the Trend – Pathways to a liveable planet as resource use spikes*. International Resource Panel. https://wedocs.unep.org/20.500.11822/44901

Vadovics, E., Richter, J. L., Tornow, M., Ozcelik, N., Coscieme, L., Lettenmeier, M., Csiki, E., Domröse, L., Cap, S., Puente, L. L., Belousa, I., & Scherer, L. (2024). Preferences, enablers, and barriers for 1.5°C lifestyle options: Findings from Citizen Thinking Labs in five European Union countries. *Sustainability: Science, Practice, and Policy*, *20*(1). https://doi.org/10.1080/15487733.2024.2375806

Van Moeseke, G., De Grave, D., Anciaux, A., Sobczak, J., & Wallenborn, G. (2024). New insights into thermal comfort sufficiency in dwellings. *Buildings & Cities*, *5*(1). https://doi.org/10.5334/bc.444

van Stijn, A. (2023). *Developing circular building components: Between ideal and feasible* [Delft University of Technology]. https://doi.org/10.7480/abe.2023.05

Van Weelden, E., Mugge, R., & Bakker, C. (2016). Paving the way towards circular consumption: Exploring consumer acceptance of refurbished mobile phones in the Dutch market. *Journal of Cleaner Production*, *113*, 743–754. https://doi.org/10.1016/j.jclepro.2015.11.065

Verkade, N., & Höffken, J. (2017). Is the Resource Man coming home? Engaging with an energy monitoring platform to foster flexible energy consumption in the Netherlands. *Energy Research & Social Science*, *27*, 36–44. https://doi.org/10.1016/j.erss.2017.02.015

Vita, G., Lundström, J. R., Hertwich, E. G., Quist, J., Ivanova, D., Stadler, K., & Wood, R. (2019). The Environmental Impact of Green Consumption and Sufficiency Lifestyles Scenarios in Europe: Connecting Local Sustainability Visions to Global Consequences. *Ecological Economics*, *164*(May), 106322. https://doi.org/10.1016/j.ecolecon.2019.05.002

Wang, F., Huisman, J., Stevels, A., & Baldé, C. P. (2013). Enhancing e-waste estimates: Improving data quality by multivariate Input-Output Analysis. *Waste Management*, *33*(11), 2397–2407. https://doi.org/10.1016/j.wasman.2013.07.005

Warde, A. (2005). Consumption and theories of practice. *Journal of Consumer Culture*, *5*(2), 131–153. https://doi.org/10.1177/1469540505053090

Wastling, T., Charnley, F., & Moreno, M. (2018). Design for circular behaviour: Considering users in a circular economy. *Sustainability (Switzerland)*, *10*(6). https://doi.org/10.3390/su10061743

Werner, S. (2017). District heating and cooling in Sweden. *Energy*, *126*, 419–429. https://doi.org/10.1016/j.energy.2017.03.052

Wilson, C., Hargreaves, T., & Hauxwell-Baldwin, R. (2015). Smart homes and their users: a systematic analysis and key challenges. *Personal and Ubiquitous Computing*, *19*(2), 463–476. https://doi.org/10.1007/s00779-014-0813-0

Wolske, K. S., Gillingham, K. T., & Schultz, P. W. (2020). Peer influence on household energy behaviours. *Nature Energy*, *5*(3), 202–212. https://doi.org/10.1038/s41560-019-0541-9

Woods, R., Heidenreich, S., Korsnes, M., & Solbu, G. (2024). Energy-efficiency policies reinforce energy injustices: The caring energy practices of low-income households in Norway. *Energy Research and Social Science*, *116*(November 2023), 103663. https://doi.org/10.1016/j.erss.2024.103663

World Commission on Environment and Development. (1987). *Our Common Future*. https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf

Zangheri, P., Serrenho, T., & Bertoldi, P. (2019). Energy savings from feedback systems: A meta-studies' review. *Energies*, *12*(19). https://doi.org/10.3390/en12193788

Zimmerman, J., & Forlizzi, J. (2014). Research Through Design in HCI. In J. S. Olson & W. A. Kellogg (Eds.), *Ways of Knowing in HCI* (pp. 167–189). Springer Science+Business Media. https://doi.org/10.1007/978-1-4939-0378-8