Social Structures of households' Heat Consumption

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CV

Anders Rhiger Hansen has a bachelor's degree in sociology from Aalborg University and a master's degree in sociology from the University of Copenhagen with a specialisation in quantitative sociological methods (MSc Sociology[1]). He finished his master's thesis in 2013 and shortly after became a PhD student at the Danish Building Research Institute (SBi) at Aalborg University.

His master's thesis was written in collaboration with the Danish Building Research Institute. The thesis investigated the housing careers of immigrants coming to Denmark based on Bourdieu's theory on the homological relationship between social and spatial structures, and with the use of cluster and regression techniques. Anders is part of the 'Sustainable Cities and Housing Research Group'[2] at SBi, whose research revolves around the interaction between technology, users and planning.

Anders's PhD is concerned with the social structures of households' consumption of energy used for space heating and hot water. He investigates this from a social practice perspective using quantitative data and methods. In so doing, he explores a rather overlooked sociological aspect of energy consumption.

The PhD forms part of the UserTEC project funded by Innovation Fond Denmark.

[1] In Danish cand.scient soc

[2] http://www.sbi.dk/om-sbi/afdelinger/by-bolig-og-ejendom/sustainable-cities-and-housing-research-group

ENGLISH SUMMARY

Although earlier sociological studies of energy consumption investigated the social structures of energy consumption using quantitative methods and data, this approach and focus seem to have been forgotten in more recent studies. This dissertation aims to reintroduce a quantitative sociological approach by investigating the social structures of energy consumption using the empirical case of energy used for space heating and hot water in Danish single-family detached houses. The objective of the dissertation is to provide empirical evidence on why households consume energy differently by focusing on structural aspects such as socio-cultural differences between households, including how embodied habits and cultural understandings are shared and reproduced through social group affiliation.

The dissertation consists of four empirical papers and one theoretical paper. The empirical papers use different econometric techniques on various forms of data, which include annual heat consumption, survey data, and administrative data.

The theoretical basis of the dissertation is inspired by three related theoretical accounts. The first inspiration is Bourdieu's version of practice theory with a focus on the homological relationship between objective social structures (for example social group affiliation), cognitive dispositions (for example cultural understandings), and practice. The second inspiration is the version of practice theory that has been developed within energy consumption research, primarily represented in the works of Shove and Gram-Hanssen, where the focus is on how energy consumption results from the performance of socially and materially configured everyday practices. The third inspiration is Lutzenhiser and Hackett's cultural approach to studying energy consumption with a focus on energy as embedded in social structures and statuses.

In the dissertation, I show that heat-related habits, and the opportunity to adjust these habits, depend on the social and material contexts, which I argue reflects differences in embodied habits and cultural understandings of appropriate ways of acting. I also show that approximately one third of social differences between households (based on income and education) reflect differences in heat-related habits, while the remaining two thirds reflect differences in housing and household composition. Furthermore, I show how heat consumption patterns are similar to the patterns of parents, which suggests that family relations play a very important role in the production and reproduction of embodied heat-related habits.

With this dissertation, I contribute to the sociological field of energy consumption with new empirical evidence on the social structures of households' heat consumption and the reproduction of embodied habits. Moreover, I contribute with

sociological interpretations on well-known empirical correlations, for example the correlation between energy prices and energy consumption.

In doing so, I contribute to reintroducing quantitative sociological methods to investigate energy consumption together with an outline of a theoretical framework to understand social structures of energy consumption. Thus, this dissertation demonstrates the huge potential of a quantitative sociological approach to better understand how and why households consume energy as they do, and moreover, to better inform energy policy from a sociological perspective.

DANSK RESUME

Hvor tidligere sociologiske studier undersøgte den sociale struktur af energiforbrug ved hjælp af kvantitative metoder og data, så er denne tilgang og fokus underbelyst i nyere sociologiske studier. Denne afhandling sigter derfor efter at reintroducere en kvantitativ, sociologisk tilgang ved at undersøge den sociale struktur af energiforbrug på baggrund af den empiriske case, som er danske husstandes forbrug af energi til rumopvarmning og opvarmning af vand i enfamilies huse. Formålet med afhandlingen er at levere empirisk evidens til at forklare hvorfor husstande forbruger energi forskelligt ved at undersøge betydningen af strukturelle forhold som sociokulturelle forskelle mellem husstande, herunder hvordan kropsliggjorte vaner og kulturelle forståelser er delt og reproduceret gennem social gruppe tilhørsforhold.

Afhandlingen består af fire empiriske artikler og en teoretisk artikel. De empiriske analyser er baseret på forskellige former for data, som inkluderer årligt varmeforbrug, survey-data og register data, som bliver undersøgt ved hjælp af forskellige former for økonometriske metoder.

Det teoretiske grundlag for afhandlingen er inspireret af tre beslægtede teoretiske udlægninger. Den første inspiration er Bourdieu's version af praksisteori med fokus på homologe forhold mellem objektive sociale strukturer (for eksempel social gruppe tilhørsforhold), kognitive dispositioner (for eksempel kulturelle forståelser) og praksis. Den anden inspiration er den version af social praksisteori som er udviklet indenfor energiforbrugsforskning, og primært præsenteret i Shoves og Gram-Hanssens arbejde, hvor fokus er på, hvordan energiforbrug er et produkt af udførelsen af socialt og materielt konfigurerede hverdagspraksisser. Den tredje inspiration er Lutzenhiser og Hacketts kulturelle tilgang til at studere energiforbrug med fokus på energi som indlejret i sociale strukturer og statusser.

I afhandlingen viser jeg, hvordan varme-relaterede vaner, og muligheden for at justere disse vaner, afhænger af den sociale og materielle kontekst, hvilket, jeg argumenterer for, reflekterer forskelle i kropsliggjorte vaner og kulturelle forståelser af passende måder at handle på. Jeg viser også, at cirka en tredjedel af de sociale forskelle mellem husstande (baseret på uddannelse og indkomst) relaterer sig til forskelle i varme-relaterede vaner, mens de resterende to tredjedele relaterer sig til forskelle i boligforhold og husstandssammensætning. Endvidere viser jeg, hvordan varmeforbrugsmønstre ligner forældrenes, hvilket indikerer, at familierelationer spiller en meget vigtig rolle i produktion og reproduktion af kropsliggjorte vaner.

Med denne afhandling bidrager jeg til det sociologiske felt for energiforbrug med ny empirisk evidens om den sociale struktur af husstandes varmeforbrug og den kulturelle reproduktion af kropsliggjorte vaner. Derudover bidrager jeg med sociologiske fortolkninger på kendte empiriske sammenhænge som for eksempel

sammenhængen mellem energipriser og energiforbrug. Derved bidrager jeg til at reintroducere sociologisk, kvantitative metoder til at undersøge energiforbrug samtidig med, at jeg skitserer en tilhørende sociologisk teoretisk ramme til at forstå sociale strukturer af energiforbrug. Således demonstrerer denne afhandling det kæmpe potentiale, der ligger i en kvantitativ, sociologisk tilgang til bedre at undersøge, hvordan og hvorfor husstande forbruger energi, som de gør, samt til bedre at kunne bidrage med sociologisk viden til politikudvikling.

MANDATORY PAGE

Title: *Social Structures of Households' Heat Consumption*

PhD Student: Anders Rhiger Hansen

Main supervisor: Kirsten Gram-Hanssen

Co-supervisor: Anders Holm

The Thesis comprises five papers:

Paper I — Hansen, Anders Rhiger (2016), *The social structure of heat consumption in Denmark: New interpretations from quantitative analysis*. Energy Research & Social Science 11, 109-118. doi:10.1016/j.erss.2015.09.002

Paper II — Hansen, Anders Rhiger, *Heating homes: Understanding the impact of prices*. Submitted to *Energy Economics.*

Paper III — Hansen, Anders Rhiger, Kirsten Gram-Hanssen and Henrik N. Knudsen, *Material and social structures of heat-related habits.* Invited for revise and resubmit in *Building Research & Information*.

Paper IV — Hansen, Anders Rhiger and Mette Hove Jacobsen, *Reproduction of habits: Do adults share inconspicuous consumption practices with their parents?* Under review in *American Journal of Sociology*.

Paper V — Jacobsen, Mette Hove and Anders Rhiger Hansen, *(Re)introducing embodied practical understandings to the sociology of sustainable consumption.* Submitted to *Journal of Consumer Culture*.

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This PhD dissertation has been a tough, but also rewarding process, and fortunately, I've received help from a lot of people that I would now like to thank.

First of all, I would like to thank my main supervisor, Professor MSO Kirsten Gram-Hanssen. As project leader of UserTEC, of which my PhD forms part of, she encouraged me to apply for the job after recommendations from my colleagues Rikke Skovgaard Nielsen and Hans Skifter Andersen. Thus, Kirsten introduced me to the sociological field of energy consumption, which was totally new to me. As a true sociologist, I was sceptical at the start, but since then I have only become more and more committed. Today, I'm very concerned about the consequences of the world's current levels of (energy) consumption, convinced about the importance of social science research on energy consumption, and enthusiastic about the potential role of sociology in contributing to dealing with these problems. This is an agenda of which I hope to be part of in the future. Finally, I need to thank Kirsten for believing in me and my ideas.

As Kirsten only works with qualitative methods, I needed a co-supervisor, and I'm honoured that Professor Anders Holm said yes. I've learned a great deal from Anders, not merely on econometrics and quantitative sociology, but also on making sound decisions and forming clear sociological paper narratives. It has been challenging at times that Kirsten and Anders came from such different sociological fields with very different sociological approaches, but on the bright side, my position has been located right in the middle of their positions.

Moreover, I owe a special thanks to my PhD colleagues Mette Hove Jacobsen, Line Valdorff Madsen and Freja Friis for nerdy discussions and moral support, but also for being great company and source of a lot of laughter. Especially Mette, with whom I ended up writing two papers, has had a great impact on this dissertation by contributing to strengthen my sociological competences and imagination. We complement one another and I hope that we can continue working together in the future.

Furthermore, I would like to thank my colleagues at the Danish Building Research Institute, especially Toke Haunstrup Christensen for insights and discussions and Henrik N. Knudsen for co-authoring a paper, commenting on the dissertation and for being a constant reminder of the more technical way of seeing energy consumption.

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During the conferences and seminars that I attended during my PhD, I have met many prominent people within the field, for example Yolande Strengers, Alan Warde, Elizabeth Shove, Russell Hitchings, and Mikko Jalas. These conversations have encouraged me to stay sharp and to prove the worth of my ideas within the field.

I also need to thank Ulrik Nielsen and Lars Misser from the Ministry of Taxation for helpfully answering all my questions regarding heat consumption data and accommodated my wishes regarding this data.

Finally, I wish to thank my family and particularly my girlfriend Sofie for support and for reminding me that there are more important things in life than work such as our three-year-old twins.

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

The everyday lives of households are heavily dependent on energy consumption, and in places like Denmark, this particularly concerns energy used for heating homes, which together with domestic hot water covers approximately 80% of households' total energy consumption (Energistyrelsen, 2015, p. 35). In addition to the dependency of energy in everyday life, research on households' energy consumption is highly relevant because the current amount of energy consumed by households has an adverse impact on the environment as, for example, households account for approximately one-fourth of the total energy consumption in OECD countries (IEA, 2015). Knowledge of how households consume energy is therefore crucial to ensure a sustainable and energy secure future. Insights from "objective" disciplines such as engineering and economics have dominated energy studies, whilst insights from studies from other social science fields such as sociology have been treated as secondary (Sovacool, 2014). However, as attention to social differences in final consumption is required to understand the dynamics of sustainable development (McMeekin and Southerton, 2012), and there is a need for social science perspectives that go beyond the economic and technological perspectives and illuminate the world as more complex and heterogeneous (Lutzenhiser, 2014), sociological evidence on energy consumption could play a more important role in ensuring the sustainable development of society.

While earlier sociological studies of energy consumption studied the social structures of energy consumption to understand why households consume as they do based on quantitative data and methods (Hackett and Lutzenhiser, 1991; Lutzenhiser and Hackett, 1993), this approach seem to have been forgotten in more recent sociological studies of energy consumption. Instead, more recent studies apply qualitative methods and the main focus is on studying how social conventions of energy-consuming practices are socially and materially configured. This focus is strongly related to the development of social practice theory within energy consumption research, which primarily has been driven by Elizabeth Shove and colleagues (Shove, 2003a; Shove et al., 2012, 2015; Shove and Walker, 2014), and the more empirical researchers Kirsten Gram-Hanssen (2011, 2010a, 2010b) and Yolande Strengers (2012, 2011a).

Although the level of sociological energy studies has increased rapidly within the last decade, only a few studies show an interest in the social structuring of energy consumption, and none of these studies are based on quantitative data and methods.

Investigating the social structures of energy consumption is important in order to understand how energy-related habits are shared and reproduced through social group affiliation and, moreover, how the material context of these habits has a strong social dimension; therefore, a quantitative sociological approach is necessary

to uncover the underlying social structuring of energy consumption that are not directly visible or observable, but only appear "in disguise". This is a core sociological task that this dissertation takes up regarding households' heat consumption.

1.1. AIM AND RESEARCH QUESTIONS

This dissertation uses quantitative sociological methods and data to investigate the social structures of households' energy consumption by using the case of energy used for space heating and hot water in Danish single-family houses. Here, social structures refer to how different objective (and material) structures, for example in the form of social groups, reflect certain cultural understandings that are formed historically, which lead to certain patterns of consumption through the performance of everyday practices. The theoretical basis of the dissertation is primarily inspired by the version of practice theory developed by Pierre Bourdieu (e.g. 1984, 1980, 1977), but also the type of practice theory primarily represented within the field of energy consumption by Elizabeth Shove (Shove et al., 2015, 2012) and Kirsten Gram-Hanssen (Gram-Hanssen, 2011, 2010a), and finally, the cultural model of household energy consumption suggested by Loren Lutzenhiser and Bruce Hackett (Hackett and Lutzenhiser, 1991; Lutzenhiser, 1992a)

This dissertation aims to explain and understand why households consume differently, and more specifically, what role differences in socio-cultural understandings between households, family relations and the social and material context of heat-related habits play in the development and reproduction of these differences. To guide the overall research objective, I have four sub-questions; one for each empirical paper included in the dissertation.

1. How do social differences between households correlate with heat consumption directly and indirectly? (Paper I)

2. How do the material and social contexts influence and moderate the relationship between price level and heat consumption level of households? (Paper II)

3. How are heat-related habits structured by social differences and material arrangements? (Paper III)

4. How are heat-related habits reproduced through parent-child relations? (Paper IV)

These four empirical papers address different aspects of social structures of households' heat consumption, and provide evidence that social relations, for example in the form of social class structures and family relations, are essential to

investigate in order to understand how households consume energy for heating differently.

This dissertation contributes to sociological literature on energy consumption by nuancing well-known correlations with new interpretations based on practice theory and providing new evidence on the social differences of households' heat consumption. Moreover, the dissertation contributes by (re)introducing quantitative methods and emphasising social relations as dynamics for the change and reproduction of heat-consuming habits, and moreover, by proving that using quantitative methods in combination with practice theory provides new insights to understand how households consume different quantities of heating.

As similar aims have been suggested by others (see for example Galvin and Sunikka-Blank, 2016; Gram-Hanssen, 2014a; Lutzenhiser and Gossard, 2000; McMeekin and Southerton, 2012), this dissertation does not rely on an original idea. However, by providing empirical evidence on the social structuring of heat consumption based on extensive quantitative data material and advanced quantitative sociological methods, which is interpreted in a practice theoretical context, this dissertation sets foot on somewhat uncharted grounds, which might point at an emerging research field.

1.2. OUTLINE OF THE DISSERTATION

The dissertation starts by presenting the empirical case, including data and methods. As methods and data are also described in each empirical paper, this section will focus on providing an overview of data and methods used in each of the empirical papers. This chapter also includes some considerations to the representativity and generalisability of the findings in the empirical papers.

In chapter 3, I review the sociological literature on households' energy consumption and argue that quantitative analysis of social structures of energy consumption is missing in recent literature. This is, however, addressed (albeit in another way) by studies within what I term individualistic approaches to energy consumption, consisting of socio-technical, psychological and economic approaches, and these will be presented next. I summarise the chapter by outlining what can be learned from these studies.

In chapter 4, I present my suggested approach to quantitatively studying social structures of energy consumption. This includes a summary of paper V, which I have written together with my PhD colleague, Mette Hove Jacobsen. In this paper, we identify how systems of dispositions (habitus) have, to a large extent, been forgotten in favour of an emphasis on practical understandings embedded in systems of material entities. We therefore seek to (re)introduce Bourdieu's concept of embodied practical understandings incorporated in habitus to the sociology of

sustainable consumption. This is followed by a section on the theoretical and methodological considerations of this dissertation on how to study heat consumption.

In chapter 5, I present a summary of the four empirical papers of the dissertation. This is followed in chapter 6 by a discussion of the results as well as the contributions and insights of the dissertation as well as some research and policy implications.

CHAPTER 2. THE DANISH CASE

The empirical case of this study is energy used for space heating and hot water by households living in Danish single-family homes supplied with either district heating or natural gas[3]. This will subsequently be referred to as heat consumption.

To understand the findings of the empirical papers, it is important to describe the empirical context. Therefore, this chapter starts by describing what heat consumption in the empirical case of this dissertation refers to in the Danish context. This is further described in Appendix A regarding the history of heat planning and housing types in Denmark.

Following this, the chapter gives an overview of the methods and data used in the dissertation, which leads to a discussion on representativity and generalisability of data. The data used are described in further detail in Appendix B.

2.1. WHAT DOES HEAT CONSUMPTION REFER TO?

In this empirical case, heat consumption refers to energy used for both space heating and hot water. It is estimated that 30% of the energy used in older buildings, and 40% in newer buildings is used for water heating and the rest for space heating (Gram-Hanssen, 2003)[4]. Due to the system of provision in Danish houses, it is not possible to separate the use between space heating and hot water. Moreover, because the data of this dissertation does not include amount of energy used for secondary heating sources such wood-burning stoves and heat pumps, this part of households' heat consumption is not included in the empirical case, but a secondary heating source is added as a control variable in all analyses.

As heat consumption covers energy used for space heating, it reflects everyday routines of adjusting thermostats and opening/closing windows. These routines refer, among other aspects, to the household members' expectations of comfort and a healthy indoor environment, for example the preferred indoor temperature during day and night. In this way, heat consumption plays a role in almost all activities within the home during winter.

Heat consumption in this empirical case also refers to energy used for domestic hot water, and therefore it reflects everyday routines of showering, washing hands, dish

[3] The single-family detached houses were chosen because these are individually metered.

[4] The percentage of water heating and space heating probably has changed since 2003, so that there are now larger differences.

washing and cooking, which relate to understandings of what occupants consider tidy, clean, and healthy.

The performance of practices by the households is largely dependent on the material arrangements which, in the case of heat consumption, primarily concerns the building envelope of the houses and the energy supply.

This dissertation uses single-family detached houses supplied with district heating or natural gas as the case study. Single-family detached houses cover 44% of the residential building stock in Denmark, and are thereby the most common form of housing in Denmark. Equally, the most common forms of heating in Denmark are district heating and natural gas, which together supply 78% of all households. The historical context of this is further described in Appendix A.

