Thesis for the degree of Master of Science

HOW USERS SHAPE A COMFORTABLE INDOOR CLIMATE: A SOCIO-TECHNICAL ANALYSIS OF VISIONS IN RESEARCH AND DAILY PRACTICE AT HOME

A CASE STUDY BASED EXPLORATION ON COMPLEXES UNDERLYING DIFFERENCES BETWEEN CALCULATED AND ACTUAL ENERGY CONSUMPTION IN HOUSING

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PREFACE AND ACKNOWLEDGEMENT

This report contains my thesis project as being part of the master program Philosophy of Science Technology and Society (PSTS) at the University of Twente. The main aim of the PSTS master is to critically analyze and assess the influence of science and technology on society. Within this program I choose the specialization profile Science, Technology and Society (STS) track, because of its ‘empirical orientation’: research that analyses empirically specific technologies and technological practices and discourses. The purpose is to understand the way in which technological artifacts and practices give shape to, and are themselves shaped by our society and culture; and subsequently, provide evaluations of technologies and their correlated social and cultural impacts.

Due to my Bachelor’s program Industrial Design Engineering (IDE), I am trained to design new products, and developed a specific interest in what comes about next. What happens to the products in the world of users? My previous training and current interest fit well with STS area of ‘shaping use in design’ and ‘shaping design in use’. Or in other words, how ‘use’ is anticipated and pre-structured during the design process and how the resulting technology is ‘completed’ or (re)shaped in use. In my graduation project I aimed to study an innovation from the perspective of co-shaping technology and use. It was my goal to conduct research where theoretical knowledge and research skills from the STS track are integrated with know-how and competences gained during my education as industrial designer. Furthermore, I would welcome the chance to orientate as an intern on the professional field. As I sit down to write the final words of this thesis, I realize that it worked out very well, that I can feel satisfied and am happy that the thesis is written.

But this thesis would not exist without support of others. On this page, I would like to thank them cordially. I have had good fortune of having two supervisors while working on this project: Ellen van Oost at the University of Twente and Marleen Spiekman at TNO research institute. Thanks for letting me take part in the research, giving free rein to develop my project and let me carry it out at my own pace. I am grateful for your time spend on my thesis, your support, critical discussion, helpful guidance and comments, and for your belief in my work. Furthermore, I would like to thank my second assessor Kornelia Konrad for her useful feedback as well. I also want to thank the research group Energy and Comfort Systems of TNO for giving me a place to work.

Special thanks to those researchers-informants who took time out their busy schedules to talk to me about their work, gave access to documents and facilities. I am also highly indebted to those who participated in the interviews, welcomed my at their homes and shared personal details about their indoor climate practices with me. The informants provided the necessary foundation for this study.

The next big thank-you goes to all people who helped me in the process of writing this thesis by motivating me, giving advice, critical discussion, reviewing my English writings, and commenting on my drafts. Special thanks to Boudewijn, Julia, Daan and Michiel for their effort and Joke and Silvia who never hesitated to help me with any problem.

I am really grateful for the encouragement of my family, especially my parents, and friends, who always kept confidence in a good result despite the ups and downs I passed through, and of course for the valuable distraction during this project. Finally, Michiel thank you for your love, support and patience, which has been a great motivation through this time.

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Abstract

The indoor at home, the place in which most of us spend most of our lives, is surrounded with energy-intensive technologies to keeping us comfortable, whether through heating, cooling, ventilation or warm tap water. These climatic technologies are studied by TNO's research group 'Energy and Comfort Systems'. The researchers investigate the technical aspects of the dual purpose of these systems: save energy and improve comfort. Problematic is that these systems should reduce energy at home; however calculated energy use in research setting differs from actual energy consumption in housing. Within ECS grows awareness that users and their behavior play an important role too in saving energy at home. Yet, social and technical considerations of energy savings are studied separately within TNO institute and the insight in mutual interdependencies are still limited. An exploratory study into users' behavior and indoor climate technologies at home with a socio-technical perspective towards the problem was desirable.

The purpose of this thesis was to identify underlying dynamics behind the difference between calculated energy use in research and actual energy consumption in housing, by comparing how users shape a comfortable indoor climate at home with how researchers anticipate users, their behavior and comfort needs in ECS research on indoor climate systems.

In line with this purpose, two separate studies were designed to gather data about the ECS research domain and cases of everyday practice at home. The method of research included semi-structured interviews with researchers at work and as well as with users at home.

