



Original research article

# The social structure of heat consumption in Denmark: New interpretations from quantitative analysis

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## ABSTRACT

The role of households in relation to heat and energy consumption has been well-described in both quantitative and qualitative studies. However, where practice theory has developed as the main theoretical framework within qualitative studies on energy consumption, the more recent quantitative studies do not interpret the results within a sociocultural differences between households such as income, education, occupation, and immigration status influence the amount of heat consumed by a household; directly as an indicator of household practices and indirectly through type of building and household characteristics. New interpretations based on theories of practice show that factors such as the social structure of heat consumption, status of houses and unreflective practices are important for understanding the role of households in relation to heat consumption, and for forming policies for sustainable development.

In this paper, the methodology of the quantitative studies is combined with the theoretical perspectives of the qualitative studies, emphasising how energy consumption is a result of energy-consuming practices. Focusing on heat consumption used for space heating and heating of water in single-family detached houses in Denmark, it is found that sociocultural differences between households such as income, education, occupation, and immigration status influence the amount of heat consumed by a household; directly as an indicator of household practices and indirectly through type of building and household characteristics. New interpretations based on theories of practice show that factors such as the social structure of heat consumption, status of houses and unreflective practices are important for understanding the role of households in relation to heat consumption, and for forming policies for sustainable development.

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## 1. Introduction

Although the role of building and psychical structures dominates research and policies on energy consumption [7], the role of households in relation to the consumption of energy and heat has generally also gained attention. Accordingly, many empirically studies show that energy consumption varies greatly according to variations in household characteristics and the behaviour of the householders [11,12,29,30,18,32,35].

The primary interest in many of these studies is to show how energy consumption varies according to differences in household characteristics such as household size, income, age of the householders and various indicators of behaviour. However, many of these studies do not interpret the results distinctly within a theoretical context. Although useful for showing variation in energy consumption, the lack of a theoretical interpretation of the results limits the conclusion to being descriptive without contributing significantly to understanding how and why households consume energy differently. Consequently, the perspective on the householders becomes rather rational, reducing their impact to their use

of buildings and technologies. For example, this means that household income is not interpreted as an indicator of social differences resulting in different ways of practicing everyday life and a house is conceived as something which can accommodate families more or less energy efficiently. Therefore, the social structure of heat consumption is underexposed, or even neglected, and the conclusions and policy implications based on these studies become more restricted. The aim of these studies is to predict and explain variation in heat consumption, but to fully conceptualise the complexity of heat consumption, it is necessary to understand the underlying structure of the consumption, and through that provide a more thorough interpretation of the statistical results.

A range of qualitative studies on energy consumption document well how energy consumption occurs as a result of agents performing energy-consuming everyday practices, and how these practices are structured by social and material structures (See e.g. [15,20,33,37]). Based on theories of practice, these studies place priority on the practices rather than individuals and materiality, and therefore, the agents become carriers of practices within a certain social and material context.

The aim of this paper is to apply theories of practice in an empirical, quantitative study using aggregated data, and to respond to the challenge of combining quantitative forms of data and analysis with 'human-centred' research methods [34]. It is not the

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methodological approach or the type of data material used in this paper that are significantly different from previous studies explaining variation in heat or energy consumption; instead, the difference lies mainly in the interpretation of the statistical results and the overall theoretical framing of the study. Based on a practice theoretical perspective, which provide a more sociological understanding of energy consumption, this paper differ from more theory-testing studies with economic or psychological understandings of energy consumption (e.g. [1]). Moreover, in relation to previous studies, this study uses a unique dataset regarding size and extent.

Although studies that combine practice theory, or even sociological theory, and quantitative research methods are very infrequent, there are signs that other researchers are starting to take a similar approach [8], and more of this kind of research is probably on its way as aggregated data becomes better and more widespread. However, some earlier work has applied similar theoretical ideas as practice theory on quantitative energy-consumption research (e.g. [19,24,25,31]), and the aim is to reinvent and develop their ideas in empirical studies. Newly developed research methods and statistical programs have also improved the possibilities of doing quantitative studies compared to earlier studies.