2.2. METHODS AND DATA

In this chapter, I present the data and methods used in the empirical contribution of the dissertation. Each empirical paper presents relevant information on data and methods, and therefore this chapter will provide an overview rather than a detailed description.

The analyses in the empirical papers of the dissertation are based on a range of data sources.

1. Panel data on annual heat consumption in kWh from 2009 to 2014 for single-family detached houses supplied with district heating or natural gas.

2. Survey data from a survey questionnaire named after the funding project 'UserTEC'. The questionnaire includes questions on heat-related habits, attitudes, and energy-efficiency improvements of the house. Full questionnaire is found in Appendix C.

3. Publically available data on price levels of district heating suppliers in Denmark with information on variable prices (price per kWh) and a standardised prices from 2010 to 2014

4. Administrative data from 2009 to 2014 provided by Statistics Denmark with information on individuals such as age, disposable income, education and occupation, on households such as number of occupants, and on buildings such as heated area, year built and supplementary heating sources.

I have described each of these data sources in further detail in Appendix B.

In the empirical papers, I have used different regression techniques. I have described these regression techniques further in the respective papers and I here present an overview of the regression methods and data that has been used in the four empirical papers.

	Paper I	Paper II	Paper III	Paper IV
Data:				
- **Annual heat consumption**	X	X		X
- **Survey data**			X	
- **Public records on district heating price level**		X		
- **Administrative data**	X	X	X	X
Method				
- **Ordinary Least Square regression (OLS)**	X	X	X	X
- **Random Intercept regression (RI)**		X		
- **Negative binomial regression**			X	
- **Logistic regression**			X	
- **Fixed effect panel regression**				X

Table 1. Overview of data and regression techniques used in the four empirical papers

2.3. REPRESENTATIVITY AND GENERALISABILITY

In order to assess the generalisability of the empirical results, it is relevant to look at how well the empirical samples represent the population. In Appendix D, I present a table showing that the representativity of the samples in each of the empirical papers, to a high degree, represent the full population, which shows minor deviations that are explained in Appendix D.

The empirical contribution of this dissertation is focused solely on the case of heat consumption in Denmark. Nonetheless, I consider the insights gained from the analysis to also be useful for energy consumption beyond the Danish context, especially in regions with similar conditions to Denmark regarding climate and types of housing. This may be particularly pertinent to regions in the Northern

Hemisphere where heating is needed rather than cooling, such as northern Europe and the northern part of North America. However, although this would require empirical testing, I also believe that the mechanisms investigated in this dissertation, for example the reproduction of embodied habits, are also generalizable to cooling habits and electricity-consuming habits.

CHAPTER 3. ANALYTICAL APPROACHES TO STUDY ENERGY CONSUMPTION

In this chapter, I present the relevant literature on energy consumption. Although the empirical case is heat consumption, I have chosen to focus on energy consumption in general, which might also include energy used for cooling and the use of appliances. The reason for this is that, in many studies, it is difficult to distinguish between different forms of energy consumption and, moreover, that sociological mechanisms frequently apply to different types of energy consumption.

I start by describing how earlier sociological studies on energy consumption looked at social structures of energy consumption using quantitative data and methods; however, this approach is missing in more recent studies that instead primarily focus on the material configuration of social conventions and energy-consuming practices. Following this, I present how quantitative methods are frequently used by other social science approaches, which I refer to as individualistic approaches, including technological, psychological and micro-economical approaches. Finally, I present a summary of what sociological approaches can learn from the individualistic approaches, and vice versa.

3.1. EARLIER SOCIOLOGICAL STUDIES ON ENERGY CONSUMPTION

In the early 1990s, an important sociological contribution to the study of energy consumption was provided by Loren Lutzenhiser, both alone (1992a, 1992b, 1993, 1994) and together with Bruce Hackett (Hackett and Lutzenhiser, 1991; Lutzenhiser and Hackett, 1993). Although the approach of Lutzenhiser and Hackett shows a close resemblance to what later became known as social practice theory (a similar argument is made in Stephenson et al. (2010)), the analytical focus and methods used were quite different.

Lutzenhiser and Hackett outlined an account of understanding the role of sociology in energy consumption analyses, which they termed a cultural model of household energy consumption (Hackett and Lutzenhiser, 1991; Lutzenhiser, 1992a). Their main point was that energy consumption should be understood as embedded in cultural processes referring to social structures, situations and statuses. They were inspired by economic sociology saying that economic activities are embedded in social structures. These cultural processes include different "styles" of life, but also social processes as "[…] *consumption is tied to social statuses and governed by*

considerations of social appropriateness" (Hackett and Lutzenhiser, 1991, p. 450). Thus, the individual is described as being implicated in evolving and adapting cultures, and energy consumption becomes an emergent product of social actors adapting to social situations and supplies at hand, and perhaps as a social act affirming or constituting social group affiliation such as a membership in a distinct community (Hackett and Lutzenhiser, 1991). Further, they argued that energy consumption is embedded in ongoing human actions such as showering and cooking a meal, and consequently, energy consumption should be viewed as part of performing everyday routines. Given the example of consumers with different cultural backgrounds, Lutzenhiser (1992) argues that they bring habits with them which influence the use of technologies in the new setting. However, the focus is on how these technologies are appropriately deployed rather than how they meet pre-existing wants and needs. In this sense, individual demand becomes an emergent product of how social actors adopt to (new) situations and supplies at hand.

Hackett and Lutzenhiser applied the cultural model in a study where they investigated the impact of shifting from paying a set fraction of the total cost of the complex (master metering) to paying for the households' own energy consumption (individual metering) in apartment blocks (Hackett and Lutzenhiser, 1991). In this study, they found that when the way households were billed changed to paying per household. Consequently, a new form of social responsibility among the residents concerning their energy use emerged. This meant that air conditioning changed meaning to become more of a luxury, which they argue is in contrast to a more rational response of calculating costs and benefits. The study indicated that energy consumption is "[…] *governed by considerations of appropriateness or "normality" in given social settings or situations*" (Hackett and Lutzenhiser, 1991, p. 462). Another finding in the study was that cultural background, in the form of 'home continent', had an impact on how households responded to the change in billing procedures and on energy consumption in general. Moreover, as tenure (as opposed to ownership) and length of residence had an effect on energy consumption, the study indicated that, over time, occupants adapted to norms, which supports that consumption norms have histories and therefore might be "[…] *outcomes of the same energy-using practices they might otherwise be thought to explain*" (Hackett and Lutzenhiser, 1991, p. 466).

In another study, Lutzenhiser and Hackett looked at the association between social stratification and environmental degradation (Lutzenhiser and Hackett, 1993). Motivated by a debate on suggestions for a carbon tax, the study focuses on households' carbon emission, and therefore it combined residential energy consumption and car use. The starting point of the study was that the realities of social class structures are obscured in assumptions of demands located in the choice of the individual consumer upon which some economists rely. Based on regression models of residential energy consumption on combined survey and administrative data from utilities, they found that half of the variation is explained by differences

between social groups, which relate to, for example, type of family, housing, appliances and behaviour, but also to travel, as car use was included. Their analysis also showed that high-income and high-consumption families were more likely to occupy newer and more energy-efficient houses, which indirectly contributed to a social stratification of energy consumption. Moreover, when children moved out, parents tended to continue to live in houses built for families with children. Lutzenhiser and Hackett argue that energy consumption becomes socially stratified, where energy consumption is associated with a social hierarchy, which primarily relates to the indirect effect of material culture, for example in the form of the symbolic value of houses. The social significance of privately owned single-family detached houses are thus not just a functional provision of shelter, but also an reflection of social standing in terms of a cultural value placed on, for example, space, proximity and privacy.

In line with the studies of Lutzenhiser and Hackett, status and cultural differences were also the subject of other earlier studies. For example, in a study by Wilk and Wilhite (1985), they show the weatherisation of houses to be unpopular and lacking glamour and appeal in the marketplace in spite of the clear economic benefits. In another study also involving Wilhite, ethnographic comparison of energy habits in Japan and Norway in 1996 was investigated (Wilhite et al., 1996). Using ethnographic interviews, they show cultural differences between Norwegian and Japanese energy consumers. For example, they show that space heating and lightning habits are important for the presentation of Norwegian homes, whereas these habits are more disciplined and less culturally significant in Japan, and that bathing routines are extremely important to the Japanese lifestyle, and consequently very energy intensive.

3.2. RECENT SOCIOLOGICAL STUDIES ON ENERGY CONSUMPTION

In the early 2000s, the sociological focus turned towards how increased energy efficiency has social implications for energy demand. The focus is illustrated by a sociological approach set out by Wilhite et al. (2000), in which they reframed energy demand as a social demand dependent on social norms and a network of social institutions. This focus was further proven in Shove's early analyses of how social conventions are formed by technologies (e.g. Shove, 2003a).

This shift from a focus on social (class) structures, social status and cultural differences towards how energy-efficiency of technologies affects notions of comfort and convenience also entailed a shift from quantitative methods to qualitative methods.

The focus on social conventions, together with the later introduction of practice theory into sociological energy consumption, where Shove also played a significant

role, came to dominate the majority of the subsequent sociological literature on energy consumption. Although the studies on social conventions and practice theory are deeply interlinked in terms of, for example, analytical approach and methodology, I have chosen to present these separately as a way to categorise the two main trends in recent studies.

3.2.1.1 Technically-configured social conventions

Shove's aim was to show how conventions of comfort, cleanliness and convenience are integrated into systems of provision, which means that these systems reconfigure what is appropriate, for example appropriately clean clothes, and "normality", for example, the normalisation of laundry and bathing practices. Here, I will focus on the three C's presented by Shove (2003c) in the form of conventions of comfort (primary relating to space heating), cleanliness (primarily relating to the use of hot water), and convenience.

Comfort

Shove (2003b) argues that processes of the invention of heating and cooling technologies (as well as use of these technologies) are also processes of redefining normal conditions of comfort. Consequently, the risk is that energy-efficient heating and cooling technologies reconfigure the meanings of comfort in an unsustainable direction. This means that the development of standards, regulations and technologies of indoor climate control also entail ideas of comfort (deliberately or not), which have consequences for meanings and definitions of comfort, and the embedded expectations of comfort, that change in directions that cannot be predicted (Shove et al., 2008). For example, Strengers (2008) demonstrates that demand management trials that take control over supply and demand for air conditioning may lead to distancing consumers from their own comfort expectations instead of making the consumers co-managers of their own demand (and comfort).

Heating comfort expectations and understandings are shown to vary across social groups. Day and Hitchings (2011) show that, due to physiological change and changes in daily activities, older respondents express that they feel the cold more than they had previously. Moreover, the study showed how older people were required to deal with age-related stigma. The older respondents did not want to be seen as undesirably old, where certain clothing and devices and the associated practices carried age-related stigma. In another analysis based on the same study, Hitchings and Day (2011) show a discrepancy between generational conventions of what older people feel as the "right" ways of doing things, which they perform in the presence of others and what they actually did privately to keep warm. This shed light on how perceived conventions are not necessarily translated into actions in accordance with these conventions, and how social relations affect heat-related activities.

Cleanliness

As with comfort, understandings of cleanliness are also configured by historically technological developments, for example the domestic washing machine, and the meaning of cleanliness for those that do the laundry (Shove, 2003b).

Where Shove (2003a) focuses on how the historical technological developments have shaped cleanliness conventions, Jack explores the social constructions of conventions of cleanliness. Using the empirical case of (not) washing jeans, she shows that social acceptability does not correspond with dirty jeans (Jack, 2013a) and how individual performances of practices dynamically reproduce collective conventions of cleanliness (Jack, 2013b). In so doing, she brings the important perspective that social structuring, in the form of social acceptability (or social status), is important to gain an understanding of inconspicuous consumption practices alongside the material structuring (Jack, 2016).

Thus, there are also mechanisms in play other than the technological development. Motivated by a rapid increase in number of showers in the UK, Hand et al. (2005) explored how conventions of cleanliness are historically formed by three factors that contribute to explaining the current practice of showering. The first factor is technological innovation the form of infrastructural arrangements and material resources. This innovation is illustrated by how the practice of showering has moved from communal bathing houses to individual homes. The second factor is how the development of socially shared cultural understandings of the body from requiring regeneration and care to self-representation also has had an impact on current showering practices. The third factor concerns the immediacy and convenience of practices, or in other words, how the practice of showering is situated in everyday life of families as a routine that has to fit into the daily rhythm of the everyday life, which has also changed during this period. This leads to the third C, namely convenience.

Convenience

The temporal dimension of practices is an important aspect of energy consumption as most energy-related activities are routinized and repetitive, and thus form rhythms in everyday life. The development of convenience technologies affects these daily rhythms, with consequences for convenience. For example, a convenience device such as a freezer is seen by Shove and Southerton (2000) as a ‘time machine’ that enables a reorganisation of everyday routines.

In the same way, inconvenient technologies also affect the rhythms of the everyday. A study on the time and temporality of heating practices by Jalas and Rinkinen (2013) shows that wood-based heating creates rhythms in everyday life and that technical systems imply certain rhythms that affect everyday life in general. Moreover, these rhythms were perceived a source of joy and ease, although wood-

based heating could be seen as an inconvenient technology. This suggests that the feeling of satisfaction through coping with weather and staying warm is important.

3.2.1.2 Social practice theoretical studies

In the wake of the turn towards the ordinary and everyday aspects of consumption within the sociology of consumption (Gronow and Warde, 2001; Shove and Warde, 2002) and the 'practice turn' within social sciences (Schatzki et al., 2001), social practice theory emerged as a useful analytical frame for understanding energy consumption practices. Shove also played an important role in this development, particularly more recently together with colleagues (see e.g. Shove et al., 2012, 2015)[5].

Kirsten Gram-Hanssen is another important contributor to the introduction of practice theory into the sociological field of energy consumption, especially in terms of demonstrating how practice theory can be used in the empirical analysis of energy consumption and related practices (Gram-Hanssen, 2011, 2010a). According to Gram-Hanssen, energy consumption practices are held together by four key elements: know-how and embodied habits, institutionalised knowledge and explicit rules, engagements and technologies. Gram-Hanssen aims to show how practice theory, in the form of these elements, can be used to understand how energy consuming practices are held together and adapted due to changes in these elements. In so doing, she empirically demonstrates how rationality cannot, in isolation, explain occupants' standby consumption habits (Gram-Hanssen, 2010b), how households in similar material arrangements can display very different energy consumptions due to difference in understandings of comfort, know-how and embodied habits (Gram-Hanssen, 2010a), and how teenagers' cleanliness practices are strongly influenced by peer-group relations and inherited habits from their parents (Gram-Hanssen, 2007).

Yolande Strengers is another important contributor to the empirical application of social practice theory. Among other projects, Strengers (2012, 2010) uses social practice theory in two studies of dynamic peak energy pricing, where she highlights the importance of energy price as a conveyer of meaning to energy-consuming practices rather than a matter of information and rational decision making[6].

Practice theory has become popular within sociological energy consumption research, especially by providing a framework for incorporating the material

[5] See also paper V '(Re)introducing embodied practical understandings to the sociology of sustainable consumption' for a further introduction of Shove's developments of social practice theory.

[6] See also paper II for further presentation of Strengers' studies.

configuration of practices. An example of how materials configure practice is shown by Rinkinen, together with Jalas and Shove. Using a range of different qualitative methods (interviews, house tours, diary collections and photographs), they show how material objects can function as actionable and meaningful tools in one practice and a more passive material milieu in another, and that practices most often deal with more than one object at the same time (Rinkinen et al., 2015). In another study by Rinkinen and Jalas that uses the example of moving into a new house, they show that heating practices are formed and reproduced in relation to the material arrangements and the flexibility of the practice (Rinkinen and Jalas, 2016).

Also relying on practice theory, Hards (now Royston) explores personal environmental values in a sociological sense, where values and practices are considered as co-constructs (Hards, 2011). The study finds that the way people reconcile with their values around normality is shaped by their personal biography and social context, and she highlights that environmental values are shaped according to three interrelated mechanisms: performance of practices, contextual experience, and interaction with others[7].

Moreover, associated energy consumption studies have been inspired by social practice theory, an example of this being studies of energy efficiency improvements of a house such as energy retrofits and renovation project, which have shown the important role of social relations such as neighbours and family (Bartiaux et al., 2011), in what constitutes a nice home (Haines and Mitchell, 2014), and the compatibility with everyday life routines (Judson and Maller, 2014; Vlasova and Gram-Hanssen, 2014). In addition, studies of information and communication technologies (ICT) (Røpke et al., 2010) and energy consumption feedback (Strengers, 2011) have also been inspired by the practice theoretical approach.

In contrast to the majority of social practice theoretical studies, Butler et al. (2014) draw more directly on Bourdieu's account of practice theory as an analytical lens for studying energy consumption. Based on qualitative interviews and visual data, they focus on how choices and values relating to energy consumption should be seen in their social and material context. For example, they show how 'choices' can be more or less restrictive depending on past experiences, in the form of habitus, which might result in intergenerational tensions or conflicts. They argue that these tensions are central to understanding social change in the form of emerging appropriate ways of doing things (unconsciously). Their empirical analysis suggests that energy

[7] Although Hards is not referring to Bourdieu, this resembles Bourdieu's concepts of habitus and fields, for example can personal biography be understood as habitus, social context as objective structures in a field, and where the mechanisms shaping values (or understandings) are linked to the historicity of fields and habitus relying on a relational perspective. In this sense, cultural understandings (or values) only have "effect" or value in accordance with specific practices.

consumption should be seen in the context of socially reproduced notions of, for example, child caring, and moreover, how pro-environmental values may be deeply embedded in habitus, and that social and material structures are important regarding how people act according to values.

3.3. FORGOTTEN ASPECTS OF SOCIAL STRUCTURES AND QUANTITATIVE METHODS

In the previous section, I have presented recent sociological studies within the field of energy consumption, which demonstrated that, within the last decade, the number of sociological studies has increased rapidly and sociological insights on energy consumption have become much stronger and more widespread. However, despite this increase, the review also revealed that only a few studies explore the underlying mechanisms of social structures, and none of these studies use quantitative methods. Following the studies of Lutzenhiser and Hackett (Hackett and Lutzenhiser, 1991; Lutzenhiser and Hackett, 1993), similar studies of the social structuring of energy consumption have not been conducted[8].

However, the perspective of social structures is not totally forgotten, as there are examples that touch upon similar subjects. In the form of the transmission of cleanliness, understandings between social relations, as mentioned above, Gram-Hanssen (2007) shows how social relations contribute to forming the conventions of cleanliness among teenagers. Jack (2016) refers to social structuring of laundry practices and the attached social acceptability, and social status is addressed in several studies (see for example Day and Hitchings, 2011; Hards, 2013; Hitchings and Day, 2011). Another example is Butler et al. (2014), who investigate energy consumption using Bourdieu's concepts of dispositions, objective structures and habitus, which they find contributes to understanding how energy is consumed. However, none of these studies use quantitative data to uncover the underlying social structure of energy consumption or the social mechanisms of social structures.