The research questions for ECS research were answered concerning constructions of comfort, user representations and design logics behind the research process. The findings demonstrated that normalization and standards play a major role in the research setting. The cases at home showed a great variety of daily practices. Nevertheless, the research questions were answered by identifying shared dimensions of users' meaning and realization of comfort in regards to the indoor climate. It was difficult to explain user climatic behavior by their use logics only, also 'household logics' and the material infrastructure have influence.

The findings of ECS research and daily practices at home were compared to deduce clues for differences between calculated and actual energy consumption in housing. It can be concluded that a major underlying dynamic is the mismatch that researchers understand shaping a comfortable indoor climate at a technical achievement of technology, while the shaping of a comfortable indoor climate in daily practice turns out to be a socio-technical achievement that depends on the home environment.

CONTENTS

1 INTRODUCTION

The indoor at home, the place in which most of us spend most of our lives, is surrounded with technologies for heating, ventilation and cooling. Whatever the weather outside, we can use the central heating to create a pleasing temperature, open windows for fresh air, or turn on the airco when it is too warm inside. These devices enable us to create a comfortable indoor climate in our house.

The indoor climate of buildings is set to be one of the crucial sites to battle energy problems of the built environment in the Netherlands. The Dutch built environment[1] contributes up to 30% of the national energy consumption, and thus has a great potential for savings. Therefore, it is able to make an important contribution to the realization of energy objectives (Rijksoverheid, 2012). A core measure for energy savings in the built environment is to improve the energy performance in buildings. The development of energy efficient buildings requires building related technologies that need less energy (BZK, 2011).

However the success of energy reductions of such technologies will depend strongly on how people interact with them. The innovations have not yet lead to substantial behavioral changes, in particular with regard to energy savings. Various studies have shown that, for instance, heating behavior of residents is even more important than it has previously been assumed (BZK, 2011; IEA-ECBCS, 2012; Jeeninga, Uyterlinde, & Uitzinger, 2001). Also, new energy saving technologies are quite often difficult to use in an appropriate way. (BZK, 2011). As a result, it still seems difficult to achieve more energy efficient behavior by only introducing new technology in buildings. Actors in the built environment[2] have recognized this problem and acknowledge that the actual role of users of new technologies should be taken under stronger consideration during the development of energy efficient technologies (BZK, 2011).

At home, we do not simply consume energy resources when they interact with energy efficient technologies to heat or cool ventilate their place. Much of the energy used in habitation is devoted to keeping people *comfortable*, whether through heating, cooling or ventilation (Shove, 2010). It is the user's need of a *comfortable indoor climate* that requires the use of energy efficient technologies. Seen from this perspective, what matters is the service of "comfort" that the energy efficient technologies provide. In simple related energy terms, if saving energy is the focus and the goal is to stimulate energy efficient use behavior of indoor climate systems, then so are users' meaning of comfort and the manners of its provision by energy efficient systems (Shove, 2010; Wilhite, Shove, Lutzenhiser, & Kempton, 2000).

Research organization TNO is actively involved in research aiming to reduce energy in the built environment. Both energy efficient technologies as well as energy use behavior are studied, however the insights into the mutual interdependencies still are limited. TNO gave me, as PSTS student, the opportunity to explore an area that focusses on a better understanding of the impact of user-technology interactions on energy performance. However, the energy consumption itself of these user-technologies interactions is not at the center of attention, but rather the *comfortable indoor climate* that they provide at home. This thesis aims to contribute, from a Science and Technology

[1] The 'built environment' is the material and spatial human-made living environment that provide setting for living, working and playing, ranging in scale from buildings to cities that often include their supporting infrastructure such as energy networks.

[2] The 'built environment' is also a national program which goal is to reduce energy in the built environment. A national network of various actors works towards energy reduction.

Studies (STS) perspective, to insights how users behave with building related systems, their meaning of *comfort* regarding the indoor climate and the provision of comfort at home.

The outline of this this introductory chapter is as follow: section 1.1 energy saving research at TNO. This section introduces research institute TNO, the research group Energy & Comfort Systems, and current research approach to energy savings within TNO. Section 1.2 gives a short overview of academic energy research with a socio-technical perspective. Section 1.3 describes the problem, the goal of this thesis, the research question and research plan. Section 1.4 gives the justification of this thesis, and finally, the structure of the thesis is given in section 1.5.