The objective of this paper is to elucidate the role of social and cultural differences between households in relation to residential heat consumption. By investigating the effect of socio-cultural household characteristics on residential heat consumption using regression modelling, and then interpreting these findings using theories of practice, it is shown that such an interpretation contributes to understanding better the social structuring of heat consumption. The data on heat consumption in Danish single-family detached houses have been available since 2014. Although data is from Danish households, previous studies have shown that results are comparable across regions; for example, Santin et al. [30] and Estiri [11] find similar patterns in data from respectively the Netherlands and USA. Therefore, there is good reason to believe that the results of this study are generalizable to regions similar to Denmark, especially regarding climate (e.g. northern Europe and northern part of North America).

The sample in this paper consists of Danish single-family detached houses with central heating supplied by either gas heating or district heating. Detached housing is widespread in Denmark as more than half of the population live in this type of housing ([www.statistikbanken.dk](http://www.statistikbanken.dk)). The most widespread heating source in DK is district heating which more than 60% of all homes have, and second most widespread heating source is gas which covers approximately 15% [10]. Thus, the sample in this study comprises a very widespread type of housing and energy use.

Energy consumed by households with central heating in Denmark can be divided into electricity consumption and heat consumption and each of these two types of energy consumption is measured distinct from the other [14]. Both electricity and heat consumption refers to consumption related to several different practices. Electricity is used for appliances and lighting and thus relates to practices such as cooking or watching television, whereas energy for heating relates to both space-heating (comfort related practices) and heating of water (cleanliness practices) [14]. This paper only includes heat consumption, and it is thus important to notice that this consumption relates to practices related to space-heating and heating of water. It is estimated that 30% of heat consumption is used for water heating and the rest for heating space [17].

The paper begins by presenting some examples of newer empirical studies that model energy consumption and describes how these studies lack a theoretical interpretation of the results. This is followed by an introduction to the sociological, and mainly qualitative, perspective of residential energy consumption. Next is a section about the theoretical foundation of the analysis, namely

what is referred to as theories of practice, where energy consumption occurs as a part of performing social practices. Then, the methodology is presented with primary focus on the regression modelling technique. This part also includes a description of the data and descriptive statistics. This is followed by a section presenting the empirical findings demonstrating that socio-cultural factors like income, educational status, occupational status and immigration status have a significant impact on the amount of heat consumed by the household, also when controlling for type of building, household composition and heat supplier. In Section 6, the findings are interpreted within the context of practice theory. Finally the conclusion elucidates the importance of investigating heat consumption within the context of practice theory to extend knowledge about householders' way of consuming heat. Moreover, some research and policy implications are given.

## 2. Empirical studies on residential heat consumption

While the sociological interest in investigating the impact of socio-cultural differences between households on heat consumption at an aggregated level is limited, several more technically oriented and recent studies have shown how household characteristics and behaviour affect residential heat and cooling consumption [11,12,26,30,35,43]. The main household determinants in these papers can be divided into three groups; demographic factors, socio-economic characteristics and behavioural indicators.

The group of demographic factors is primarily centred on various measurements of household size and age of householders, where household size is found to be positively correlated with heat consumption, and older householders tend to consume more [30,35,43]. Although behavioural indicators could be very different things, the focus is often on use of equipment and presence in time and space, for example if the householders are heating or cooling all their rooms and whether or not they are at home during the week or at weekends. All these factors are positively correlated with heat or energy consumption. This means that frequency of use of air conditioning equipment correlates with energy used for cooling [43], number of heated or cooled rooms correlates with heat or energy used for cooling [30,35,43], and households tend to consume more, the more they are at home during the week and at weekends [30].

Socio-economic variables are often reduced to annual income, and more often only interpreted as economic means. As an example, Steemers and Yun [35] and Santin et al. [30] found that household income is positively related to energy consumption, which indicates that household income is linked to energy consumption. Like this study, these two studies, as well as Estiri [11], distinguish between the direct effect, where household characteristics refer to the behaviour of the occupants and the indirect effect, where household characteristics refer the effect that is due the building they live in, and in these studies, income has primarily an indirect effect on energy consumption through the type of building. Estiri [11] constructed a latent variable called socioeconomic status (SES) out of household income, household education and employment status, which he found to have a negative direct effect and total effect and a positive indirect effect. This means that households with a higher SES consumed more energy per capita due to an indirect effect through, for example, type of building, but apparently had a behaviour that affects energy consumption negatively. In addition to the three groups, ethnicity is also included in Estiri [11], showing both a positive direct and indirect effect.

To sum up, the studies presented here focus on what could be termed predicting factors, where the socio-cultural dimension is often reduced to income. Thus, some of the studies do not include socio-economic variables such as educational status, immigration status and occupational status, which might be valuable for

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