In fact, only a limited number of studies within the field of sociological energy consumption include quantitative data and use quantitative methods. Quantitative data has been used to describe patterns of water practices (Browne et al., 2014) and the change in laundry practices across time (Anderson, 2016), but although these studies apply quantitative methods, they primarily use it for describing practices

[8] Lutzenhiser has, together with Bender (2010), conducted a survey study combined with metered data to investigate variation in energy consumption. They find large variations in energy use and carbon emission between households, and that the structuring of energy use differed across different climate zones. Although they use a sociological understanding in the methodological setup, they do not interpret the empirical analysis within a sociological context. Therefore, Lutzenhiser is not relying on his own cultural approach in this particular study.

instead of analysing the underlying structure or mechanism of practices. This leaves some potential for quantitative sociological methods to address underlying structures and explanations of why practices came to be the way they are, and to investigate relations such as how practical understandings or material arrangements relate to energy consumption and energy-consuming practices.

3.4. QUANTITATIVE STUDIES OF ENERGY CONSUMPTION

In the previous section, I described that recent sociological literature on energy consumption have not focused on social structures of heat consumption and quantitative methods. However, where this approach is overlooked in the sociological literature, other social science approaches have made extensive use of quantitative data and methods, and investigate social structures of energy consumption, although in a different way – in the form of socio-economic differences between households. The individualistic approaches, as I have collectively chosen to describe the other social science approaches, are represented by technological, psychological and micro-economic literature.

I think that the sociological approach can be inspired by each of these social science approaches, especially regarding the use of quantitative methods and data, and the investigation of the direct and indirect effects of social differences on energy consumption. However, the individualistic approaches often seek to predict rather than understand, and the lack of interpretation of empirical results in these approaches leading to a loss of valuable (perhaps more sociological) insights on how households consume energy. In the following, I will describe each of the three individualistic approaches and present examples of empirical contributions.

3.4.1. TECHNOLOGICAL APPROACH

The most prevalent characteristic of the technological approach for studying energy consumption is the emphasis on the role of technologies and materiality. The main interest is on how people use or interact with technologies or materiality, which is framed as the user perspective or the human factor of energy use. With regard to home heating, this clearly shows in a division between what is due to occupants and the materiality, for example in explaining variation in energy consumption. However, in so doing, empirical studies risk overlooking how occupants interact differently with technologies.

Technological studies are predominantly based on quantitative data that is ideally monitored or metered, at least for the dependent variable, where some prefer indoor temperatures (e.g. Shipworth, 2011; Shipworth et al., 2010) and others actual energy consumption measured in kWh (e.g. Majcen et al., 2013). However, some studies also study behaviours such as window opening (Andersen et al., 2013, 2009).

The most common data source within the technological approach are survey questionnaires. These include national surveys such as the British CARB-HES survey[9] (Kelly et al., 2013; Shipworth, 2011; Shipworth et al., 2010; Yang et al., 2015) and the American RECS[10] (Estiri, 2016, 2015a, 2015b, 2014; Steemers and Yun, 2009; Yun and Steemers, 2011), and self-conducted surveys, for example by Santin (2013, 2011) and Andersen et al. (2013, 2009).

Another characteristic of the technological studies is that they generally lack interpretation; for example, what does the result say about how households consume? Instead, the studies provide results based on empirical evidence without discussing what the results suggest. This also means that the majority of technological studies do not explicitly rely on individualistic models of behaviour or rational choice models, but as Hackett and Lutzenhiser (1991, p. 451) note: "[…] *the engineering approach is "rational" in the sense that it conceives a house, for example, as a simple instrument, primarily a shelter, capable of housing a potentially wide variety of social structures (especially families) in a more or less efficient fashion- efficiency* […]". The occupant behaviour is thus investigated in relation to the use of technology and buildings. This means that it is sometimes difficult to "find" the consumer perspective in technological studies. However, we do get some specific insights on actual correlations, for example, from Santin et al. (2009), we can observe that how many occupants are at home during weekdays and weekends has an effect on energy consumption. Moreover, according to a study by Shipworth (2011), it appears that the temperature setting (by occupants) has not changed significantly from 1984 to 2007.

The most frequent topic of the technological studies is investigating determinants of residential energy consumption. Thus, it is shown how both occupants and buildings significantly contribute to explaining variation in energy consumption (Santin et al., 2009), and that the occupant characteristics also have an indirect effect through the buildings in which certain groups tend to live (Estiri, 2015a, 2015b, 2014; Steemers and Yun, 2009). Regarding explaining variation in residential energy consumption, it is shown that household size is positively correlated with heat consumption as well as older households, and higher income households tend to consume more (Santin et al., 2009; Steemers and Yun, 2009).

3.4.2. PSYCHOLOGICAL APPROACH

The psychological approach emphasises the application of different theories of individual behaviour to study energy consumption. In so doing, Abrahamse and Steg (2009) tested the theory of planned behaviour (stemming from Ajzen (1991)), where

[9] Carbon reduction in buildings 2007 home energy use survey.

[10] Residential Energy Consumption Survey.

behaviour is seen as a result of a process of reasoning, where the costs and benefits of the relevant behaviour are assessed (form of rational choice theory) and the norm activation model (based on (Schwartz, 1977)), where pro-environmental behaviour requires individuals to give up personal benefits for collective interests, in this case the environment. Their findings indicate that the norm activation theory is better at explaining energy consumption than the theory of planned behaviour (Abrahamse and Steg, 2009). Moreover, they find that variation in energy consumption is determined by socio-demographic factors, whereas changes in energy consumption are better explained by psychological factors (Abrahamse and Steg, 2009). Another example of a psychological approach is that of Thøgersen and Grønhøj (2010) that applies the social cognitive theory based on Bandura (1986), where a form of behaviour is more likely to occur if the individual has confidence in performing it. They find that both structural and motivational factors contribute to explaining households' electricity consumption and that their electricity saving effort depends on the strength of their internalised norms. They asked women and men of the same household and, through analysing gender differences, they found that women are slightly more inclined to save electricity than were men, but men were found to put more pressure on their partner in cases where they believed they did the most to save electricity.

What these models of behaviour have in common, is that they are based on an individualistic approach to behaviour, which entails a understanding of individuals 'bringing' something to the practice in the form of values, abilities, certain behaviours or a set of pre-existing beliefs and desires, which is sometimes referred to as the portfolio model of the actor (Whitford, 2002).

The questionnaire survey is the most frequently used method within the psychological approach as it allows for the operationalisation of the psychological theoretical models. As with the technological approach, this includes self-conducted surveys (e.g. Abrahamse and Steg (2009) and Thøgersen and Grønhøj (2010) and national surveys such as RECS (e.g. Sanquist et al., 2012).

3.4.3. MICRO-ECONOMICAL APPROACH

A general characteristic of the micro-economical approach is that it emphasises the econometric modelling of associations between different factors (often referred to as determinants) on the one side and energy consumption or energy expenditures on the other. The factors are most often variables of economic matters such as energy prices (e.g. Alberini et al., 2011; Alberini and Filippini, 2011; Nesbakken, 1999), income (e.g. (Alberini et al., 2011; Brounen et al., 2012; Harold et al., 2015; Longhi, 2015) and house ownership (Meier and Rehdanz, 2010; Rehdanz, 2007), but also behaviour and attitudes (Sapci and Considine, 2014) and socio-economic characteristics other than income.

The micro-economical approach relies purely on quantitative data and methods. However, this approach distinguishes itself from the other approaches by having seemingly higher standards for data and methods, for example regarding robustness of models, representativity of samples, and thereby also the extensiveness of data. This is in line with an inclination towards panel data, which enables more advanced econometric models and, moreover, a general discussion of data and methodological strengths. The preferred data within this approach seems to be national surveys, preferably longitudinal ones, that may be combined with administrative data (see for example, Alberini et al., 2011; Longhi, 2015).

The focus on the empirical models means that the theories of human behaviour are deemphasised or not mentioned at all. Consequently, the focus is on what predicts energy consumption rather than how to understand variations in energy consumption. Therefore, these studies seem to rely on a rational actor model, which assumes that consumers are autonomous and deliberate decision makers that choose behaviours based on what maximises their benefit or some static preferences (Axsen and Kurani, 2012).

Due to a generally high quality of models and data, the micro-economic literature on energy consumption contributes sound evidence on a range of subjects. Regarding a presentation of literature on the effect of prices on energy consumption, I will refer to paper II, where I present some studies on the effect of prices on heat consumption. In addition to prices, a Dutch study, Brounen et al. (2012) uses administrative data to reveal that residential gas consumption for heating primarily depends on what they term structural house characteristics such as building type and characteristics, whereas electricity consumption depends more on family composition and income. Another study by Brounen et al. (2013), now based on survey data, finds that awareness and "energy literacy", which could perhaps be called competences, of energy consumption are very low, and further that literacy and awareness do not have a direct effect on heating and cooling behaviour. In contrast, this behaviour depends on demographics and consumer attitudes. In accordance with this, Longhi (2015) finds that both levels and changes in energy expenditure level are principally influenced by household size, but also socio-economic characteristics such as income, occupation, health, and pro-environmental behaviour. Regarding consumer attitudes, a study by Sapci and Considine (2014) suggests that environmentally concerned households tend to consume less energy. However, as Ohler and Billger (2014) show, the perception and environmental concern does not change the fact that self-interests have a greater impact on energy-saving behaviours and electricity use than social interests such as global climate change.

3.5. SUMMING UP

While earlier sociological studies studied social structures of energy consumption using quantitative data and methods, this approach has been overlooked in the recent sociological literature. Instead, the brief introduction of three other social science approaches to energy consumption, the technological, psychological and micro-economic shows that these approaches use quantitative data and methods to for example study social differences in energy consumption. However, these approaches all rely (more or less explicitly) on individualistic models of action and primarily focus on use of technology, behavioural theories and econometric modelling, and not on the underlying social structures of energy consumption.

Table 2 shows an overview of the individualistic approaches' use of data. The purpose of this is to give an overview of the differences between the approaches.

Approach	Main focus	Independent variables	Dependent variables	Type of data
Technological	Human perspective of energy use Determinants of energy consumption	Building characteristics Socio-economic characteristics Occupant behaviour (not based on theories)	Energy consumption (metered or monitored) Indoor temperatures Energy behaviours	National surveys Self-conducted surveys
Psychological	Test different psychological behaviour theories	Operationalisation of psychological theories, for example norm activation model and theory of planned behaviour	Energy consumption (metered or monitored) Pro-environmental behaviour	Self-conducted surveys National surveys
Micro-economic	Econometric modelling of energy consumption	Energy prices (elasticity) Income (elasticity) House ownership	Metered energy consumption Energy expenditures	Longitudinal or panel data National surveys Administrative data

Table 2. Overview of characteristics for each 'individualistic' approach

From a practice theoretical perspective, the individualistic approaches lack four important insights. First, energy is not consumed for its own sake, but rather in the course of accomplishing everyday practices (Shove and Walker, 2014). This means that when a factor, for example price or attitude, has a statistically significant effect on energy consumption, this effect relates to energy consumption through energy-consuming practices such as cleaning, showering and cooking. Moreover, these practices are performed in relation to shared understandings of, for example,

comfort, cleanliness and a healthy indoor environment and tied to the position and status of the household (Lutzenhiser, 1992a). A closer examination of collective aspects of action as inscribed in historical class structures of practices, might give more adequate understandings of energy-consuming behaviour through statistical modelling.

Second , it seems unlikely that a stable and pre-existing set of beliefs and desires are carried by the individual from one context to another as it is known from the portfolio model of the actor (Whitford, 2002). Instead, agents "carry" embodied habits and cultural understandings, but these are formed and shaped in the performance of practices, where practices and values become co-constructs (Hards, 2011). Therefore, measures of beliefs, attitudes or knowledge should rather be interpreted as cultural understandings that are shared by people with a similar social trajectory. Thus, the answers in questionnaires are no more than indications of the respondents' understandings regarding a specific practice in a specific context. These understandings only exist and have "effect" (or should be interpreted as having such) within practices where these specific understandings are valued or relevant for behaviour (deliberate or otherwise)[11].

Third, instead of habits and routines being presented as human deficiencies, these should be seen as challenging the individualistic understanding of action (Southerton, 2012). Habits and routines both configure and are shaped by collectively shared understandings of how to perform practices, which vary according to social group affiliation. Thereby, these understandings reproduce and change through struggles between different social groups' understandings of appropriate conduct. Thus, habitual and less reflexive actions have an important social dimension that is bound to dynamic social class structures.

Fourth, the social and material contexts of practices are socially structured in the sense that these structures rely on historical struggles over status, understandings and possession (Bourdieu, 1977). For example, the acquisition of a house is not only a matter of economic means, but also preferences, tastes and status (see e.g. Bourdieu, 2005, pp. 15–17; Lutzenhiser and Hackett, 1993), for example considering the symbolic value of different architectural designs or simply the size of a house. The social structures of energy consumption work both directly through energy-consuming behaviour and indirectly through houses and households. This means that the type of house (e.g. more or less energy-efficient) and type of household or family that constitutes the frame for energy-consuming practices are also socially structured, and thereby are an important component in how households consume energy differently. Similarly, an acquisition of a technology such as solar

[11] In the same manner as Bourdieu (1984, p. 113) describes that various forms of capital, as internalised in dispositions, only function as a capital in relation to the specific logic of the field in question, and thereby become a factor explaining practice.

panels, wood-burning stoves and heat pumps are also socially structured (Wilhite and Lutzenhiser, 1999).

Boldly speaking, and perhaps also somewhat simplified, one can say that the problem within the technological approach is that, due to occupant behaviour, "houses" are not performing optimally according to energy efficiency measures, which leads to 'performance gaps'. In the psychological approach, individuals do not act as they are "supposed" to according to psychological theories of behaviour because of complex social and material contexts (or habits) which, for example, lead to what could be referred to as the value-action gap. In the micro-economic approach, consumers do not "behave" economically rationally due to habitual and routinized (and thereby unreflective) behaviour, which for example leads to rebound effects.

Although this might be somewhat harsh on the individualistic approaches, I believe sociological studies on energy consumption can, in several regards, nonetheless learn from the individualistic approached studies, primarily in the use of quantitative methods and data. This includes, for example, the focus on quality of data and methods such as robustness checks in the econometric approach, how to operationalise theories of human conduct using clustering techniques and survey methodology in the psychological approach, and the use of metered or monitored data in combination with registers and survey data by the technological approach, where the validity of energy consumption data and data on materials are perceived as extremely important.

CHAPTER 4. THEORETICAL AND METHODOLOGICAL CONTRIBUTION

In the literature review, I have described that recent sociological literature on energy consumption lacks focus on the social structures of heat consumption and quantitative empirical research, which have instead been subject of research within technological, psychological and micro-economical approaches.

The purpose of this dissertation is to combine sociological understandings, in the form of practice theory, with a quantitative sociological methodology to investigate the social structuring of heat consumption. I rely on Bourdieu's view on the social world as consisting of homologous relationships between objective structures, incorporated structures and patterns of action, and I investigate the relationship between these structures using statistical methods to identify correlations between variables, which are interpreted in the theoretical context of practice theory. In this chapter, I will elaborate upon these theoretical and methodological considerations by first summarising the theoretical paper of the dissertation and then continuing with some theoretical and methodological consideration regarding how to sociologically investigate social structures of energy consumption.

4.1. SUMMARY OF THEORETICAL PAPER (PAPER V)

I have written the theoretical paper entitled "*(Re)introducing embodied practical understandings to the sociology of sustainable consumption*" together with my PhD fellow Mette H. Jacobsen. In the paper, we argue that embodied practical understandings (for example in the form of habitus) have, to a large extent, been overlooked within the field of sociology of sustainable consumption in favour of a focus on practical understandings embedded in systems of material entities with Shove and co-authors as the central protagonists.

We give two primary reasons for this. The first reason is that, in the wake of the cultural turn within sociology of consumption, the focus has been on rethinking the role of materiality. The second reason is the engagement with science and technology studies.

The paper aims to introduce Bourdieu's concept of embodied practical understandings incorporated in habitus to the sociology of sustainable consumption and to integrate it with embedded practical understandings in order to better understand the complexity of sustainable consumption practices and how they reproduce and change.

4.2. THEORETICAL AND METHODOLOGICAL CONSIDERATIONS

In continuation of the theoretical paper summarised in the previous section, this section will present my theoretical and methodological considerations on how a practice theoretical approach, primarily inspired by Bourdieu, can be framed more directly in the use of this dissertation. This involves how to understand the social world and how to investigate it.

Theoretical considerations

According to Bourdieu, an important task of sociology is to ask how and why certain forms of habitual behaviour emerge, develop and reproduce. How do habits come to be the way they are? In addressing these questions, it becomes important to uncover the social structures that constitute social life and the mechanisms ensuring its reproduction and transformation (Bourdieu and Wacquant, 1992).

Embedded in this task is the perception that social life exists in two ways: First, social life exists as an objective structure that is formed by the composition of *capital*, where the history of these objective structures is what Bourdieu refers to as (practice) *fields*. Bourdieu describes this as "*the distribution of material resources and means of appropriation of socially scarce goods and values*" (Bourdieu and Wacquant, 1992, p. 7). The three fundamental forms constituting agents' composition of *capital* is economic capital, for example economic means, cultural capital, for example educational qualifications, and social capital, referring to social connections (Bourdieu, 1986).

Second, social life exists as incorporated biographical history in agents, which Bourdieu (1980, p. 66) refers to as habitus. Habitus is a system of durable, transposable dispositions and classification of appropriateness, which can be attached to agents as well as social classes (understood as social groups) that share objective social conditions and social trajectories, but also specific cultural understandings of appropriate conduct (Bourdieu, 1977, pp. 85–86). The individual habitus of members of the same class then becomes structural variants of the others in the same social class (Bourdieu, 1980, p. 60).

In Distinction, (Bourdieu, 1984) shows the tendency towards homological relationships between three social structures: first, objective structures (distribution of resources in practice fields), second, habitus (cognitive dispositions such as cultural understandings), and third the performance of social practices. The social group (or class) affiliation of an agent is therefore reflected in cultural understandings and knowledge of appropriate ways of acting, which is "invested" (consciously or not) in ordinary activities (Bourdieu and Wacquant, 1992, p. 9). By introducing the homologous relationship between these three social structures (objective structures, habitus and practice), Bourdieu attempted to break with

historical antagonisms within sociology including the dichotomies of structure and agency as well as micro- and macro analysis. In addition, the classical distinction between methodological collectivism and individualism becomes changed to methodological relationism, which means that social reality lies in relations, and therefore should be investigated as such. For example, this means that the concepts of *habitus* and *practice field* only function in relation to one another (Bourdieu and Wacquant, 1992, p. 19), and social reproduction then becomes a result of interaction between objective structures and actions of agents. The homologous relationship also means that the objective structures should not be interpreted as having causal powers, where objective structures determine action. Instead, agents, due to their composition of capital (and embodied cultural understandings), are more likely to act in certain ways compared to others with another composition of capital. They do not necessarily act in accordance with the social group affiliation, but the potential for certain ways of acting is higher, depending upon how agents transform their cultural understandings into ways of performing practices. Choices and actions are socially structured, which means they are associated with cognitive structures and objective structures resulting from historical social processes, which means that some actions and choices are more likely than others due to incorporated history and objective social and material structures.

