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## House Owners' Interests and Actions in Relation to Indoor Temperature, Air Quality and Energy Consumption

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### Abstract

*In order to make better and more realistic predictions of energy consumption in dwellings, more knowledge is needed about how individuals and households control the indoor environment. A questionnaire survey was conducted with the objective of studying the interest and actions taken in relation to indoor temperature, air quality and energy consumption by Danish house owners living in single-family detached houses with district heating. The house owners state that they are interested in, and concerned about, the indoor temperature and air quality and that it is an important element in caring for each other in the family. Actions are taken in relation to the temperature in the way that house owners are trying to keep different temperatures in differently heated rooms, e.g. to sleep in a cool bedroom or to save heat. Besides they wear warmer clothing, slippers or thick socks indoors during the winter compared with the rest of the year. Actions are taken to improve the air quality by the majority of the house owners by opening windows. The most frequent reasons for opening windows once or several times a day was "to get fresh air" and "in relation to showering". House owners are interested in saving energy for the sake of the environment and for their own economy, and quite a lot of households indicate that they know their own energy consumption, though only few follow it closely. Thus being concerned about energy is not necessarily related to an interest in detailed feedback on one's own energy consumption. Results show that well-planned communication about feedback possibilities is important. Women and men answer slightly differently to some of the questions, e.g. women are more active in airing, and they wear warmer clothing, whereas men are more actively following their energy consumption.*

**Keywords – airing; heat consumption; indoor temperature; questionnaire survey; ventilation**

### 1. Introduction

Several studies have shown a significant gap between households' actual energy consumption and the predicted calculated energy demand of buildings under standard conditions made during the design phase and in energy certification schemes. One of

the causes for this discrepancy is differences between the assumed energy behaviour of households used for the calculations and the actual behaviour of households [1, 2]. Differences in energy consumption among households due to occupant behaviour have been thoroughly investigated [3-7]. Moreover, some studies have focused on behaviour in relation to control of the indoor climate [8-9].

In order to make better and more realistic predictions of the actual energy consumption, more knowledge about how individuals and households control the indoor environment is needed. This includes e.g differences in gender which has been in focus when addressing energy consumption and indoor climate preferences. On this background, a questionnaire survey was conducted as part of the broader project UserTEC (User Practices, Technologies and Residential Energy Consumption) [10]. The overall purpose of UserTEC was to obtain more detailed knowledge about households' energy-related activities and engagement, and further to relate this to residential heat consumption.

The objective of this paper was to analyse interests and actions taken in relation to indoor temperature, air quality and energy consumption by Danish house owners living in single-family detached houses with district heating. This paper is based on a descriptive analysis, whereas forthcoming papers will explore in more detail relations between the factors and their interdependent explanations for energy consumption and energy-consuming behaviour.

## **2. Methods**

This paper is based on a questionnaire survey among selected residents living in detached single-family houses with district heating in Aarhus, Denmark's second largest city, with a population of 320,000. The residents were 97% house owners and 3% tenants (for convenience, all residents are hereinafter referred to as "house owners"). The questionnaire included questions on the occupants such as interests and actions in relation to indoor temperature and air quality, including questions on how they adjust temperature, clothing and airing of the houses. It also included questions on their interest in and knowledge about their own heat consumption. Moreover, there were questions on house characteristics such as the heating and ventilation systems.

The residents were all customers of AffaldVarme Aarhus who supplies district heating to 90% of the inhabitants with district heating in Aarhus. The selection criteria for the households of the survey was that they have heat meters with remote reading of the hourly heat consumption, and access to a web portal, eButler, which allowed them to see their heat consumption via PC or mobile phone. They were all informed about this opportunity by digital mail.

The data collection of the survey was conducted by Statistics Denmark in February and March 2015 as a combination of a web-based questionnaire and a telephone interview with respondents who did not answer online. The population consisted of 3,637 households with a total of 6,198 individuals. The selection process had two steps: first, one person from each household was randomly selected, and second, among these individuals, 1,750 persons were randomly selected and offered to participate in the survey. The respondents received a letter with a brief description of the project, a

promise about anonymity and an invitation to participate in the survey. 1,216 persons answered, 921 (75.7%) via the web and 295 via phone (24.3%) corresponding to a total response rate of 69.5%. The respondents consisted of 53% (646) men, 83% lived with a spouse or partner and the median age of the respondents was 56 years.

### 3. Results and Discussion

The following data are all based on the respondents' self-reported answers to the questions of the survey.