1.1 ENERGY SAVINGS AT TNO

TNO is a Dutch research institute for applied science that facilitates innovation in contemporary society. TNO supports companies, government bodies and public organizations with innovative, practicable knowledge. The institute often works in association with the government and works closely together with universities and industries. Research at TNO is organized around themes that all have a prominent place in the Dutch national innovation agenda[3]. Each theme is studied by three centers of expertise: Technical Sciences; Earth, Environmental and Life Sciences; and Behavioral & Societal Sciences. Each center of expertise is subdivided in research groups[4].

RESEARCH GROUP ENERGY AND COMFORT SYSTEMS & TECHNOLOGIES WITH A DUAL PURPOSE

One of TNO's research groups is Energy & Comfort Systems (ECS). The ECS of researchers are technical experts and ECS research covers projects that belong to the theme "build environment[5]". The ECS group was formed after a merger of two teams from Apeldoorn and Delft. The research activities in Apeldoorn were previously focused on the engineering of building related systems and those in Delft were more directed towards the quality of the indoor environment. Since the two teams joined into the research group Energy & Comfort Systems, the common goal is to create innovations that contribute to the realization of an energy neutral built environment in 2050[6] (TNO, 2014b).

In the quest to reduce energy in the build environment, ECS research is directed at technical innovations in areas like building related systems, indoor environment, energy monitoring and performance. Some of the ECS researchers investigate energy efficient building related technologies that aim to improve the quality of the indoor environment. Building related systems are also called "indoor climate systems". Such systems should contribute to a comfortable indoor environment of buildings by heating, cooling, ventilation and warm tap water. As the name of the research group Energy & Comfort Systems already suggest, the climatic systems pursue two objectives, viz. both energy efficiency as comfort. Accordingly, ECS has a dual approach towards these systems, the researchers focus on their energy performance as well as its "comfort" as the quality of the indoor climate. The ECS research activities include functional testing, modelling, simulations, evaluation of quality of the indoor climate, and certification of new indoor climate systems. Other ECS researchers

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[3] TNO focuses its research on seven societal themes: healthy living; defense, safety and security; transport and mobility; information society; industrial innovation; energy; built environment. TNO research is geared to evaluate new developments around these seven themes and how they interact.

[4] For more information about TNO and its organization, visit their website: www.tno.nl

[5] For TNO, the built environment refers to "the urban environment in which we live, being determined by the interrelationship between design, building and infrastructure"(TNO, 2014a). ECS is one of the actors that are involved in the national network that works together towards energy savings in the built environment.

[6] This means that new buildings need to be energy-neutral and total energy in built environment used in 2030 will be half the energy used now (TNO, 2014b).

are involved in the development of new energy performance standards, like the so called "energy label[7]". Furthermore, the group also offers consulting services for energy monitoring and performances of building related systems to industries. All these and other ECS research activities and innovations aim to reduce energy consumption in the build environment.

GROWING AWARENESS IN ECS: USER BEHAVIOR IS IMPORTANT FOR ENERGY SAVING TECHNOLOGIES

In theory, the technological innovations should result in more energy efficient buildings. However in practice, there are some problematic matters around these innovations. One of the problems that estimated energy consumption of these innovations in research differs from the actual energy consumption of these innovations in buildings[8]. For example, when indoor climate systems are tested in the TNO laboratories, the systems show excellent energy performance. But as soon these systems are placed in buildings with users, they show "shortcomings" and do not match with the predicted energy savings.

Within the ECS department awareness grows that user behavior plays an important role in causing differences between calculated and actual energy consumption of energy efficient innovations. It seems that the required energy is not only determined by the "material" efficiency of for instance indoor climate systems, but also by the "human capability" of use behavior. Users are mainly anticipated by means of standards in ECS research. But in reality users often behave rather different as envisioned during research work. Some researchers come to recognize that that unforeseen aspects on user's side (partly) reduce the energy saving potential of technologies.

CURRENT ENERGY RESEARCH AT TNO: SEPARATION OF SOCIAL AND TECHNICAL CONSIDERATIONS

While it seems that the users and technologies together contribute to energy saving, are social and technical considerations of energy research approached independently within TNO organization. The technical experts of ECS mainly address the technical considerations of innovations. Although that ECS does research the actual energy consumption in household settings[9], ECS has difficulties to apply these insights to contribute effectively to energy savings. In such research, they tend to describe energy efficiency and comfortable indoor climate conditions in technical terms and search for technical solutions to save energy and deliver comfort by means of a technology. The research innovation should technically guarantee that the intended energy and comfort functions are performed and work under specified circumstances. Users are not necessarily absent in such work, but the ECS researchers often think about them in abstract notions. Users are implicated[10] and the heterogeneity and complexity of users are usually not taken into account in ECS research. In reality

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7 The energy label is an example of an innovative method that gives insights in the energy performance of a house.