Bourdieu's concepts have been introduced to the field of energy consumption by Butler et al. (2014), who write that the incorporation of objective structures results in embodied action characterised by being socially constructed, habitual and taken-for-granted. Wallenborn and Wilhite (2014) also use Bourdieu's concept of habitus in relation to energy consumption by focusing on the body as a repository of past experiences that presents itself in the form of memories and perceptions. Furthermore, when underlining that understanding the processes of social differentiation of final consumption has importance to a sustainable development, McMeekin and Southerton (2012) highlight Bourdieu's account of social distinction. Accordingly, they argue that consumption is reproduced and transformed through the relations between social groups with different understandings of competent performance of practices. Therefore, variation in the performance of practices, as well as social stratification of the acquisition of new products, is important for a sustainable transition.

Thus, other authors are proposing similar ideas to those of this dissertation and, in some respects, Bourdieu's theories already influence current versions of practice theory within the sociology of energy consumption in the way it is developed by Shove and others. Nevertheless, I still think a more Bourdieu-inspired approach to studying energy consumption is needed and would contribute to the field by providing a more complex theoretical frame for understanding action as bound to social class structures. In particular, I think the incorporated history of agents and classes (in the form of habitus), and thereby also the relational perspective, are perspectives that are missing in current sociological literature on energy

consumption because the accumulated history of agents, and classes are an important component in the formation, reproduction and changing of energy habits.

Compared to Lutzenhiser and Hackett's cultural approach introduced in chapter 3, Bourdieu's approach brings in the struggle over social position and cultural understanding and the social reproduction of these (as McMeekin and Southerton, (2012) suggest). Moreover, the concept habitus as incorporated history adds some analytical power to interpretations of social group behaviour (as Wallenborn and Wilhite (2014) suggest).

According to Bourdieu (1986, p. 46), the social world is accumulated history, which means that we need to take historical accumulation, and all its effects, into account to avoid reducing the social relations between agents to what is observable here and now. To illustrate how the practice is a product of historical structures, Figure 1 shows how practices or practice fields can be seen as including material and objective social structures and that this, via the incorporated history, in the form of habitus, relates to practice.

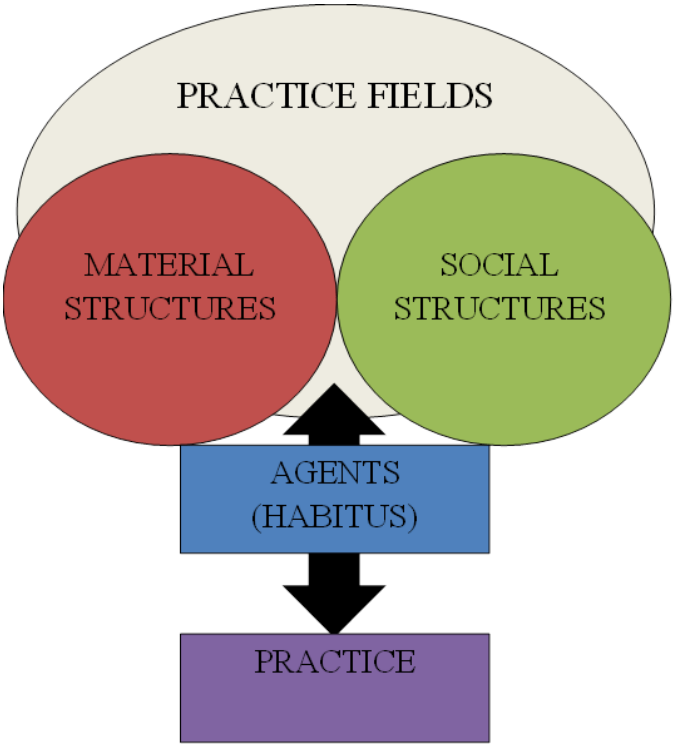

Figure 1. Theoretical understanding of heating practice.

Regarding energy consumption, it is perhaps beneficial to reduce habitus to cultural understandings of appropriate ways of acting. Concepts such as know-how, practical knowledge, practical understandings, attitudes and values all fall into this broad category as, common among them, is that they are cultural understandings in different guises, where certain cultural understandings are shared with others with similar lifestyle and social trajectory.

The objective social structures are the product of historical cultural struggles over appropriate ways of performing the practice. An important point when considering energy-consuming behaviour is that these struggles over practical understandings, or class struggles over social position, appear in small "manifestations" in everyday life, for example in the form of daily routines that show where the agent "belongs", which refer to keeping up with social relations (e.g. family, peer group, colleagues) or affirming social group affiliation as Lutzenhiser (1992) highlights.

The appropriate ways of performing practices and what gives meaning to agents within the specific practice are historically constituted. For example, culturally shared understandings of a comfortable indoor climate or cleanliness are products of the historicity of the objective social and material structures.

Methodological considerations

In Distinction, Bourdieu (1984) provides an example of how quantitative analyses based on statistical methods (together with qualitative methods) can be used to study the homology of social structures and mechanisms of social and cultural reproduction. In so doing, Bourdieu emphasised the advantages of quantitative analysis by trying to break from the traditional regression analysis. However, although quantitative methods other than regression analysis, for example correspondence analysis as used in Distinction (Bourdieu, 1984), better reflect Bourdieu's methodological relationism, the development of statistical methods and data analysis has improved significantly within the last decades to "model" much more complex conceptualisations of behaviour. For example, panel data models allow for as much social heterogeneity, individuality and social dynamics as qualitatively oriented analysis (Jæger, 2008). This means that multivariate regression analysis of correlations does not necessarily equate to a "*general linear reality*", and consequently do not, as Abbott (1988, p. 183) suggested, reflect a limited way of understanding social processes. Instead, I think, in line with Vandenberghe (1999, p. 46), that systematically reinterpreting statistical correlations "[…] *as a function of the system of relations that give meaning to the observed statistical relation*", for which I use Bourdieu's theories. Therefore, I consider regression techniques as useful tools for investigating energy consumption using a practice theoretical approach.

Operationalising the theoretical concepts of, for example, Bourdieu into an applicable quantitative methodological design requires certain simplifications. In my

analyses, I focus on (simple) correlations between variables, where I, for example, measure the objective structure in the form of social groups instead of measuring habitus or composition of capitals. Measures of these social groups are then modelled using regression techniques to estimate their correlation with heat consumption. I thereby leave the role of embodied habits or practical understandings (or habitus) to the interpretation of the statistical correlations between, for example, measures of the objective structure in the form of social groups and practice in the form of heat-related habits or heat consumption.

A straightforward Bourdieu-inspired approach to investigate social (class) structures would be to construct measures of cultural, economic and social capital to investigate the importance of habitus on energy consumption. One reason for not doing this is that I did not have good measures of the "typical" capitals. I have measures of income, education, occupation and so forth, but as Bourdieu points out in Distinction (Bourdieu, 1984), there is not a universal set of capitals that can be transferred from one field to another. Instead, each field (or practice) determines what capitals give value in the certain context. Thus, specific definitions of capital cannot just be transmitted from on field to another with the same meaning, it needs to be investigated what capital compositions give value within the specific field or practice. Therefore, I chose to find indicators of the socio-cultural context and objective structure rather than specific capitals.

CHAPTER 5. EMPIRICAL RESULTS

In this section, I will summarise the findings and insights from the empirical papers of the dissertation that explore aspects of the social structure of heat consumption from different angles.

5.1.1. SUMMARY OF RESULTS FROM PAPER I

The first paper, *The Social Structure of Heat Consumption in Denmark: New Interpretations from quantitative analysis,* shows socio-cultural differences in heat consumption. It provides evidence that households' heat consumption levels vary across social groups that are measured by variables of disposable income level, educational level, occupational status and immigration status. Furthermore, I show that the impact of socio-cultural differences on heat consumption is divided into two parts: first, social groups indicate differences in heat-consuming habits, where some social groups are more likely to have heating intensive habits and will thereby directly manifest in higher consumption levels than other groups. For example, the results show that higher educated and higher income households tend to consume more heating than lower educated and lower income households. This suggests that habits of higher classes (or higher social status households) have more energy-intensive habits, whereas habits of lower classes are more energy-saving, which is a pattern that resembles the idea of Bourdieu's original divide between the taste of luxury and of necessity. Second, social groups indicate differences in houses and households, where some social groups are more likely to live in larger households and larger houses, which indirectly results in higher household consumption.

The results of the paper indicate that around one third of the impact of educational and income differences between households on heat consumption are due to differences in heat-consuming habits (direct effect), whereas the rest, two thirds, are due to differences in households and houses (indirect effect).

5.1.2. SUMMARY OF RESULTS FROM PAPER II

The second paper, *Heating homes: Understanding the impact of prices,* concerns the impact of district heating prices on heat consumption. Where previous studies, primarily from an economic perspective, have emphasised the econometric modelling of price effects on consumption rather than the interpretation of price responsiveness, I provide an example of how price responsiveness can be understood using practice theory. This entails understanding heat consumption as part of accomplishing everyday practices within the scope set by the social and material context.

In the paper, I show that price level differences between district heating suppliers significantly correlate with heat consumption levels of households, which suggests that the price level has an impact on consumption level and that occupants respond to price level. I argue that this responsiveness is more a matter of adjusting heat-related habits than households being more likely to retrofit their houses in more expensive areas.

Understood from a practice theoretical perspective, price level conveys meanings to everyday practices and practices related to improving the energy efficiency of houses, and the results of this study suggest that, in areas with more expensive district heating, heat-consumption activities are given more consideration than in cheaper district heating areas. Similarly, the energy-saving potential of renovation projects might be given stronger focus and more consideration in renovation projects in expensive areas compared with cheaper areas.

5.1.3. SUMMARY OF RESULTS FROM PAPER III

The third paper, *Material and Social Structures of Heat-related Habits,* is co-authored with Kirsten Gram-Hanssen and Henrik N. Knudsen. Using self-conducted survey data in combination with administrative data, the paper shows that heat-related habits are material and socially structured. The variables indicating various heat-related habits were frequency of adjusting thermostats, frequency of opening windows to ventilate the house, amount of clothing worn during winter and considered indoor temperature. These were constructed using a range of questions from the survey on activities of the occupants.

We found that clothing habits and indoor temperature are correlated with the energy efficiency of buildings, whereas habits of adjusting thermostats and opening of windows seemed more associated with the specific heating installations in the house.

The social or cultural factors were important, primarily regarding habits of adjusting thermostats and clothing habits, but also window-opening habits and considered indoor temperature were found to be socio-culturally structured.

5.1.4. SUMMARY OF RESULTS FROM PAPER IV

The fourth paper, *Reproduction of habits: Do adults share inconspicuous consumption practices with their parents,* co-authored with PhD fellow Mette H. Jacobsen, shows that heat-consuming patterns of adults are strongly correlated with that of their parents. This indicates that embodied habits and practical understandings are transmitted through family relations, and that inherited consumption habits have a large impact on the consumption patterns later in life. Moreover, we find that the intergenerational correlation is somewhat stronger for the

lower classes, and much stronger when the geographical distance to parents is significant.

The results indicate that the reproduction of practical understandings related to heat-consumption patterns are more a question of bodily learning, where children imitate their parents, than a question of transmission of capital from parent to child. This also means that the reproduction is more a question of keeping family relations intact than of a pursuit of status.

The study was based on panel data on heat consumption from 2009 to 2014, and the (exogenous) natural variation across years, for example due to weather, enabled us to compare the response to yearly variation of parent and grown-up child.

CHAPTER 6. CONCLUDING REMARKS

The overall research objective of the dissertation is to investigate the social structures of heat consumption through the use of quantitative sociological methods. Throughout the dissertation, I have argued that this objective has been overlooked in recent sociological studies of energy consumption.

In this chapter, I will offer some concluding remarks on the dissertation. I will start by discussing the findings of the four empirical papers of the dissertation together with the theoretical considerations presented in the dissertation and the theoretical paper. Following this, I will present what I consider to be the contributions of this dissertation and, finally, what research and policy implications can be drawn from it.

6.1. DISCUSSION

In this dissertation, I focus on two primary ways that heat consumption is socially structured: first as a result of differences in the heat-related habits of occupants, which is the main focus of this dissertation, and secondly as a result of the social structures of housing and households that indirectly affect consumption level.

The results of paper I show that around one third of the social structure of heat consumption is due to social differences in heat-consuming habits. This means that members of social groups perform everyday practices differently, which might be explained by the objective social realities of the social groups or the cultural understandings tied to social groups. The results indicate that higher social classes (based on income and educational level) have a more energy-consuming lifestyle, which is reflected in the everyday practices of the household members. The tendency to act in accordance with what is perceived as “normal” and appropriate within the social context means that the performance of these everyday practices (unreflectively) takes part in affirming group affiliation. In contrast, lower social classes seem to have less energy-consuming habits that might stem from embodied energy-saving habits. According to the findings of paper IV, these habits might be inherited from parents and thereby reproduced within the social group.

To further understand the association between objective social structures and practice, we need to know more about what understandings and (embodied) habits that (historically) are tied to social groups. One way to doing this is to look at the social structure of heat-related habits. In paper III, the focus was on how different social groups performed repetitive routine heat-related activities. Using the examples of adjusting thermostats, opening windows, wearing additional clothing and regulating indoor temperature, the results showed that income did not correlate with the specific routines, but that occupants with higher education tend to wear warmer clothes during winter, for example wearing warm socks and using blankets,

and similarly for women as opposed to men. This suggests that distinct cultural understandings of how to be appropriately dressed during winter are tied to these social groups, where dressing more warmly might be a way of responding to colder outdoor temperatures. An explanation could be that wearing warmer socks or wearing a warm sweater is to a higher degree recognised as sensible clothing within these social groups. There might, however, also be a biological element in the difference between women and men. The findings also indicate that the group of immigrants and their descendants have distinct habits relating to adjusting thermostats and opening windows, which might be due to other experiences with district heating or radiators, which are especially common in Denmark. This suggests that the process of adapting to "new" technologies might have a stronger cultural factor than first expected in accordance with the cultural approach of Lutzenhiser and Hackett. (Hackett and Lutzenhiser, 1991; Lutzenhiser, 1992a).

In paper IV, it is shown how heat-consumption patterns are strongly correlated between grown-up children and their parents. This suggests that family relations, and, for example, the (unconscious) imitation of parents, has a huge impact on the formation of embodied habits with consequences for heat consumption patterns later in life. Taking this into account, the examples of social groups' embodied habits might have deeper roots and stronger inertia than first expected as it potentially derives from social reproduction of cultural understandings from generation to generation. Further, this strongly supports that incorporated personal (or class) history (e.g. in the form of habitus or cultural understandings) is a very important factor in explaining habitual behaviour.

The results of paper II indicated that households were able to adjust heat-related habits from year to year in accordance to the demand, which seems more likely in households with higher income levels and more energy-efficient houses. This suggests that households with lower income and low home energy-efficiency already limited their consumption to the maximum extent and therefore are not able to adjust habits according to price level or demand from, for example, a colder or longer winter. Although the evidence is not strong enough to make a clear conclusion, from the analysis it appears that, in colder winters where the demand for heating is higher, households adjust their habits to become more energy-saving, and vice versa in warmer winters. This suggests that the households that respond best to price are already in the most advantageous social and material contexts.

In conclusion, the empirical results of the dissertation show that heat-related habits (and the possibilities of adjusting these habits) are affected by objective social and material structures, which relate to cultural understandings of appropriate actions and the social reproduction of these. Although differences in habits are important in understanding the social structure of heat consumption, the most important factor for social structures of heat consumption is indirectly through the energy-efficiency of houses and composition of households, primarily related to family type and size.

The results of paper I show that around two thirds of the explanation for higher social classes higher heat consumption level is due to these two indirect factors. As both Bourdieu (2005) and Lutzenhiser and Hackett (1993) highlight, houses are status symbols. Therefore, the homes households occupy are a result of social mechanisms of class-bound tastes and preferences, for example regarding architecture and size, which have great impact on the energy-efficiency of houses.

6.2. CONTRIBUTION

The aim of this dissertation was to empirically demonstrate how households' energy consumption is socially structured and, in so doing, provide new insights into how households consume energy and shed light on the importance of underlying social structures in understanding the social dynamics of energy consumption. Furthermore, the aim was to reintroduce a quantitative sociological methodology into the sociological field of energy consumption and, concurrently, prove the potential of a quantitative approach to better understand how and why households consume as they do.

Using quantitative sociological methods, I have investigated aspects of the social structures of energy consumption based on the case of heat consumption of Danish households living in single-family detached houses with district heating and natural gas. In so doing, this dissertation has provided a quantitative empirical example of how the social structures of households' heat consumption can be investigated. In addition, the dissertation includes initiating ideas of a theoretical framework for quantitative sociological analysis of energy consumption. In conclusion, I would like to highlight three main contributions of this dissertation.

The first contribution is that the findings of the empirical papers have nuanced and refined already known correlations by providing new empirical evidence and adding a sociological interpretation of this evidence. This concerns the correlation between social differences and heat consumption, between heating price level and heat consumption, and between social differences and heat-related habits. Previously, these correlations have primarily been investigated in technological and economic studies, but sociology has a very important contribution to make in understanding these correlations, for example by focusing on how energy is consumed in the course of accomplishing everyday practices. In addition, this dissertation has provided novel evidence on the association between the energy consumption patterns of grown-up children and parents. This has never been investigated, and it contributes to the field by providing empirical evidence (together with a theoretical understanding) of how social relations affect the dynamics and reproduction of heat consumption. This opens up a range of new potential studies on the part played by social relations in forming embodied habits, which, for example, could focus on the role of family (e.g. siblings), extended family (e.g. cousins, grandparents), neighbours or friends. By focusing on interpreting results within the material and

social (historical) context, sociology can go beyond the somewhat descriptive statistical analyses of, in particular, the more technological approaches to statistical analysis and the sometimes narrow focus on economic and psychological factors. It is necessary to analyse why people act as they do, due, for example, to embodied habits and dispositions that are formed during lifelong experiences which form part of keeping or affirming a position within a social group (family, friends etc.). By doing so, new understandings of the inertia in changing (embodied) consumption habits can be gained.

The second contribution of the dissertation is methodological, by reintroducing quantitative sociological methods to sociological studies of energy consumption. Although quantitative methods have been applied in earlier studies, this dissertation stands out by using much stronger (and much more extensive) data as well as more advanced statistical models. Within the sociology of sustainable consumption, the use of quantitative methods has been almost non-existent, but quantitative methods hold a huge potential for understanding the social structures of energy consumption and the underlying mechanisms of reproduction and change of, for example, embodied habits and cultural understandings. In addition, a quantitative sociological approach would also be useful for providing stronger sociological contributions to associated research questions such as how energy feedback does, or does not, work (and for whom it works), how ICT interacts with people's everyday lives and why households choose to renovate with more or less focus on energy efficiency. The potential for quantitative methods is especially strong within sustainable consumption because of the opportunities for obtaining reliable micro-level data. In contrast to the majority of other sociological fields, energy consumption has the advantage of being a very concrete measure in the form of kWh, although energy consumption is a result of the performance of very different social practices that are considerably more difficult to measure. In this way, energy consumption also makes an excellent case for studying the social mechanisms underlying the inconspicuous and routinized aspects of human conduct more generally.