#### A. *The investigated houses and their HVAC systems*

The houses represented in the survey were built before 1981 (70%), from 1981-2006 (20%) or after 2006 (7%), and 25% of the houses had a basement. The houses were equipped with heating systems in different rooms according to Table 1. About 8% of the houses had a wood burning stove in the living room.

Table 1. Heating systems in different rooms (%)

	Radiator with Thermostat	Radiator without Thermostat	Under-floor heating with thermostat
Living-room	76	2	27
Bedroom	78	3	15
Bathroom	41	2	71

Around 10% of the houses had a mechanical ventilation system with heat recovery, 96% have an exhaust hood in the kitchen and 57% have mechanical ventilation or mechanical exhaust in bathroom, toilet or utility room.

#### B. *Interest in indoor temperature, air quality and energy consumption*

From Fig. 1 it is seen that the respondents were concerned about the indoor temperature and air quality and that it was an important element in caring for each other in the family. The respondents also agreed that it was important to save energy for environmental reasons (75%) and for economic reasons (68%), with a tiny tendency of women to be more interested in saving energy compared with men.

Fig. 2 shows that around two thirds of the respondents to a large extent felt that indoor temperature, air quality, daylight and noise met their wishes. As this survey was performed almost exclusively among home owners who, opposed to e.g. many people who rent apartments, could be assumed to have chosen their own house and were themselves responsible for maintenance and retrofitting of it, this high level of satisfaction was not that surprising. The differences between women and men were small. In general, it appeared that women were slightly more satisfied with their home than men.

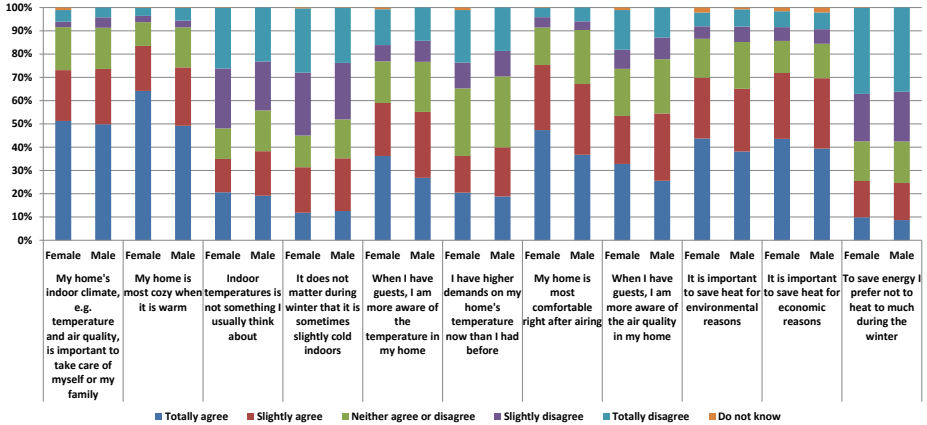


Fig. 1 The frequency of responses with regard to how much the respondents disagree or agree with a number of statements in relation to indoor temperature, air quality and energy consumption

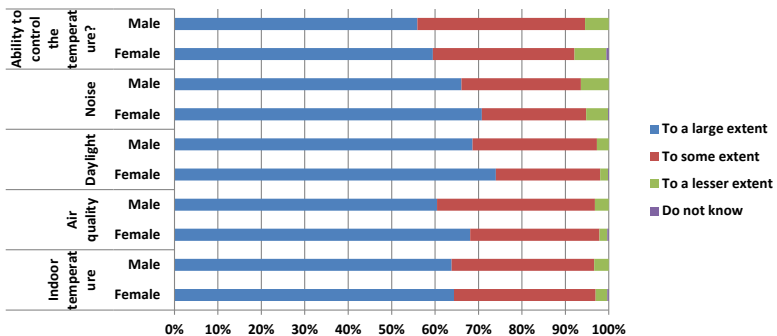


Fig. 2 The frequency of responses regarding to what extent the respondents feel that their home meets their wishes with respect to...

### C. Indoor environmental actions

As seen above, most of the respondents were concerned about the indoor temperature. 72% of the respondents stated that they owned a thermometer to measure the indoor temperature. 60% of the respondents tried to keep different temperatures in differently heated rooms. This was explained by a desire to sleep cool (87%) and to save heat (47%). Among the respondents who had a basement (25%), 32% heated their basement during winter, 43% partly heated their basement and 24% did not heat the basement during winter.