The third contribution is conceptual, as this dissertation provides an initial theoretical framework for interpreting quantitative results regarding energy consumption in a sociological perspective. This is primarily based on Bourdieu's theory on a homologous relationship between social structures, cognitive dispositions and practice. Moreover, this dissertation has presented a recently overlooked way of understanding change and reproduction of habits (and thereby also energy consumption). In forgetting this, we might face the consequence of overlooking that practice is partially reliant on patterns formed through upbringing and internalised in bodies as a imitating of family members, neighbours and friends. Moreover, it is important to consider that buildings and technologies both have a social dimension, where social status and symbols are important factors.

6.3. RESEARCH AND POLICY IMPLICATIONS

With the above factors in mind, there is consequently a need for sociological research to investigate how households consume energy, why these households consume as they do, and how underlying social structures and mechanisms influence the reproduction and change of energy-related habits. This contributes to better understanding energy-consuming behaviour, but also to qualify debates over performance gaps and rebound effects, where 'user' behaviour deviates from the expected.

First and foremost, I would like to advocate for sociological analyses of micro-level processes that are grounded in quantitative (and/or qualitative) empirical analysis that are interpreted using sociological theories. My hope is that this dissertation, and the papers included in it, will contribute to encouraging such a development. More sociological empirical evidence will strengthen the position towards informing policy, and thereby contribute to driving sustainable development and reaching political energy and climate goals. Three points are important in this regard.

The first is to focus on the sociological understandings of energy consumption as embedded in everyday practices. This entails a stronger focus on how price signals are incorporated into practices through reconfiguring understandings and meanings of practices. For example, when higher prices convey a meaning of value to energy that makes occupants reconfigure everyday routines and habits in a less energy-consuming direction or gives energy consumption a larger role in renovation projects. In line with this, seeking to support the status of more energy-efficient housing (e.g. smaller or newer houses) could provide a valuable addition to focus on economic incentives. Sociological research proves that there are other factors at stake than economic incentives, for example status and cultural understandings of family life.

The second point is that social structures may contribute with a 'third' explanation of already known empirical correlations. For example, performance gaps, where energy-efficient houses consume more than predicted, have a social dimension in the sense that there is a social selection into the energy-efficient houses. This means that the buying of a house is socially structured by for example preferences, economic means, and the households that move in 'carry' certain habits with them as well as these habits are being shaped by the new material and social setting. Thus, performance gaps and rebound effects are not solely a matter of individual behaviour but also of social class structures.

The last and third point is a suggestion to remember that the differences between occupants or households also entails that they may respond differently to changes in their social and material context. For example, different types of household respond differently to energy efficiency improvements or increased prices. Therefore, much

could be gained by directing the implementation of initiatives and interventions towards how the target groups consume energy differently. Certain effects may only "work" for certain groups or in certain contexts. This means a focus on heterogeneous effects and how the material and social context interacts.

LITERATURE LIST

Abbott, A., 1988. Transcending General Linear Reality. Sociol. Theory 6, 169. doi:10.2307/202114

Abrahamse, W., Steg, L., 2009. How do socio-demographic and psychological factors relate to households' direct and indirect energy use and savings? J. Econ. Psychol. 30, 711–720. doi:10.1016/j.joep.2009.05.006

Ajzen, I., 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process., Theories of Cognitive Self-Regulation 50, 179–211. doi:10.1016/0749-5978(91)90020-T

Alberini, A., Filippini, M., 2011. Response of residential electricity demand to price: The effect of measurement error. Energy Econ. 33, 889–895. doi:10.1016/j.eneco.2011.03.009

Alberini, A., Gans, W., Velez-Lopez, D., 2011. Residential consumption of gas and electricity in the U.S.: The role of prices and income. Energy Econ. 33, 870–881. doi:10.1016/j.eneco.2011.01.015

Andersen, R., Fabi, V., Toftum, J., Corgnati, S.P., Olesen, B.W., 2013. Window opening behaviour modelled from measurements in Danish dwellings. Build. Environ. 69, 101–113. doi:10.1016/j.buildenv.2013.07.005

Andersen, R.V., Toftum, J., Andersen, K.K., Olesen, B.W., 2009. Survey of occupant behaviour and control of indoor environment in Danish dwellings. Energy Build. 41, 11–16. doi:10.1016/j.enbuild.2008.07.004

Anderson, B., 2016. Laundry, energy and time: Insights from 20 years of time-use diary data in the United Kingdom. Energy Res. Soc. Sci. 22, 125–136. doi:10.1016/j.erss.2016.09.004

Axsen, J., Kurani, K.S., 2012. Social Influence, Consumer Behavior, and Low-Carbon Energy Transitions. Annu. Rev. Environ. Resour. 37, 311–340. doi:10.1146/annurev-environ-062111-145049

Bandura, A., 1986. The Explanatory and Predictive Scope of Self-Efficacy Theory. J. Soc. Clin. Psychol. 4, 359–373. doi:10.1521/jscp.1986.4.3.359

Bartiaux, F., Gram-Hanssen, K., Fonseca, P., Ozoliņa, L., Christensen, T.H., 2011. A practice-theory based analysis of energy renovations in four European countries. Build. Res. Inf. 42, 525–538. doi:10.1080/09613218.2014.900253

Bourdieu, P., 2005. The Social Structures of the Economy. Polity, Cambridge.

Bourdieu, P., 1986. The Forms of Capital, in: Szeman, I., Kaposy, T. (Eds.), Cultural Theory: An Anthology. John Wiley & Sons.

Bourdieu, P., 1984. Distinction: A Social Critique of the Judgement of Taste. Harvard University Press, Cambridge, Massachusetts.

Bourdieu, P., 1980. The Logic of Practice. Stanford University Press, Stanford, California.

Bourdieu, P., 1977. Outline of a theory of practice. Cambridge University Press, Cambridge.

Bourdieu, P., Wacquant, L.J.D., 1992. An Invitation to Reflexive Sociology. University of Chicago Press, Chicago.

Brounen, D., Kok, N., Quigley, J.M., 2013. Energy literacy, awareness, and conservation behavior of residential households. Energy Econ. 38, 42–50. doi:10.1016/j.eneco.2013.02.008

Brounen, D., Kok, N., Quigley, J.M., 2012. Residential energy use and conservation: Economics and demographics. Eur. Econ. Rev., Green Building, the Economy, and Public Policy 56, 931–945.

Browne, A., Pullinger, M., Medd, W., Anderson, B., 2014. Patterns of practice: a reflection on the development of quantitative methodologies reflecting everyday life related to water demand and consumption in the United Kingdom. Int. J. Soc. Res. Methodol. 17.

Butler, C., Parkhill, K.A., Pidgeon, N.F., 2014. Energy consumption and everyday life: Choice, values and agency through a practice theoretical lens. J. Consum. Cult. doi:10.1177/1469540514553691

Chittum, A., Østergaard, P.A., 2014. How Danish communal heat planning empowers municipalities and benefits individual consumers. Energy Policy 74, 465–474. doi:10.1016/j.enpol.2014.08.001

Day, R., Hitchings, R., 2011. "Only old ladies would do that": Age stigma and older people's strategies for dealing with winter cold. Health Place 17, 885–894. doi:10.1016/j.healthplace.2011.04.011

Energistyrelsen, 2016. Sammenhængen mellem boligers energistandard og forekomst af sygdomme hos beboerne - analyse baseret på registerdata.

Energistyrelsen, 2015. Energistatistik 2014.

Estiri, H., 2016. Differences in Residential Energy Use between US City and Suburban Households. Reg. Stud. 50, 1919–1930. doi:10.1080/00343404.2015.1079310

Estiri, H., 2015a. The indirect role of households in shaping US residential energy demand patterns. Energy Policy 86, 585–594. doi:10.1016/j.enpol.2015.08.008

Estiri, H., 2015b. A structural equation model of energy consumption in the United States: Untangling the complexity of per-capita residential energy use. Energy Res. Soc. Sci. 6, 109–120.

Estiri, H., 2014. Building and household X-factors and energy consumption at the residential sector: A structural equation analysis of the effects of household and building characteristics on the annual energy consumption of US residential buildings. Energy Econ. 43, 178–184.

Galvin, R., Sunikka-Blank, M., 2016. Schatzkian practice theory and energy consumption research: Time for some philosophical spring cleaning? Energy Res. Soc. Sci. 22, 63–68. doi:10.1016/j.erss.2016.08.021

Gram-Hanssen, K., 2014a. New needs for better understanding of household's energy consumption – behaviour, lifestyle or practices? Archit. Eng. Des. Manag. 10, 91–107.

Gram-Hanssen, K., 2014b. Existing buildings – Users, renovations and energy policy. Renew. Energy 61, 136–140. doi:10.1016/j.renene.2013.05.004
Gram-Hanssen, K., 2011. Understanding change and continuity in residential energy consumption. J. Consum. Cult. 11, 61–78. doi:10.1177/1469540510391725
Gram-Hanssen, K., 2010a. Residential heat comfort practices: understanding users. Build. Res. Inf. 38, 175–186.
Gram-Hanssen, K., 2010b. Standby Consumption in Households Analyzed With a Practice Theory Approach. J. Ind. Ecol. 14, 150–165.
Gram-Hanssen, K., 2007. Teenage consumption of cleanliness: how to make it sustainable? Sustain. Sci. Pract. Policy 3.
Gram-Hanssen, K., 2003. Boligers energiforbrug: sociale og tekniske forklaringer på forskelle. Statens Byggeforskningsinstitut, Hørsholm.
Gronow, J., Warde, A., 2001. Ordinary Consumption. Routledge, New York.
Hackett, B., Lutzenhiser, L., 1991. Social Structures and Economic Conduct: Interpreting Variations in Household Energy Consumption. Sociol. Forum 6, 449–470.
Haines, V., Mitchell, V., 2014. A persona-based approach to domestic energy retrofit. Build. Res. Inf. 42, 462–476. doi:10.1080/09613218.2014.893161
Hand, M., Shove, E., Southerton, D., 2005. Explaining showering: A discussion of the material, conventional, and temporal dimensions of practice. Sociol. Res. Online 10.
Hards, S., 2011. Social Practice and the Evolution of Personal Environmental Values. Environ. Values 20, 23–42. doi:10.3197/096327111X12922350165996
Hards, S.K., 2013. Status, stigma and energy practices in the home. Local Environ. 18, 438–454. doi:10.1080/13549839.2012.748731
Harold, J., Lyons, S., Cullinan, J., 2015. The determinants of residential gas demand in Ireland. Energy Econ. 51, 475–483. doi:10.1016/j.eneco.2015.08.015
Hitchings, R., Day, R., 2011. How Older People Relate to the Private Winter Warmth Practices of Their Peers and Why We Should Be Interested. Environ. Plan. A 43, 2452–2467. doi:10.1068/a44107
IEA, 2015. World Energy Outlook 2015. OECD Publishing.
Jack, T., 2016. Cleanliness and consumption: Exploring material and social structuring of domestic cleaning practices. Int. J. Consum. Stud. 1–9. doi:10.1111/ijcs.12315
Jack, T., 2013a. Laundry routine and resource consumption in Australia: Laundry routines and consumption. Int. J. Consum. Stud. 37, 666–674. doi:10.1111/ijcs.12048
Jack, T., 2013b. Nobody was dirty: Intervening in inconspicuous consumption of laundry routines. J. Consum. Cult. 13, 406–421. doi:10.1177/1469540513485272
Jæger, M.M., 2008. Kvantitative metoder i dansk sociologi. Dan. Sociol. 17, 97–103.

Jalas, M., Rinkinen, J., 2013. Stacking wood and staying warm: Time, temporality and housework around domestic heating systems. J. Consum. Cult. 16, 43–60. doi:10.1177/1469540513509639

Judson, E.P., Maller, C., 2014. Housing renovations and energy efficiency: insights from homeowners' practices. Build. Res. Inf. 42, 501–511. doi:10.1080/09613218.2014.894808

Kelly, S., Shipworth, M., Shipworth, D., Gentry, M., Wright, A., Pollitt, M., Crawford-Brown, D., Lomas, K., 2013. Predicting the diversity of internal temperatures from the English residential sector using panel methods. Appl. Energy 102, 601–621. doi:10.1016/j.apenergy.2012.08.015

Knudsen, H.N., Andersen, R.K., Hansen, A.R., Gram-Hanssen, K., 2016. Clima 2016 - Proceedings of 12th REHVA World Congress CLIMA 2016 : volume 6. Presented at the CLIMA 2016 - 12th REHVA World Congress.

Lind, O., 1996. Bag hækken- det danske parcelhus i lyst og nød. Arkitektens Forlag, Kbh.

Longhi, S., 2015. Residential energy expenditures and the relevance of changes in household circumstances. Energy Econ. 49, 440–450. doi:10.1016/j.eneco.2015.03.018

Lutzenhiser, L., 2014. Through the energy efficiency looking glass. Energy Res. Soc. Sci. 1, 141–151. doi:10.1016/j.erss.2014.03.011

Lutzenhiser, L., 1994. Sociology, Energy and Interdisciplinary Environmental Science. Am. Sociol. 25, 58–79.

Lutzenhiser, L., 1993. Social and Behavioral Aspects of Energy use. Annu. Rev. Energy Environ. 18, 247–289. doi:10.1146/annurev.eg.18.110193.001335

Lutzenhiser, L., 1992a. A cultural model of household energy consumption. Energy 17, 47–60. doi:10.1016/0360-5442(92)90032-U

Lutzenhiser, L., 1992b. A question of control: alternative patterns of room air-conditioner use. Energy Build. 18, 193–200. doi:10.1016/0378-7788(92)90013-7

Lutzenhiser, L., Bender, S., 2010. The "Average American" Unmasked: Social Structure and Differences in Household Energy Use and Carbon Emissions, in: Ehrhardt-Martinez, K., Laitner (Eds.), People-Centered Initiatives for Increasing Energy Savings. Presented at the American Council for an Energy-Efficient Economy, Washington, p. 10.1-10.14.

Lutzenhiser, L., Gossard, M.H., 2000. Lifestyle, status and energy consumption, in: Proceedings of the 2000 ACEEE Summer Study of Energy Efficiency in Buildings. pp. 8–207.

Lutzenhiser, L., Hackett, B., 1993. Social Stratification and Environmental Degradation: Understanding Household CO2 Production. Soc. Probl. 40, 50–73. doi:10.2307/3097026

Majcen, D., Itard, L.C.M., Visscher, H., 2013. Theoretical vs. actual energy consumption of labelled dwellings in the Netherlands: Discrepancies and policy implications. Energy Policy, Decades of Diesel 54, 125–136. doi:10.1016/j.enpol.2012.11.008

Marsh, R., Larsen, V.G., Kragh, M., 2010. Housing and energy in Denmark: past, present, and future challenges. Build. Res. Inf. 38, 92–106. doi:10.1080/09613210903226608

McMeekin, A., Southerton, D., 2012. Sustainability transitions and final consumption: practices and socio-technical systems. Technol. Anal. Strateg. Manag. 24, 345–361. doi:10.1080/09537325.2012.663960

Meier, H., Rehdanz, K., 2010. Determinants of residential space heating expenditures in Great Britain. Energy Econ. 32, 949–959. doi:10.1016/j.eneco.2009.11.008

Nesbakken, R., 1999. Price sensitivity of residential energy consumption in Norway. Energy Econ. 21, 493–515. doi:10.1016/S0140-9883(99)00022-5

Nierop, S.C.A., 2014. Energy poverty in Denmark? Master's Thesis for the Joint European Master in Environmental Studies–Cities & Sustainability at Aalborg University.

Ohler, A.M., Billger, S.M., 2014. Does environmental concern change the tragedy of the commons? Factors affecting energy saving behaviors and electricity usage. Ecol. Econ. 107, 1–12. doi:10.1016/j.ecolecon.2014.07.031

Rehdanz, K., 2007. Determinants of residential space heating expenditures in Germany. Energy Econ. 29, 167–182. doi:10.1016/j.eneco.2006.04.002

Rinkinen, J., Jalas, M., 2016. Moving home: houses, new occupants and the formation of heating practices. Build. Res. Inf. 0, 1–10. doi:10.1080/09613218.2016.1143299

Rinkinen, J., Jalas, M., Shove, E., 2015. Object Relations in Accounts of Everyday Life. Sociology 49, 870–885. doi:10.1177/0038038515577910

Røpke, I., Haunstrup Christensen, T., Ole Jensen, J., 2010. Information and communication technologies – A new round of household electrification. Energy Policy 38, 1764–1773. doi:10.1016/j.enpol.2009.11.052

Sanquist, T.F., Orr, H., Shui, B., Bittner, A.C., 2012. Lifestyle factors in U.S. residential electricity consumption. Energy Policy 42, 354–364. doi:10.1016/j.enpol.2011.11.092

Santin, O.G., 2013. Occupant behaviour in energy efficient dwellings: evidence of a rebound effect. J. Hous. Built Environ. 28, 311–327. doi:10.1007/s10901-012-9297-2

Santin, O.G., 2011. Behavioural Patterns and User Profiles related to energy consumption for heating. Energy Build. 43, 2662–2672. doi:10.1016/j.enbuild.2011.06.024

Santin, O.G., Itard, L., Visscher, H., 2009. The effect of occupancy and building characteristics on energy use for space and water heating in Dutch residential stock. Energy Build. 41, 1223–1232.

Sapci, O., Considine, T., 2014. The link between environmental attitudes and energy consumption behavior. J. Behav. Exp. Econ. 52, 29–34. doi:10.1016/j.socec.2014.06.001

Schatzki, T.R., Knorr-Cetina, K., Savigny, E. von, 2001. The practice turn in contemporary theory. Routledge, London; New York.

Schwartz, S.H., 1977. Normative Influences on Altruism, in: Berkowitz, L. (Ed.), Advances in Experimental Social Psychology. Academic Press, pp. 221–279.

Shipworth, M., 2011. Thermostat settings in English houses: No evidence of change between 1984 and 2007. Build. Environ. 46, 635–642. doi:10.1016/j.buildenv.2010.09.009

Shipworth, M., Firth, S.K., Gentry, M.I., Wright, A.J., Shipworth, D.T., Lomas, K.J., 2010. Central heating thermostat settings and timing: building demographics. Build. Res. Inf. 38, 50–69. doi:10.1080/09613210903263007

Shove, E., 2003a. Comfort, Cleanliness and Convenience: The Social Organization of Normality. Bloomsbury Academic.

Shove, E., 2003b. Converging Conventions of Comfort, Cleanliness and Convenience. J. Consum. Policy 26, 395–418. doi:10.1023/A:1026362829781

Shove, E., 2003c. Users, Technologies and Expectations of Comfort, Cleanliness and Convenience. Innov. Eur. J. Soc. Sci. Res. 16, 193–206. doi:10.1080/13511610304521

Shove, E., Chappels, H., Lutzenhiser, L., Hackett, B., 2008. Comfort in a lower carbon society. Build. Res. Inf. 36, 307–311. doi:10.1080/09613210802079322

Shove, E., Pantzar, M., Watson, M., 2012. The Dynamics of Social Practice : Everyday Life and how it Changes. Sage, London.

Shove, E., Southerton, D., 2000. Defrosting the Freezer: From Novelty to Convenience A Narrative of Normalization. J. Mater. Cult. 5, 301–319. doi:10.1177/135918350000500303

Shove, E., Walker, G., 2014. What Is Energy For? Social Practice and Energy Demand. Theory Cult. Soc. 31, 41–58. doi:10.1177/0263276414536746

Shove, E., Warde, A., 2002. Inconspicuous Consumption: The Sociology of Consumption, Lifestyles, and the Environment, in: Dunlap, R.E., Buttel, F.H., Dickens, P., Gijswijt, A. (Eds.), Sociological Theory and the Environment: Classical Foundations, Contemporary Insights. Rowman & Littlefield Publishers, pp. 230–251.