Since the respondents had no control over the temperature of the supplied hot district heating water, they could only control the temperature by using thermostatic

radiator valves or thermostats/valves for their floor heating system (if that was present in the house). During the heating season the respondents in general did not adjust the heat often. In the living room for example, 47% did not regulate the heat during the last month, 27% adjusted the heat monthly, 13% weekly and 10% daily.

The majority of households had a sensible behaviour in relation to using energy for heating during the summer since 64% had switched off heat completely and allowed only hot water in the taps. However, during the heating season only half of the respondents stated that they made adjustments that ensured the highest possible cooling of the district heating water, which ensured the highest energy efficiency to the benefit of both energy supplier and respondent.

During the winter, 60% of the respondents believed that their indoor temperature equalled the indoor temperature of other respondents and 76% estimated it to be in the range 20°C-22°C in the living room and below 20°C while sleeping in the bedroom.

In Fig. 3, a higher proportion of males than females stated that they saw themselves as more careful in saving heat than their partner. The obvious way to save energy on heating is to lower the indoor temperature, which requires an adjustment of the clothing insulation to maintain thermal comfort. Such an adjustment took place, Fig. 4, as 71% wear warmer clothing indoors during the winter compared with the rest of the year and 65% used slippers or thick socks more often during the winter. A larger proportion of women than men indicated that they dressed warmer or used a blanket in winter than in summer. This is in agreement with the responses in Fig. 3, where a larger proportion of females than males agreed that they dressed warmer than their partner. A third indication of this is the responses in Fig. 5, where a higher proportion of females than males indicated that they wore warm clothing at the actual time of answering.

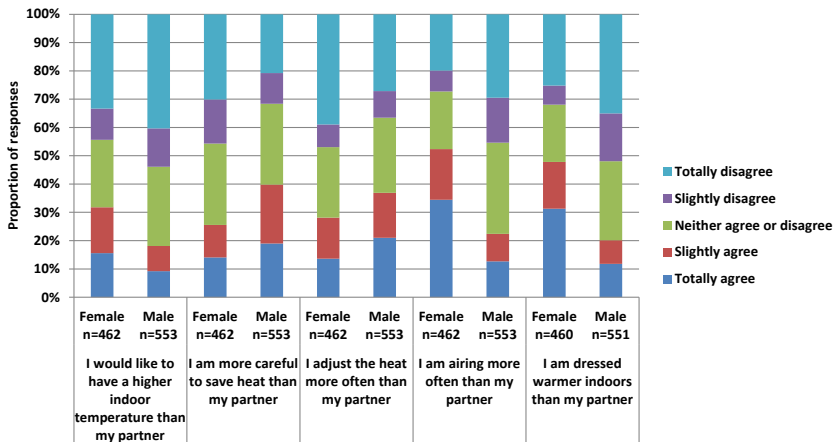


Fig. 3 The frequency of responses to "How much do you disagree or agree with the following statements?"

In Fig. 3, a larger proportion of female respondents than male respondents agreed that they aired the house more often than their partner. When asked if they had a fixed

routine for airing the house, 43% of female respondents and 36% of male respondents stated that they had a fixed routine, while 54% of female and 60% of male respondents stated that they did not have a fixed routine but rather reacted to the indoor environment.

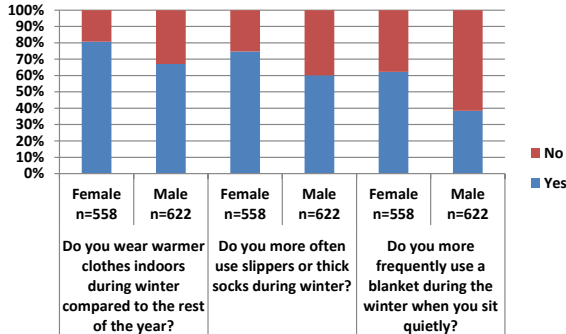


Fig. 4 Responses to questions about clothing during winter

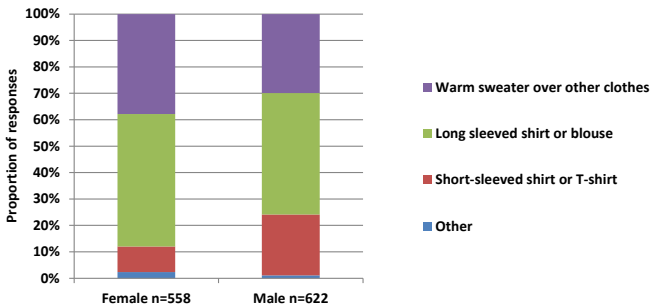


Fig. 5 The frequency of responses to the question “Which of the following descriptions best match the clothes you are wearing right now?”