Shove, E., Watson, M., Spurling, N., 2015. Conceptualizing connections: Energy demand, infrastructures and social practices. Eur. J. Soc. Theory 18, 274–287. doi:10.1177/1368431015579964

Sovacool, B.K., 2014. What are we doing here? Analyzing fifteen years of energy scholarship and proposing a social science research agenda. Energy Res. Soc. Sci. 1, 1–29. doi:10.1016/j.erss.2014.02.003

Steemers, K., Yun, G.Y., 2009. Household energy consumption: a study of the role of occupants. Build. Res. Inf. 37, 625–637. doi:10.1080/09613210903186661

Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., Thorsnes, P., 2010. Energy cultures: A framework for understanding energy behaviours. Energy Policy 38, 6120–6129. doi:10.1016/j.enpol.2010.05.069

Strengers, Y., 2012. Peak electricity demand and social practice theories: Reframing the role of change agents in the energy sector. Energy Policy 44, 226–234. doi:10.1016/j.enpol.2012.01.046

Strengers, Y., 2011. Negotiating everyday life: The role of energy and water consumption feedback. J. Consum. Cult. 11, 319–338. doi:10.1177/1469540511417994

Strengers, Y., 2010. Air-conditioning Australian households: The impact of dynamic peak pricing. Energy Policy 38, 7312–7322. doi:10.1016/j.enpol.2010.08.006

Strengers, Y., 2008. Comfort expectations: the impact of demand-management strategies in Australia. Build. Res. Inf. 36, 381–391. doi:10.1080/09613210802087648

Thøgersen, J., Grønhøj, A., 2010. Electricity saving in households—A social cognitive approach. Energy Policy 38, 7732–7743. doi:10.1016/j.enpol.2010.08.025

Vandenberghe, F., 1999. "The Real is Relational": An Epistemological Analysis of Pierre Bourdieu's Generative Structuralism. Sociol. Theory 17, 32–67. doi:10.1111/0735-2751.00064

Vlasova, L., Gram-Hanssen, K., 2014. Incorporating inhabitants' everyday practices into domestic retrofits. Build. Res. Inf. 42, 512–524. doi:10.1080/09613218.2014.907682

Wallenborn, G., Wilhite, H., 2014. Rethinking embodied knowledge and household consumption. Energy Res. Soc. Sci. 1, 56–64. doi:10.1016/j.erss.2014.03.009

Whitford, J., 2002. Pragmatism and the untenable dualism of means and ends: Why rational choice theory does not deserve paradigmatic privilege. Theory Soc. 31, 325–363. doi:10.1023/A:1016232404279

Wilhite, H., Lutzenhiser, L., 1999. Social Loading and Sustainable Consumption, in: Arnould, E.J., Scott, L.M. (Eds.), NA - Advances in Consumer Research Volume 26. Provo, UT, pp. 281–287.

Wilhite, H., Nakagami, H., Masuda, T., Yamaga, Y., Haneda, H., 1996. A cross-cultural analysis of household energy use behaviour in Japan and Norway. Energy Policy 24, 795–803. doi:10.1016/0301-4215(96)00061-4

Wilhite, H., Shove, E., Lutzenhiser, L., Kempton, W., 2000. The legacy of twenty years of energy demand management: we know more about individual behaviour but next to nothing about demand, in: Society, Behaviour, and Climate Change Mitigation. Springer, pp. 109–126.

Wilk, R.R., Wilhite, H.L., 1985. Why don't people weatherize their homes? An ethnographic solution. Energy 10, 621–629. doi:10.1016/0360-5442(85)90093-3

Yang, S., Shipworth, M., Huebner, G., 2015. His, hers or both's? The role of male and female's attitudes in explaining their home energy use behaviours. Energy Build. 96, 140–148. doi:10.1016/j.enbuild.2015.03.009

Yun, G.Y., Steemers, K., 2011. Behavioural, physical and socio-economic factors in household cooling energy consumption. Appl. Energy 88, 2191–2200. doi:10.1016/j.apenergy.2011.01.010

CHAPTER 7. PAPERS

7.1. PAPER I

APPENDICES

Appendix A. Residential heat consumption in Denmark

Due to Denmark's temperate climate, there is a need for space heating during winter, where the heating season generally lasts from October to March. These weather conditions, together with the Danish welfare system and relatively high standards of energy efficiency across the building stock, form the context of the empirical case of this dissertation, which is energy consumption used for space heating and domestic hot water in Danish single-family detached houses. In this section, I will describe the empirical case also presented in chapter 2 in greater detail.

Heat planning in Denmark

Since the oil crisis of the 1970s, low-energy initiatives directed at reducing heat consumption have had a radical impact on reducing energy consumption in buildings, primarily due to gradually stricter building regulation (Marsh et al., 2010). Some of the policy initiatives in Denmark were to support the use of more district heating and better use of surplus heat and natural gas resources in the North Sea in order to reduce dependency on fossil fuels such as oil (Chittum and Østergaard, 2014). The minimum requirements for energy performance of new buildings have, after inclusion in the Danish Building Regulations in 1979, gradually been tightened, and from 2006, an energy performance certification was mandatory for all new buildings (Gram-Hanssen, 2014b).

The two main heating forms for single-family detached houses today are district heating and natural gas. As shown in Figure 2, these two sources supplied 78% of Danish households in 2015.

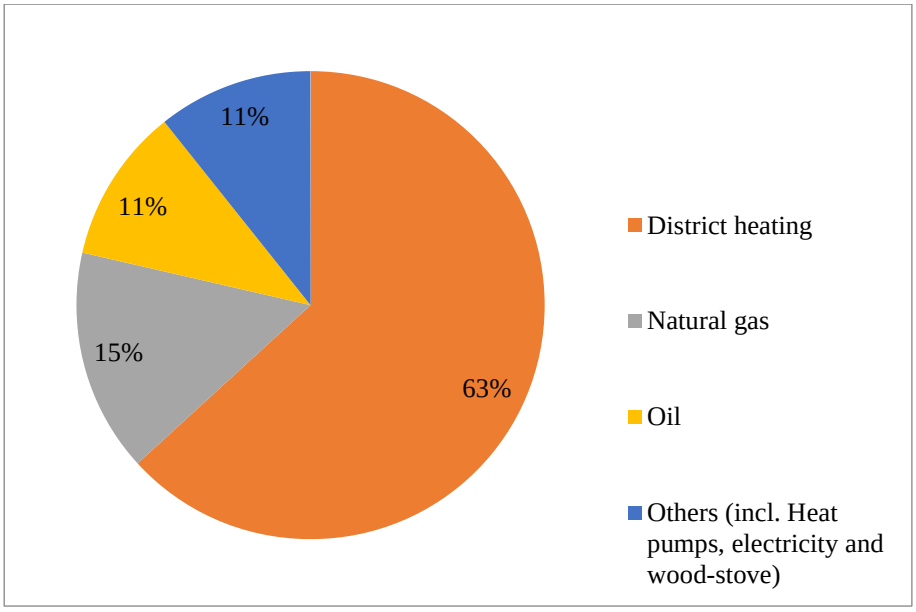

Figure 2. Primary heating forms in Denmark. All housing types 2015. Source: Statistics Denmark.

Electricity for heating is not widespread in Denmark. This is partly because of a law on restriction of electricity for heating in 1994 and because it is an expensive heating source compared to others (Chittum and Østergaard, 2014).

Today, heating is central to Danish energy planning, where local energy actors are given a high level of autonomy and flexibility to address environmental issues, which has resulted in almost half of the heating sector being reliant on renewables (Chittum and Østergaard, 2014).

House types in Denmark

The single-family detached houses that make up the empirical case of this dissertation are the most frequent housing form in Denmark, covering 44% of the housing stock (Figure 3). These are primarily built in the period from 1960 to 1980, and are typically one-storey brick houses with an attached garden. These houses are normally built from standard design and by prefabricated elements. After the oil crisis in the 1970s, the improvement of energy efficiency came more into focus, for example through thicker insulation (Lind, 1996).

In addition to ensuring more energy efficiency in new built houses, some of the older housing stock was also energy retrofitted as a response to the oil crisis, which principally concerned insulation of the stock, wall and loft and replacement of windows with improved glazing systems. Although this led to a significant reduction

of the demand for space heating in the housing sector (Marsh et al., 2010), single-family houses still have the largest potential for energy savings in the Danish building stock due to their frequency and housing size (Gram-Hanssen, 2014b). In 2006, a new chapter was added to the Danish Building Regulations concerning energy consumption, which included the implementation of the European Union Energy Performance of Buildings Directive (EPBD).

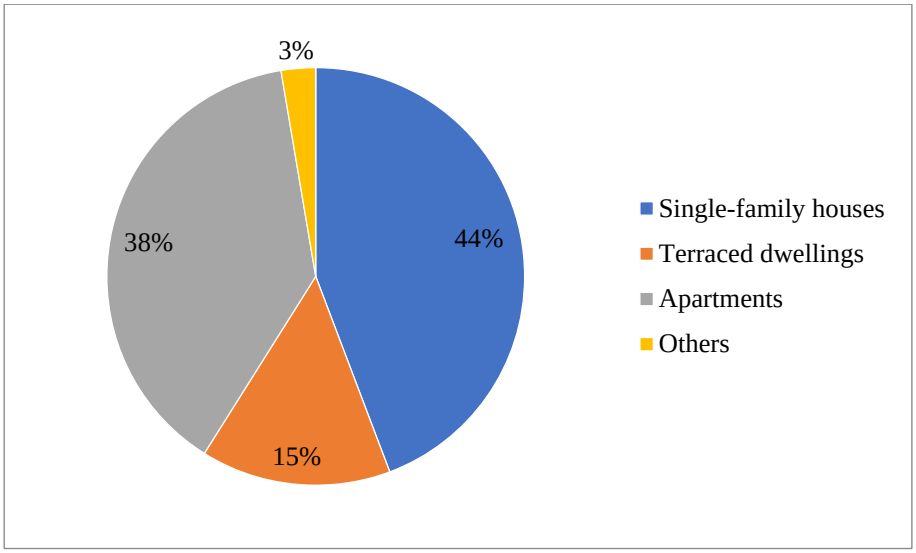

Figure 3. Housing types in Denmark. All households in 2014. Source: Statistics Denmark.

Although there is very limited empirical evidence on energy poverty or energy equity in Denmark[27], the general opinion is that energy poverty, where households cannot afford to heat their houses, is minimal due to an (rather) efficient welfare state, a generally high standard of energy efficiency of houses and relatively low energy prices. Nevertheless, energy equity is a challenge in Denmark, not least with consequences for health problems caused by poor indoor climate. For example, a recent report from (Energistyrelsen, 2016) shows some indications of a correlation between energy efficiency of houses and health condition of occupants, but no clear-cut correlation between the two, however.

[27] One master's thesis finds that there are energy-poor households in Denmark and that main drivers are low income and poor energy efficiency of houses (Nierop, 2014).

Appendix B. Data sources

Aside from the survey data, all datasets include several years, and the different papers uses data from different years. All data analyses were conducted using Statistics Denmark's data service for researchers (In Danish: Danmarks Statistiks Forskerservice), which consists of a server situated in Statistics Denmark's buildings that is available for researchers to reach externally.

Annual heat consumption

Data on annual heat consumption covers the registered use of energy for space heating and hot water within a calendar year, which means that, for example, the use of wood-burning stoves for space heating is not included because there is no registered data on this. Annual heat consumption is used as dependent variable in papers I, II and IV as a measure for how much energy a household (or single members of a household) use for heating and hot water, reflecting everyday habits (see papers for further details).

The papers of this dissertation are the first examples of application of this database on energy consumption for sociological analyses, and as a consequence, there have been some extra precautions to take, for example when discussing data quality[28].

Data is provided by the office administrating the Building and Dwelling Register (BBR), which is part of the Danish Ministry of Taxation. The data consists of information from heating suppliers based on payment records on metered heat consumption of their customers, which they are obliged to give according to Danish law. Data is corrected into annual heat consumption, where climate degree days are used to correct for weather differences across years, for example if a supplier reports consumption from October to October for one household and from March to March for another household.

The disadvantages of this model for collecting data are that some suppliers might not report data for their customers despite reminders from BBR. Moreover, the different payment structures between suppliers might also cause some "disturbance"[29], and furthermore, data is difficult to obtain for households that are not connected to collective heating infrastructure, for example when heating is provided by individual oil boilers. Due to the last point, my analysis solely relies on households heated with district heating or natural gas, which means that households

[28] Over the period of the PhD, I have had several meetings with the administrators of the data, who also collect it, to ensure the quality of the data. Moreover, I have had meetings with others using the data for other analysis to exchange experiences of using the data.

[29] This is primarily a problem in descriptive use of the data, where it is not possible to control for unattended variation between suppliers.

in single-family detached houses heated with oil, electricity and bio-fuel as the primary source are not included in the data samples of the papers. This might bias the representativity as these are found more often in rural areas than in urban ones. However, as can be seen in Appendix D showing the representativity of the papers, this is only a minor issue and the samples still reflect the common housing type and heating forms in Denmark.

Perhaps influenced by these disadvantages, I have detected some huge outliers in the data and large differences between suppliers, which I have not corrected for in the empirical analysis. To show the robustness of the analyses, I have, however, checked for models without outliers in each analysis, which has only shown negligible differences, and thereby supports my approach.

Data, particularly related to energy, is used for purposes other than research, which might cause a problem as research purposes have not been incorporated into the practice of registering data, but on the other hand, this might represent an advantage in that data is used for payment and therefore is very important for the supplier to get very accurate registrations. Besides the strong reliability of the energy data (at least within suppliers), the strongest advantage of the data is that it is the actual metered data in kWh and this data covers a large number of households. The large number of observations in my analysis, and that they span several years, means that these analyses are based on far more extensive data on heat consumption than previous studies. Further, the heat consumption data is connected to identifiers of households' addresses, which enables merging with other data such as price, socio-economic and building, as it has been performed in my analyses.

District heating prices

Data on district heating prices are used in paper II. This data consists of two variables: one concerning unit price and another concerning a standardised price for a hypothetical family. I have constructed the data myself from available online records on these two price indicators, which are collected by The Danish Energy Regulatory Authority (in Danish: Energitilsynet) about three times a year. This data cannot be used for calculating the actual expenditure of households, but instead they are indicators of price differences between suppliers and price movements over time. In these records, data is not attached to a supplier identifier such as the one used by the Central Business Register (CVR) but instead attached to names of the suppliers, which are spelled differently from year to year. Therefore, the data lacks reliable information on identifiers, and some potential biases might have emerged in the process of constructing the dataset and merging it to the other datasets. However, I have made as many tests as possible, which did not reveal uncertainties, and the final sample is not substantially different from a group of entirely single-family detached houses with district heating, which indicates that the sample represents the total population. This indicates that the data is the best available data in Denmark on heat consumption and energy prices.

Survey data on heat-related habits

Survey data is used for paper III which I wrote together with Kirsten Gram-Hanssen and Henrik N. Knudsen. The survey data stems from an occupant survey that I conducted with Gram-Hanssen and Knudsen in February and March 2015. The survey was named the UserTEC survey as it was part of, and financed by, the project UserTEC. In addition, Line V. Madsen, Per Heiselberg and Rune V.K. Andersen have contributed to the questionnaire, which has also been discussed with partners (academic and business) of the UserTEC project. The questionnaire was formed by UserTEC, but the survey was conducted by Statistics Denmark, who also conducted an initial pilot survey.

The questionnaire entailed questions on heat-related habits, improvements done to the house, technical installations and questions on attitudes, opinions and suchlike. The questionnaire was sent to selected customers[30] of Affaldvarme Aarhus, who primarily live in the outskirts of Denmark's second largest city, Aarhus. The respondents were initially approached by mail and then by phone if they did not answer. 1,216 individuals answered the questionnaire, which resulted in a response rate of 69.5% (see also Knudsen et al. (2016) for details).

In an attempt to increase the validity of different measures, we tried to ask occupants several questions related to the same issue as well as asking more directly about specific situations in everyday life. For example, we asked a range of questions on the amount of clothes they were wearing to construct one measure for this and for different everyday motives for opening windows to construct another.

Administrative data

In all of the empirical papers, I use a range of variables stemming from administrative data from Statistics Denmark. This is used for constructing indicators of the social and material structure and as controls for various individual, household and building characteristics as well as area-specific effects.

As for annual heat consumption, the primary purpose of the administrative data is not for research, which might strengthen the reliability because it figures in other reliable systems instead of being self-reported. In this way, there is no moralising in measuring different characteristics, which may occur in survey questionnaires. However, some of the information is more or less self-reported in the registers as well, but this information is supervised by the authorities.

Another advantage of the data is that it is extensive as it covers all registered citizens living in Denmark, which enables a nuanced analysis, and also because some of the variables are very detailed. For example, disposable income is a continuous variable

[30] The customers were selected if it was possible for us to obtain hourly data on heat consumption for their household, which was important to the overall project.

in contrast to many surveys where income is measured in categories that respondents might have difficulties in answering. In general, the data is considered very reliable and used in various research areas in Denmark.

Appendix C. UserTEC survey questionnaire

The UserTEC survey was conducted during winter 2015 in February and March. The questionnaire was written in Danish and only translated into English to give partners of the UserTEC an idea of the questions asked. The translation was performed by a student assistant and not by a professional. Consequently, the translated questionnaire is not comprehensively translated, but still it gives an idea of the questions asked.

Headlines and text written in *italics* or <u>underlined</u> are added to facilitate understanding of the questions/variables, and therefore not a part of the questionnaire. The text written in **bold** are names of variables. The results are displayed in percentages with the number in parentheses. The number before the response categories is the coding of the variable, which is the original coding made by Statistics Denmark who conducted the survey. Missing values are not given any code here but, in Stata, these are recorded as:

Percentage is calculated from all observations including missing values. This means that all tables sum to 1,216. The numbers in this questionnaire follow Danish (and European) punctuation, which means that decimal commas (,) and thousand point (.) are used.

Background

	1. Telephone	2. Web
Data collection method [31]	24,26 % (295)	75,74 % (921)

First, some background questions

[31] Not a question in the questionnaire

	1. Male	2. Female
Are you male or female?	53,13 % (646)	46,88 % (570)

What is your year of birth?	*Continuous*

	1. Rent	2. Owner-occupied	9. Don't know
Do you rent or own your home	2,88 % (35)	97,04 % (1.180)	0,08 % (1)

	1. Before 1981	2. 1981-2006	3. After 2006	4. Don't know	Missing
In what year was the residence built?	69,82 % (849)	19,74 % (240)	7,24 % (88)	0,25 % (3)	2,96 % (36)

	1. Yes	2. No	Missing
Does your home have a basement?	24,26 % (295)	72,78 % (885)	2,96 % (36)

	1. Yes	2. No	Missing
Do you live with a spouse or partner?	83,47 % (1015)	13,57 % (165)	2,96 % (36)

	1. Yes	2. No	Missing
Do you have children living at home who are over 10 years old?	30,26 % (368)	66,78 % (812)	2,96 % (36)

Blok A – Heating

Now there is some question about the heating in your home.