The most frequent reasons for opening windows once or several times a day was “to get fresh air” and “in relation to showering” (Fig. 6). Apart from letting pets in and out of the house, the most frequent reasons for airing was associated with the indoor air quality (either in direct form or diluting pollutants associated with specific activities). Less than 20% answered that they had opened windows to reduce indoor temperatures. The outdoor air temperatures in February and March 2015 in Denmark ranged from -13.6 °C to 14.6 °C with an average of 2.1 °C and 4.7 °C in February and March, respectively [11]. It is likely that the low outdoor temperatures resulted in few respondents indicating that they opened windows to reduce temperatures – simply because there was no need to reduce the indoor temperatures. However, the fact that the majority of respondents opened windows for reasons associated with indoor air quality,

underlines the importance of including indoor air quality indicators in any attempts of modelling occupants' window opening behaviour in residential buildings.

From Fig. 6, it is evident that cleaning was a driver for opening of windows: 70% of the respondents stated that they had aired the house in relation to cleaning at least once every second week.

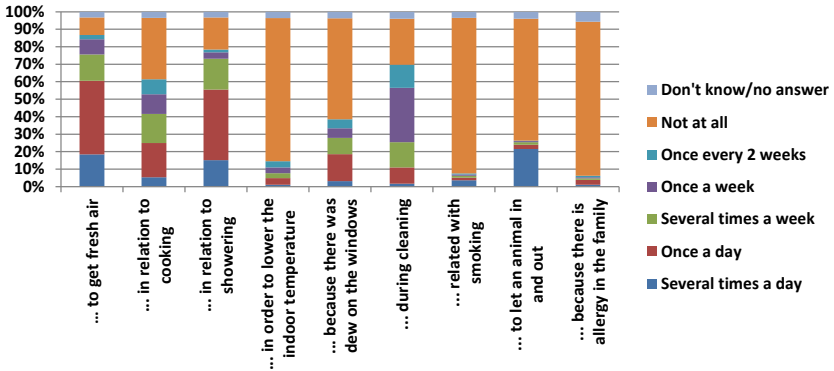


Fig. 6 The frequency of responses concerning how often in the past two weeks the respondents (n=1216) have aired the house by opening windows or doors

In Fig. 7, respondents who indicated that they aired once a week or more frequently were asked for how long they typically aired the house (for each category). In each category, the “Missing” responses corresponded to those respondents who answered “once every 2 weeks” or “not at all” in Fig. 6.

In general, only few respondents opened windows for 30 minutes or more. This result was probably dependent on the season and outdoor conditions and it is likely that the result would have been different if the survey had been carried out during summer.

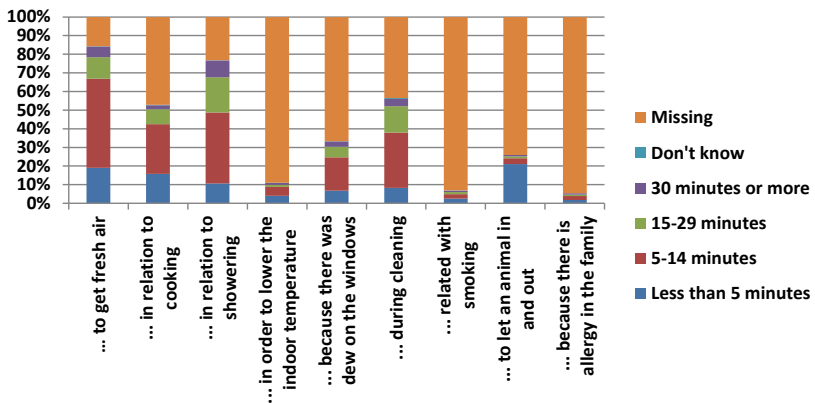


Fig. 7 The responses to the question: “For how long do you air the house...?”



*D. Knowledge and interest in heat consumption*

The respondent's interest in and knowledge of their heat consumption was investigate by looking at how often they read their district heating meters and if they are aware what their heat consumption is. There was focus on gender differences.

Fig. 8 shows that 73% of the respondents read their consumption at least once a year on their district heating meter, mobile phone or web portal. Moreover, it shows that the male respondents were reading their consumption more often than the female respondents.

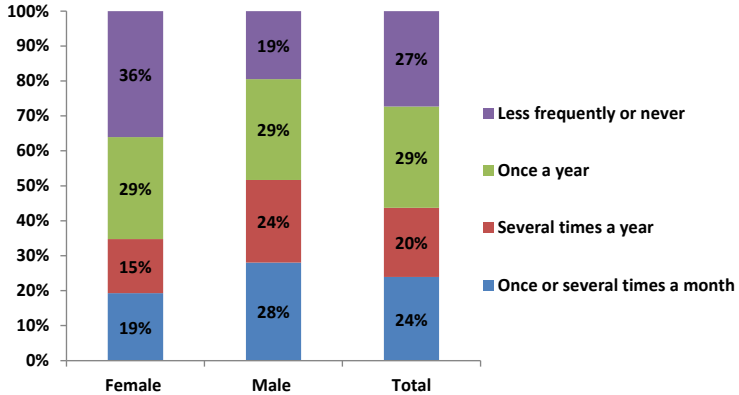


Fig. 8 The figure shows how often the respondents indicate that they read their heat consumption

In line with this, Fig. 9 shows that the males indicated more knowledge about their consumption level than the females, with 77% of the males against 56% of the females stating that they roughly knew how much heating they consumed.

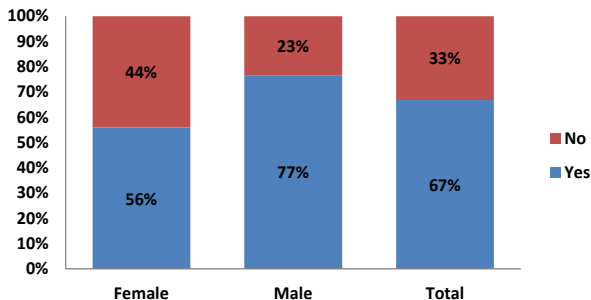


Fig. 9 The figure shows the answers to the question "Do you roughly know how much district heating your dwelling consume?"

The respondents have the possibility of reading their heat consumption on the web or smartphone, via a web portal called eButler. They have been informed about this by digital mail which was sent to them every third month for at least one year. Digital mail is a system used in Denmark by authorities and others (Banks, Utilities etc.) to send official mails to citizens. Still, only half of the respondents answered that they knew about the possibility of following their district heating consumption on the internet or via an app on the mobile phone. Moreover, a little more than half of the respondents that answered 'No' to having the possibility, expressed an interest in such a possibility as reading the consumption online. This indicates quite a high potential for better visibility and communication about this feedback solution.

35% of all respondents answered that they had read their consumption at some point in time via the internet and/or smartphone, and 13% answered that they did it one or more times a month. The web portal eButler registers the number of users and this showed that only a little more than 2% of all their customers had logged in during the latest month. The respondents were among those who had had access to the eButler system for the longest time, so comparing survey results with overall use might indicate that over time more consumers become aware of the system. Still, only 13% of the respondents using the system once a month or more are not impressive. This low percentage might relate to the design of the eButler system, e.g. how easy it is to assess, how easy it is to read and understand information, but it might also indicate that consumers may feel that it is enough to check their energy consumption for heating only once a year.

#### **4. Conclusions**

This study has contributed to more knowledge about house owner's interests and actions in relation to temperature, air quality and energy consumption, knowledge that is needed to better understand and predict house owners behaviour in relation to indoor climate and energy consumption. This knowledge is important, inter alia, for predicting energy consumption and for making efficient energy saving campaigns.

House owners expressed that they were interested in and concerned about the indoor temperature and air quality and that these parameters are important elements in caring for each other in the family. Around two thirds of the house owners found that temperature, air quality, daylight and noise in their dwelling to a high degree meet their wishes.

House owners are taking actions in relation to the indoor temperature by trying to keep temperatures different in different rooms, e.g. to sleep cool or to save heat. Besides, they wear warmer clothing, slippers or thick socks during the winter indoors compared with the rest of the year.

Actions are also taken in relation to improving the air quality by opening windows by the majority of the house owners. The most frequent reasons for opening windows once or several times a day was "to get fresh air" and "in relation to showering". The most frequent reasons for airing several times a day were to let a pet in and out of the house.

Two thirds of the house owners agree that it is important to save energy for the environment and a little less so for their own economy. When it comes to knowledge of own energy consumption, there are less households that know their consumption and even less follow it frequently compared with those stating an interest in saving energy. In general, men show more interest in following their energy consumption compared with women, whereas women are at least as interested in saving energy as men are. Thus being concerned about saving energy is not necessarily related to an interest in knowing about one's consumption. Households in this survey are on the forefront among Danish households in having access to online feedback on their heating consumption. The results show that well-planned communication about this possibility of feedback is important for the spread of it, and that interest in very frequent feedback on heat consumption is not widespread.

### **Acknowledgment**

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