Heating in the living room

		1. Radiator with Thermostat	2. Radiator without Thermostat	3. Under-floor heating with thermostat	4. Other (please note which type)	Missing
A1_11	Which type of heating is to be found in the living-room? (1ST OPTION) [32]	74,42 % (905)	1,64 % (20)	20,07 % (244)	0,90 % (11)	2,96 % (36)
A1_12	Which type of heating is to be found in the living-room? (2ND OPTION)	1,64 % (20)	0,25 % (3)	6,41 % (78)	8,55 % (104)	83,14 % (1.011)
A1_13	Which type of heating is to be found in the living-room? (3RD OPTION)			0,25 % (3)	0,74 % (9)	99,01 % (1.204)
A1_14	Which type of heating is to be found in the living-					100,00 %

[32] This is a multiple choice questions, where it is possible to giver several answers to the same questions. Therefore is shown which an independent variable for 1 to 4 option in the question.

	room? (4TH OPTION)					(1.216)

Which type of heating is to be found in the living-room?		1. selected	2. not selected
A1_11_ELM_1[33]	Radiator with Thermostat	76,07 % (925)	23,93 % (291)
A1_11_ELM_2	Radiator without Thermostat	1,89 % (23)	98,11 % (1.193)
A1_11_ELM_3	Under-floor heating with thermostat	26,73 % (325)	73,27 % (891)
A1_11_ELM_4	Other	10,20 % (124)	89,80 % (1.092)
A1_1a	Other – please note witch type	*Open response*	

Heating in Bedroom

		1. Radiator with Thermostat	2 Radiator without Thermostat	3. Under-floor heating with thermostat	4. Other – please note witch type	Missing
A1_21	Which type of heating is to be found in the bedroom? (1ST OPTION) [34]	78,29 % (952)	2,63 % (32)	14,97 % (182)	1,15 % (14)	2,96 % (36)
A1_22	Which type of heating is to be found in the bedroom? (2ND	0,08 % (1)		0,16 % (2)	0,33 % (4)	99,42 %

[33] In the tables reproduced the response of multiple-choice question above each answer.

[34] This is a multiple choice questions, where it is possible to giver several answers to the same questions. Therefore is shown which an independent variable for 1 to 4 option in the question.

	OPTION)					(1.209)
A1_23	Which type of heating is to be found in the bedroom? (3RD OPTION)					100,00 % (1.216)
A1_24	Which type of heating is to be found in the bedroom? (4TH OPTION)					100,00 % (1.216)

Which type of heating is to be found in the bedroom?		1. Selected	2. Not Selected
A1_21_ELM_1[35]	Radiator with Thermostat	78,37 % (953)	21,63 % (263)
A1_21_ELM_2	Radiator without Thermostat	2,63 % (32)	97,37 % (1.184)
A1_21_ELM_3	Under-floor heating with thermostat	15,13 % (184)	84,87 % (1.032)
A1_21_ELM_4	Other	1,48 % (18)	98,52 % (1.198)
A1_2a	Please note which type	*Open response*	

Heating in the Bathroom

	1. Radiator with Thermostat	2. Radiator without Thermostat	3. Under-floor heating with	4. Other – please note	Missing

[35] In the tables reproduced the response of multiple-choice question above each answer.

				thermostat	witch type	
A1_31	Which type of heating is to be found in the bathroom? (1ST OPTION) [36]	35,94 % (437)	1,64 % (20)	57,40 % (698)	2,06 % (25)	2,96 % (36)
A1_32	Which type of heating is to be found in the bathroom? (2ND OPTION)	5,02 % (61)	0,49 % (6)	14,06 % (171)	2,38 % (29)	78,04 % (949)
A1_33	Which type of heating is to be found in the bathroom? (3RD OPTION)				0,16 % (2)	99,84 % (1.214)
A1_34	Which type of heating is to be found in the bathroom? (4TH OPTION)					100,00 % (1.216)

Which type of heating is to be found in the bathroom		1. selected	2. not selected
A1_31_ELM_1 [37]	Radiator with Thermostat	40,95 % (498)	59,05 % (718)
A1_31_ELM_2	Radiator without Thermostat	2,14 % (26)	97,86 % (1.190)

[36] This is a multiple choice questions, where it is possible to giver several answers to the same questions. Therefore is shown which an independent variable for 1 to 4 option in the question.

[37] In the tables reproduced the response of multiple-choice question above each answer.

A1_31_ELM_3	Under-floor heating with thermostat	71,46 % (869)	28,54 % (347)
A1_31_ELM_4	Other	4,61 % (56)	95,39 % (1.160)
A1_3a	Please note which type	*Open response*	

The next question you need to answer based on what you do - not what other residents do

		1. Several times a day	2. Once or several times weekly	3. Once or several times monthly	4. I haven't regulated the heat	5. Unable to regulate the heat	Missing
A2_1	How often during the last month have you adjusted to heat on the radiators or underfloor heating in the living room?	9,70 % (118)	13,16 % (160)	26,48 % (322)	46,63 % (567)	1,07 % (13)	2,96 % (36)
A2_2	How often during the last month have you adjusted to heat on the radiators or underfloor heating in the bedroom?	14,31 % (174)	9,13 % (111)	13,57 % (165)	58,55 % (712)	1,48 % (18)	2,96 % (36)
A2_3	How often during the last month have you adjusted to heat on the radiators or underfloor heating in the bath room??	4,93 % (60)	4,85 % (59)	17,02 % (207)	68,75 % (836)	1,48 % (18)	2,96 % (36)

	1. Yes	2. No	3. Don't	4. Not possible or	Missing

				know	relevant	
A3_0	Was there any time last summer, the heat was completely off in the house, but still have hot water in the taps?	64,31 % (782)	29,44 % (358)	2,88 % (35)	0,41 % (5)	2,96 % (36)
A3_1	Was there any time last summer the heat was completely shut down in the living room ?	16,94 % (206)	14,23 % (173)	1,32 % (16)	0,25 % (3)	67,27 % (818)
A3_2	Was there any time last summer the heat was completely shut down in the Bedroom?	20,97 % (255)	10,20 % (124)	1,32 % (16)	0,25 (3)	67,27 % (818)
A3_3	Was there any time last summer the heat was completely shut down in the Bathroom?	5,18 % (63)	26,07 % (317)	1,15 % (14)	0,33 % (4)	67,27 % (818)
A3_4	Was there any time last summer the heat was completely shut down in the basement?	2,63 % (32)	3,29 % (40)	0,25 (3)	0,58 (7)	93,26 % (1.134)

Blok B - Indoor temperature

Questions related to the indoor temperature in your home.

		1. Yes	2. No	Missing
B4_1	Is there a thermometer to measure the inside temperature in the house?	72,20 % (878)	24,84 % (302)	2,96 % (36)
B4_2	Is there fairly the same temperature level in all heated rooms?	48,36 % (588)	48,60 % (591)	2,96 % (36)
B4_3	Are you trying to keep different temperatures in different heated rooms?	59,54 % (724)	37,50 % (456)	2,96 % (36)

B4_3a1 til B4_3a0 is only answered by respondents who answered B4_3 = 1. Yes

		1. To be able to sleep chillier	2. To save heat in the room, I / we live in	3. other	Missing
B4_3a1	Why do you or I different temperatures in different rooms? *(1st option)* [38]	48,60 % (591)	10,20 % (124)	0,74 % (9)	40,46 % (492)
B4_3a2	Why do you or I different temperatures in different rooms ?*(2nd option)*	3,21 % (39)	17,60 % (214)	0,41 % (5)	78,78 % (958)
B4_3a3	Why do you or I different temperatures in different rooms? *(3rd option)*				100,00 % (1216)

Why do you or I different temperatures in different rooms?		1. Selected	2. Not Selected
B4_3a1_ELM_1	To be able to sleep chillier	51,81 % (630)	48,19 % (586)
B4_3a1_ELM_2	To save heat in the room, I / we live in	27,80 % (338)	72,20 % (878)
B4_3a1_ELM_3	Other	1,15 % (14)	98,85 % (1202)
B4_3a0	Other – please note	*Open response*	

		1. Colder	2. the same	3. warmer	4. Don't know	Missing
B5	In winter - How do you feel your indoor temperature compared to others?	17,60 % (214)	59,54 % (724)	14,56 % (177)	5,35 % (65)	2,96 % (36)

[38] This is a multiple choice questions, where it is possible to giver several answers to the same questions. Therefore is shown which an independent variable for 1 to 4 option in the question.

		1. below 20° celsius	2. 20°-22° celsius	3. above 22° celsius	4. Don't know	Missing
B6_1	What temperature do you assess that generally is in the living room during the winter?	5,67 % (69)	75,74 % (921)	14,80 % (180)	0,82 % (10)	2,96 % (36)
B6_2	What temperature do you assess that generally is in the bedroom during the winter?	75,90 % (923)	17,76 % (216)	1,32 % (16)	2,06 % (25)	2,96 % (36)

B7	How many rooms for residential is not heated in your home this winter? If all rooms heated, write 0	*Count*

B7_1 is only answered by respondents who answered =1. Yes

		1. Yes	2. partly	3. No	4. Don't know	Missing
B7_1	Is your basement heated during winter?	7,81 % (95)	10,53 % (128)	5,76 % (70)	0,16 % (2)	75,74 % (921)

The next question you need to answer based on what you do - not what other residents do

		1. Yes	2. No	3. Don't know	Missing
B8	Do you regulate the heat more often in the autumn months than in the winter months, for example by adjusting the thermostats?	31,50 % (383)	61,51 % (748)	4,03 % (49)	2,96 % (36)

Do you have the ability to regulate the heat in your home, so it can be used more efficiently through large cooling of the district heating water?

	1. not at all	2 To a minor extent	3 To some extent	4. To a large extent	5. Don't know	6. Doesn't have district heating	Missing

B10	To what degree do you adjust the heat in your home in a way that ensures as much cooling of the district heating water as possible?	32,15 % (391)	13,49 % (164)	19,33 % (235)	14,88 % (181)	17,02 % (207)	0,16 % (2)	2,96 % (36)

Blok C – D

Now comes some questions about your clothing.

		1. Yes	2. No	Missing
C11_1	Have you wear warmer clothes indoors during the winter compared to the rest of the year?	71,30 % (867)	25,74 % (313)	2,96 % (36)
C11_2	Do you use more often slippers or thick socks during the winter?	65,05 % (791)	31,99 % (389)	2,96 % (36)
C11_3	Do you more frequently use a blanket during the winter when you sit quietly?	48,19 % (586)	48,85 % (594)	2,96 % (36)

C12	Which of the following descriptions best match the clothes you are wearing right now? (check only one)	
1. Short-sleeved shirt or T-shirt		16,20 % (197)
2. Long sleeved shirt or blouse		46,55 % (566)
3. Warm hoodie on other clothes		32,65 % (397)
4. Other		1,64 % (20)
Missing		2,96 % (36)

		1. Yes	2. No	3. Don't know	Missing
C12_1	Are you wearing undershirt?	52,30 % (636)	44,65 % (543)	0,08 (1)	2,96 % (36)

Blok D - district heating consumption

Questions related to district heating consumption.

		1. Yes	2. No	3. Doesn't have district heating	4. Don't know	Missing
D13	Do you know roughly how much consumption of district heating your home has	64,64 % (786)	32,07 % (390)	0,25 % (3)	0,08 % (1)	2,96 % (36)

		1. Yes	2. No	3. Don't know	Missing
D14	Do you have the ability to monitor your district heating consumption thug web portal or app on your smartphone?	50,90 % (619)	22,45 % (273)	23,68 % (288)	2,96 % (36)

The next question you need to answer based on what you do - not what other residents do

D14_a is only answered by respondents who answered D14=1. Yes

		1. One or several times a month	2. Several times a year	3. Once a year	4. Less frequently or never	Missing
D14_a	How often do you read your district heating consumption on the web or smartphone?	13,40 % (163)	9,54 % (116)	11,68 % (142)	16,28 % (198)	49,10 % (597)

D14_b til D14_d *is only answered by respondents who answered* D14=2. No or 3. don't know

	1. Yes	2. No	9. don't	Missing

				know	
D14_b	Are you interested in being able to follow your heat consumption on the Internet	22,53 % (274)	23,36 % (284)	0,25 % (3)	53,87 % (655)
D14_c	Are you interested in being able to follow your heat consumption on your smartphone?	13,57 % (165)	32,40 % (394)	0,16 % (2)	53,87 % (655)

		1. Once or several times monthly	2. Several times yearly	3. Once a year	4. Less frequently or never	5. Doesn't have a consumption meter in the house	9. Don't know	Missing
D14_d	How often do you read the district heating consumption meter in the house?	9,70 % (118)	9,62 % (117)	16,37 % (199)	10,12 % (123)	0,25 % (3)	0,08 (1)	53,87 % (655)

Blok E - Ventilation

Questions regarding your airing and ventilation of your home.

		1. Yes	2. No	3. Don't know	Missing
E16	Is there mechanical ventilation with heat recovery in the housing so that the heat is transferred from the air drawn out of the house, to the cool air that is blown into the house from the outside?	10,53 % (128)	83,55 % (1016)	2,96 % (36)	2,96 % (36)

		1. Yes	2. No	Missing
E17	Is there extractor in the kitchen?	95,81 % (1165)	1,23 % (15)	2,96 % (36)

E17_a til E17_c is only answered by respondents who answered E17=1. Yes

E17_a	How many days a week do you used the extractor in the kitchen?	*Count*

		1. Less than 15 minutes	2. 15-29 minutes	3. 30 minutes to 1 hour	4. More than 1 hour	5. don't know	Missing
E17_aa	How many minutes per. Today do you use extractor? Average	17,60 % (214)	46,05 % (560)	27,63 % (336)	2,55 % (31)	1,97 % (24)	4,19 % (51)

		1. Never	2. rarely	3. often	4. always	9. don't know	Missing
E17_b	How often is there cooked hot food at the stove without extractor switched on?	42,60 % (518)	38,32 % (466)	11,35 % (138)	3,29 % (40)	0,25 % (3)	4,19 % (51)

		1. Yes	2. No	9. Don't Know	Missing
E17_c	Used extractor in situations other than the cooking?	9,05 % (110)	86,35 % (1050)	0,41 % (5)	4,19 % (51)
E17_cc	Which case?	*Open response*			

		1. Yes	2. No	3. Don't know	Missing
E18	Is there mechanical ventilation or mechanical extraction in bathrooms, toilet or utility room?	56,58 % (688)	38,98 % (474)	1,48 % (18)	2,96 % (36)

E18_antal til E19 is only answered by respondents who answered E18=1. Yes

E18_antal	In how many rooms is there mechanical ventilation or mechanical extraction except possible extractor in the kitchen?	*Count*
E18_a	In how many of these rooms is ventilation or mechanical extraction controlled automatically? For example by moisture, light or activity	*Count*

		1. Less than 15 minutes	2. 15-29 minutes	3. 30 minutes to 1 hour	4. More than 1 hour	5. don't know	Missing
E19	How long is the mechanical ventilation or mechanical extraction operating daily? If there are several rooms with mechanical ventilation or exhaust, please indicate the total time.	17,76 % (216)	15,87 % (193)	7,24 % (88)	9,70 % (118)	6,00 % (73)	43,42 % (528)

		1. Yes	2. No	3. Don't know	Missing
E20	Is there one or more windows in the house slightly open all the time during winter?	15,38 % (187)	80,76 % (982)	0,90 % (11)	2,96 % (36)
E21	One or more airing grates, airing valve or damper always open?	51,89 % (631)	40,95 % (498)	4,19 % (51)	2,96 % (36)

Blok F – Ventilation

Try to think back to how you in the last weeks have aired out in your home. Just answer based on what you do by yourself.

We are aware that the vent can have multiple reasons. But try if you can separate reasons apart.

How often do you have in the past two weeks aired by opening windows or doors		1. Several times daily	2. Once a day	3. Several times weekly	4. Once a week	5. Once every 2 weeks	6. Not at all	9. Don't know	Missing
F22_1_1	… to get fresh air?	18,50 % (225)	42,02 % (511)	15,05 % (183)	8,72 % (106)	2,38 % (29)	10,03 % (122)	0,33 % (4)	2,96 % (36)
F22_2	... in relation to cooking?	5,43 % (66)	19,57 % (238)	16,53 % (201)	11,35 % (138)	8,47 % (103)	35,12 % (427)	0,58 % (7)	2,96 % (36)
F22_3	... in relation to bathing?	15,13 % (184)	40,38 % (491)	17,68 % (215)	3,62 % (44)	1,56 % (19)	18,42 % (224)	0,25 % (3)	2,96 % (36)
F22_9	... in order to lower the inside temperature?	1,07 % (13	3,87 % (47)	2,80 % (34)	3,29 % (40)	3,54 % (43)	81,83 % (995)	0,66 % (8)	2,96 % (36)
F22_7	... because there was dew on the windows??	3,21 % (39)	15,38 % (187)	9,29 % (113)	5,51 % (67)	5,18 % (63)	57,65 % (701)	0,82 % (10)	2,96 % (36)
F22_8	... during cleaning?	1,73 % (21)	9,21 % (112)	14,56 % (177)	31,00 % (377)	13,24 % (161)	26,32 % (320)	0,99 % (12)	2,96 % (36)

F22_9_1	... related with smoking?	3,62 % (44)	1,56 % (19)	0,99 % (12)	0,74 % (9)	0,66 % (8)	88,90 % (1081)	0,58 % (7)	2,96 % (36)
F22_9_2	... to shut animal in and out?	21,55 % (262)	2,38 % (29)	1,56 % (19)	0,49 % (6)	0,33 % (4)	69,65 % (847)	1,07 % (13)	2,96 % (36)
F22_10	... related allergy in the family?	1,07 % (13)	2,88 % (35)	0,82 % (10)	0,58 % (7)	0,82 % (10)	88,16 % (1072)	2,71 % (33)	2,96 % (36)

In the following questions battery, the Respondent replied only from the types of airing the respondent has specified in the previous question battery. For example, respondents is only ask to answer F23_1_1 if they have answered 1, 2, 3 eller 4 in question F22_1_1.

How long are you airing out							
		1. Under 5 minutes	2. 5-14 minutes	3. 15-29 minutes	4. 30 minutes or more	9. Don't know	Missing
F23_1_1	… to get fresh air?	19,00 % (231)	47,86 % (582)	11,60 % (141)	5,76 % (70)	0,08 % (1)	15,71 % (191)
F23_2	... in relation to cooking?	15,79 % (192)	26,73 % (325)	7,98 % (97)	2,14 % (26)	0,25 % (3)	47,12 % (573)
F23_3	... in relation to bathing?	10,61 % (129)	38,16 % (464)	18,91 % (230)	8,96 % (109)	0,16 % (2)	23,19 % (282)
F23_9	... in order to lower the inside temperature?	4,03 % (49)	4,77 % (58)	1,07 % (13)	1,07 % (13)	0,08 % (1)	88,98 % (1082)
F23_7	... because there was	6,83 %	17,85	5,59 %	2,96 %	0,16	66,61

	dew on the windows??	(83)	% (217)	(68)	(36)	% (2)	% (810)
F23_8	... during cleaning?	8,31 % (101)	29,69 % (361)	14,06 % (171)	3,95 % (48)	0,49 % (6)	43,50 % (529)
F23_9_1	... related with smoking?	2,47 % (30)	2,47 % (30)	1,07 % (13)	0,82 % (10)	0,08 % (1)	93,09 % (1132)
F23_9_2	... to shut animal in and out?	21,05 % (256)	3,13 % (38)	0,99 % (12)	0,82 % (10)		74,01 % (900)
F23_10	... related allergy in the family?	1,73 % (21)	2,14 % (26)	0,74 % (9)	0,74 % (9)		94,65 % (1151)

		1. By opening doors	2. By opening windows	3. By opening both	4. No airing	9. Don't know	Missing
F24_a_1	How do you airing out, windows or door or both?	7,89 % (96)	40,71 % (495)	45,23 % (550)	3,13 % (38)	0,08 % (1)	2,96 % (36)

F24_d is only answered by respondents who answered F24_a_1=2 or 3

		1. Yes	2. No	Missing
F24_d	Airing you typically by sleeping with the window open in winter?	17,68 % (215)	68,26 % (830)	14,06 % (171)

F24_e	Which of the following statements fits your way of airing best? (only one answer)
1. I am airing after a routine (eg. At particular times each day)	38,16 % (464)
I do not have a fixed routine for airing, but airing out more when I think there is using for it	55,18 % (671)
3. Don't know	3,62 % (44)
8. Refuse to answer	0,08 % (1)
Missing	2,96 % (36)

F25	If the previous questions don't reflect your way to Airing, you can add a comment about how you do it:	*Open response*

Blok G – The presence in the house

A few questions about how often the house is completely empty

		1. Under two hours	**2. 2-5 hours**	**3. 6-9 hours**	**4. More than 9 hours**	**9. Don't know**	**Missing**
G26_1	On weekdays, how many hours a day is the house completely empty, without any people at home?	37,50 % (456)	22,78 % (277)	32,98 % (401)	3,13 % (38)	0,66 % (8)	2,96 % (36)
G26_2	On weekends, how many hours a day is the house completely empty, without any people at home?	49,42 % (601)	38,16 % (464)	5,02 % (61)	3,29 % (40)	1,15 % (14)	2,96 % (36)

Blok H – household members practice

Some statements related the ventilation and heating of the house

H27_1 til H27_5 is only answered by respondents who answered Partner=1. Yes

How agree or disagree with the following statements?		1. totally disagree	2. slightly disagree	2. Neither agree or disagree	4. slightly agree	5. . totally agree	Missing
H27_1	I would like to have a higher indoor temperatures than my partner	31,00 % (377)	10,36 % (126)	21,79 % (265)	10,20 % (124)	10,12 % (123)	16,53 % (201)
H27_2	I am more careful to save energy than my partner	20,89 % (254)	10,86 % (132)	23,93 % (291)	13,82 % (168)	13,98 % (170)	16,53 % (201)
H27_3	I regulates the heat more often than my partner	27,14 % (330)	7,32 % (89)	21,55 % (262)	12,75 % (155)	14,72 % (179)	16,53 % (201)
H27_4	I am airing more often than my partner	20,97 % (255)	10,03 % (122)	22,37 % (272)	11,27 % (137)	18,83 % (229)	16,53 % (201)
H27_5	I am warmer clothed indoors than my partner	25,41 % (309)	10,20 % (124)	20,31 % (247)	10,03 % (122)	17,19 % (209)	0,33 % (4)

H27_1 til H27_5 is only answered by respondents who answered Born=1. Yes

How agree or disagree with the following statements?		1. totally disagree	2. slightly disagree	2. Neither agree or disagree	4. slightly agree	5. . totally agree	9. Don't know	Missing
H28_1	I would like to have a lower indoor temperature than one or more of my children	11,27 % (137)	3,87 % (47)	7,81 % (95)	3,70 % (45)	3,54 % (43)	0,08 % (1)	69,74 % (848)
H28_2	One or more of my children also regulates the heat	13,24 % (161)	2,71 % (33)	4,52 % (55)	5,02 % (61)	4,69 % (57)	0,08 % (1)	69,74 % (848)
H28_3	I have often warmer clothes indoors than one or more of my children	9,38 % (114)	3,04 % (37)	5,67 % (69)	5,26 % (64)	6,91 % (84)		69,74 % (848)

Blok J – Attitude to heating and ventilation

How agree or disagree with the following statements?		1. totally disagree	2. slightly disagree	2. Neither agree or disagree	4. slightly agree	5. . totally agree	8. refuses to answer	9. Don't know	Missing
J29_2	My home is cozy when it is warm	4,36 % (53)	2,71 % (33)	13,49 % (164)	21,71 % (264)	54,61 % (664)		0,16 % (2)	2,96 % (36)
J29_3	My home is comfortable right after that there have been aired out	4,85 % (59)	3,95 % (48)	19,24 % (234)	28,37 % (345)	40,46 % (492)	0,08 % (1)	0,08 % (1)	2,96 % (36)
J29_5	Temperatures inside is not something I usually think about	23,77 % (289)	22,62 % (275)	14,97 % (182)	16,37 % (199)	19,24 % (234)		0,08 % (1)	2,96 % (36)
J29_6	It does not matter if the during the winter it is sometimes slightly cold inside	24,75 % (301)	24,84 % (302)	14,80 % (180)	20,56 % (250)	11,84 % (144)		0,25 % (3)	2,96 % (36)
J29_7	To save energy heats I reduce the warm during the winter	35,44 % (431)	20,31 % (247)	16,94 % (206)	15,30 % (186)	8,96 % (109)		0,08 % (1)	2,96 % (36)
J29_7_	My home's indoor air	4,44 % (54)	3,37 % (41)	17,52 %	22,20 %	49,01 %		0,49 %	2,96 % (36)

1	quality, for example. temperature and air quality is an important component of to take care of myself or my family			(213)	(270)	(596)		(6)	
J29_8	When I have guests, I am more aware of the temperature in my home	14,39 % (175)	7,81 % (95)	19,24 % (234)	24,92 % (303)	30,35 % (369)		0,33 % (4)	2,96 % (36)
J29_9	When I have guests, I am more aware of the air quality in my home	14,39 % (175)	8,55 % (104)	21,22 % (258)	24,26 % (295)	28,13 % (342)		0,49 % (6)	2,96 % (36)
J29_10	I demand more to my home's temperature now than I have done in the past	19,90 % (242)	10,69 % (130)	28,95 % (352)	18,01 % (219)	19,00 % (231)		0,49 % (6	2,96 % (36)
J29_11	It is important to conserve heat for the environment	6,50 % (79)	5,84 % (71)	17,93 % (218)	25,82 % (314)	39,56 % (481)		1,40 % (17)	2,96 % (36)
J29_12	It is important to conserve heat for	6,83 % (83)	5,92 % (72)	13,90 % (169)	28,45 % (346)	40,13 % (488)		1,81 % (22)	2,96 % (36)

	reasons of economy								

Questions related what is important for you to feel comfortable in your home

In your home, how important that is….		1. Not important	2. Slightly important	3. Fairly important	4. Very important	9. Don't know	Missing
J30_2	... That it is safe for you and feels comfortable?	1,81 % (22)	7,32 % (89)	32,81 % (399)	54,77 % (666)	0,33 % (4)	2,96 % (36)
J30_3	... It is easy to regulate the heat so that you feel comfortable?	6,33 % (77)	23,93 % (291)	40,46 % (492)	26,07 % (317)	0,25 % (3)	2,96 % (36)
J30_4	... that is tidy, that you feel comfortable?	5,02 % (61)	19,57 % (238)	37,17 % (452)	34,87 % (424)	0,41 % (5)	2,96 % (36)
J30_5	... That is clean, to help you feel comfortable?	2,06 % (25)	20,48 % (249)	37,58 % (457)	36,84 % (448)	0,08 % (1)	2,96 % (36)
J30_6	... There is a comfortable temperature for you to feel comfortable?	0,99 % (12)	11,35 % (138)	46,63 % (567)	37,91 % (461)	0,16 % (2)	2,96 % (36)
J30_5_6	... There is a good daylight, to help you feel comfortable?	2,63 % (32)	10,77 % (131)	41,37 % (503)	42,11 % (512)	0,16 % (2)	2,96 % (36)
J30_8	... There is no noise from eg ventilation or traffic to help you feel comfortable?	5,18 % (63)	18,42 % (224)	37,83 % (460)	35,53 % (432)	0,08 % (1)	2,96 % (36)
J30_9	... There is fresh air, you feel	1,40 % (17)	14,64 % (178)	45,39 % (552)	35,44 % (431)	0,16 % (2)	2,96 % (36)

	comfortable?						
J30_10	... your home is functional for you to feel comfortable?	1,32 % (16)	9,95 % (121)	43,01 % (523)	42,19 % (513)	0,58 % (7)	2,96 % (36)

Questions about the degree to which your home lives up to your desires

To what degree do you feel that your home meets your desires with regard to		**1. lesser degree**	**2. To some degree**	**3. To a high degree**	**9. Don't know**	**Missing**
J31_1	... Indoor temperature?	2,96 % (36)	31,74 % (386)	62,17 % (756)	0,16 % (2)	2,96 % (36)
J31_2	... air quality?	2,47 % (30)	32,24 % (392)	62,17 % (756)	0,16 % (2)	2,96 % (36)
J31_3	… daylight?	2,22 % (27)	25,66 % (312)	69,08 % (840)	0,08 % (1)	2,96 % (36)
J31_4	... noise?	5,59 % (68)	25,08 % (305)	66,28 % (806)	0,08 % (1)	2,96 % (36)
J31_5	... the ability to control the temperature?	6,17 % (75)	34,70 % (422)	55,92 % (680)	0,25 % (3)	2,96 % (36)

Blok K – Renovation of the house

The intro is only answered by respondents who answered Bygaar=1,2 or 4

Now, there are some questions about the renovation of the house.

		1. Within the past 10 years	2. more than 10 years ago	3. Not been changed	9. Don't know	Missing
K32_01	Are some of the windows been replaced within the last 10 years, later or never? (1st option)	47,12 % (573)	14,72 % (179)	7,65 % (93)	0,58 % (7)	29,93 % (364)
K32_02	Are some of the windows been replaced within the last 10 years, later or never? (2nd option)	0,58 % (7)	1,56 % (19)	0,33 % (4)		97,53 % (1186)
K32_03	Are some of the windows been replaced within the last 10 years, later or never? (3rd option)					100,00 % (1216)

		1. selected	2. not selected	9. Don't know
K32_01_ELM_1	within the past 10 years	47,70 % (580)	51,73 % (629)	0,58 % (7)
K32_01_ELM_2	More than 10 years ago	16,28 % (198)	83,14 % (1011)	0,58 % (7)
K32_01_ELM_3	Not been replaced	7,98 % (97)	91,45 % (1112)	0,58 % (7)

K32_a 5 is only answered by respondents who answered K32_01_ELM_1=1. Within the past 10 years

And K32_b is only answered by respondents who answered K32_01_ELM_2=1. more than 10 years ago

		1. non	2. Under 25 %	3. 25 – 75 %	4. Over 75 %	5. All	6. Don't know	Missing
K32_a	What amounts of the windows or the glass are changed within the last 10	0,41 (5)	9,21 % (112)	10,53 % (128)	7,24 % (88)	19,74 % (240)	0,58 % (7)	52,30 % (636)

	years?							
K32_b	What amounts of the windows or the glass are changed for more than 10 years ago?	0,74 % (9)	1,81 % (22)	1,89 % (23)	2,63 % (32)	7,98 % (97)	1,23 % (15)	83,72 % (1018)

K32_c is only answered by respondents who answered K32_01_ELM_3=1. Not been replaced

		1. All have been replaced	**2. Under 25 %**	**3. 25 – 75 %**	**4. Over 75 %**	**5. Don't know**	**Missing**
K32_c	How many percent of the windows is or glass have never been replaced	0,74 % (9)	2,22 % (27)	0,90 % (11)	2,88 % (35)	1,23 % (15)	92,02 % (1119)

K32_ca til K33 is only answered by respondents who answered K32_01_ELM_1=1. within the last 10 years *or K32_01_ELM_2=1.* for more than 10 years ago

		1. non	**2. Under 25 %**	**3. 25 – 75 %**	**4. Over 75 %**	**5. All**	**6. Don't know**	**Missing**
K32_ca	What percent of the windows, which have never been changed, has removable windows?	49,67 % (604)	2,06 % (25)	1,56 % (19)	0,90 % (11)	2,38 % (29)	5,84 % (71)	37,58 % (457)

		1. Under 10 %	**2. 10 – 25 %**	**3. 26 – 75 %**	**4. Over 75 %**	**5. Don't know**	**Missing**
K33	What percentage of the windows have been sealed?	25,16 % (306)	2,47 % (30)	2,80 % (34)	11,51 % (140)	20,48 % (249)	37,58 % (457)

K34 er K33 is only answered by respondents who answered Bygaar=1,2 or 4

		1. Yes	2. No	3. Don't know	Missing
K34	Was the insulation improved after the house was built?	*50,49 % (614)*	*33,47 % (407)*	*5,84 % (71)*	*10,20 % (124)*

K34_a is only answered by respondents who answered K34=1. Yes

		1. Under 10 cm	2. 10 – 20 cm	3. more than 20 cm	4. Don't know	Missing
K34_a	How much insulation is now in the attic now?	0,58 % (7)	14,72 % (179)	29,19 % (355)	6,00 % (73)	49,51 % (602)

K35 til K36 is only answered by respondents who answered Bygaar=1,2 or 4

		1. Yes	2. No	3. Don't know	Missing
K35	Are exterior walls insulated, eg improvement in the insulation in the cavity wall, since the house was built?	*27,14 % (330)*	*53,13 % (646)*	*9,54 % (116)*	*10,20 % (124)*

		1. No	2. Insulation of the floor	3. Insulation of the socket	4. other	9. Don't know	Missing
K36	Has there been any change in the insulation material,	70,97 %	14,80 % (180)	1,89 % (23)	0,90 %	1,23 %	10,20 % (124)

	such as change in the isolation of the floor or the socket?	(863)			(11)	(15)	
K36_1	Which?	*Open response*					

Blok L – Secondary heating

Now some questions about other heating sources.

L37	**Is there a fireplace or wood burning stove in the house?**
1. Fireplace	4,36 % (53)
2. Wood burning stove	36,76 % (447)
3. Both	0,82 % (10)
4. Non	55,10 % (670)
Missing	2,96 % (36)

K37_a is only answered by respondents who answered L37=1, 2 or 3

		1. Under 5 %	**2. 5 – 25 %**	**3. 26 – 75 %**	**4. More than 75 %**	**5. Don't know**	**Missing**
L37_a	How much contribute the fireplace or stove for heating during the winter?	15,46 % (188)	14,56 % (177)	8,96 % (109)	1,64 % (20)	1,32 % (16)	58,06 % (706)

	1. Yes	**2. No**	**3. Don't have district**	**9. Don't know**	**Missing**

				heating		
L39	Is the district heating supplemented by other energy supply for heating and hot water? eg instance direct electric heating, hot water heating with electricity, solar heating systems for DHW or heat pump	5,76 % (70)	90,71 % (1103)	0,49 % (6)	0,08 % (1)	2,96 % (36)

K39_a is only answered by respondents who answered L39=1. Yes

		1. less than 25 %	**2. 25 - 50 %**	**3. 51 – 75 %**	**4. more than 75 %**	**5. Don't know**	**Missing**
L39_a	How much the heating will you estimate the other energy contribute with?	3,37 % (41)	0,82 % (10)	0,33 % (4)	0,16 % (2)	1,07 % (13)	94,24 % (1146)

Blok M – Use of domestic hot water

Finally a few questions regarding the use of domestic hot water

M41	How many times per week do you shower at home?	*Count*
M42	The total number of showers in your household per week	*Count*

M43	If you have comments or clarifications to some of the questions about your home, you can add them now:	*Open response*

Appendix D. Representativity of samples

In this dissertation, I introduce some variables that have not previously been used for sociological analysis. This is first and foremost yearly heat consumption, but also the two price indicators used in paper II and the variables stemming from the UserTEC survey in paper III. These variables do not cover all households in the population, and this may lead to biased samples. This section shows how the samples of the papers are not significantly biased and only one some variables differ from the population, and thereby does not damage the validity of the results.

Table 3 below shows how accurately the samples of paper I, paper IV and paper II represent the total population. I have made a few adjustments to fit the samples in one table according to the population in a specific year. This means that the number of observations is not equal to the one in the models in the papers, but still the numbers are calculated on the same sample.

	Households living in single-family houses in 2012 supplied with district heating or natural gas			Households living in single-family houses in 2014 supplied with district heating		All households in single-family houses in 2012
	Paper I sample[39]	Paper IV sample	All	Paper II sample	All	
Household disposable income (sum)	66,719.3	45,683.2	64,732.6	58,499.0	63,199.7	61,712.7
Highest attained education						
Elementary school or no education	12.4%	7.7%	12.8%	14.4%	13.2%	14.8%
High school level	42.1%	44.1%	42.4%	43.7%	41.9%	43.5%
Bachelor's level	32.1%	34.0%	31.9%	31.6%	32.2%	30.3%
Master's level and PhD	13.4%	14.2%	13.0%	10.3%	12.7%	11.4%
Age	54.9	41.1	54.9	56.3	56.1	55.0
Household size	2.7	3.4	2.5	2.5	2.5	2.4
Geographical area						
Urban - major city	53.7%	55.4%	53.2%	45.5%	54.2%	43.9%
Urban - minor city	17.4%	15.8%	18.6%	29.5%	23.0%	15.9%
Rural - major city	15.2%	16.5%	14.8%	10.1%	11.0%	18.3%
Rural - minor city	13.7%	12.3%	13.5%	14.9%	11.9%	21.8%
No. of obs.	599,503	119,985	678,843	172,150	440,541	1,011,481

Table 3. Representativity of samples in paper I, II and IV

[39] In paper I there is a similar comparison

Table 3 shows that the sample in paper I does not differ from the population and that the number of observations in the sample is close to the number of observations in the population.

Table 3 also shows that the sample in paper IV is biased according to age, household size, and education. This was expected, as the individuals in this sample are required to have parents that are also living in single-family houses. Therefore, these households are, to greater degree, younger families where, for example, the household size is larger.

Finally, Table 3 shows that the sample in paper II is to some degree skewed according to geographical area. This might be explained by some data limitations in the Copenhagen area in the price level data that also changes the other percentages. I am aware of this, but I do not think that it has biased my results considerably.

	Adults living in single-family houses in 2012 supplied with district heating	
	Paper III sample (Aarhus)	All
Disposable income	35,940.3	32,429.0
Highest attained education		
Elementary school or no education	17.4%	24.0%
High school level	45.0%	43.9%
Bachelor's level	26.3%	23.9%
Master's level and PhD	11.4%	8.2%
Age	55.7	51.1
Household size	2.7	2.7
No. of obs.	1,143	857,892

Table 4. Representativity of sample in paper III

Table 4 shows the representativity of the sample in paper III. This shows that the sample is slightly skewed regarding educational level, which is probably explained by the respondents in the survey living in the outskirts of Aarhus, where education level is expected to be higher compared to that of a greater distance from the larger cities. Aside from this, the sample seems to represent the population.

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