8 An clear example of this issue is the estimated energy-use indicated by the energy label quite often deviates from energy consumption in actual practice (Guerra Santin, 2010; Menkveld & Leidelmeijer, 2010). In theory, the label gives an indication of the building required energy. The energy consumption presented on the label is a reflection of the quality of a house. This means that it provides information about i.e. the degree of isolation and the energy performance of the building related installation. Thus, the energy label suggests nothing about how the house is used. In practice, the energy-use of houses also depends on its residents. Use behavior is an important factor in explaining the actual energy consumption (Branco, Lachal, Gallinelli, & Weber, 2004; De Groot, Spiekman, & Opstelten, 2008; Linden, Carlsson-Kanyama, & Eriksson, 2006). Although there are indications that behavior seriously affects the energy performance of a house, little is known about it (Itard, Meijer, & Guerra Santin, 2009).

9 This research is directed at actual energy consumption. It emphasizes the measuring of what happens and attempt to discover correlations between energy level, temperature or ventilation at home as function of type of building, climate installations, income etc. Studies investigate that people open their window if it is warm, but do not investigate underlying reasons, how this is part of daily life and how it influences their behavior.

10 Implicated actor is a term that refers to "those silent or not present, but affected by the action" and refer to two categories of actors: "those not physically present but who are discursively constructed and targeted by others" and "those who are physically present but who are generally silenced by those in power (Oudshoorn & Pinch, 2008, p. 546).

however, the circumstances vary and so it is difficult to predict the effectiveness of energy efficient technologies.

The more social issues and behavioral aspects related to energy reduction are studied too within TNO; but elsewhere by research groups that are covered by TNO's expertise center Behavioral & Societal Science. In general, behavioral science research inclines to track down the reasons of users for behaving as they do in handling energy or reveal social factors that explain certain energy consumption. But here the complexities of interaction with i.e. indoor climate systems are hardly considered. Most studies on energy use are quantitative studies and investigate underlying social, psychological, demographic and economic factor that influences individual households' energy consumption (Guerra Santin, 2010; Itard et al., 2009; Menkveld & Leidelmeijer, 2010). These studies are performed to gather and develop useful insights for influencing behavior (Jeeninga et al., 2001; Jelsma, 2005). Behavioral science research on energy consumption within TNO takes place in similar ways.

As a consequence, social and technical issues of energy reduction are studied separately within TNO. The insights into the mutual interdependencies are still limited. A perspective that treats the social and technical aspects of energy consumption equally at the same time is lacking. Because awareness grows among ECS researchers that users and technologies co-operate in energy consumption, a socio-technical viewpoint desirable for ECS research.

1.2 Energy research in Science and Technology Studies

In the field of Science and Technology Studies (STS), some academics like Ganzevles, Jelsma and Shove have studied energy efficient innovations with a socio-technical perspective; however limited research on the dual purpose of such technologies is available.

A prime example of socio-technical perspective that researched the a dual approach on energy is Jurgen Ganzevles' dissertation about the development of energy technologies for housing[11] (2007). He gives an actor-network analysis of how engineers of Energieonderzoek Centrum Nederland (ECN) claim dual effectively of ECN energy technologies and concepts, in the sense these energy innovations protects the environment by being energy efficient and please consumers with comfortable houses at the same time. Ganzevles explored four cases of how ECN engineers try to fulfill this promise in the practice of designing, developing and testing. However, the actual fulfillment of the dual promise of energy efficiency and comfort of ECN technologies and concepts at homes of users was outside Ganzevles' research scope.

The actual use practice is within range of another STS academic Jaap Jelsma. Jelsma attempts to bridge the gap between technology and behavior (Jelsma, 1999, 2005, 2006b; Jelsma & Knot, 2002) and explores concepts of use in engineering, psychology, economics, sociology and anthropology that suffer from the conceptual break between material objects on the one hand and social phenomena on the other. For Jelsma is it relevant that developers in advance take the actual use of a technology into account to reduce unintended outcomes. They should develop a suitable "script" for technology so that users understand it's the energy efficient purpose and are able live with it in a meaningful way. He offers developers an analytical approach based on the *script method* in which social and technical sides get equal attention, as a tool for making energy efficient household technologies that are more socially informed, so that it corresponds to what users consider comfortable. Although that

11 Full Dutch title is "Technologie voor Mens en Milieu, Een actor-netwerk analysis van de ontwikkeling van energietechnologie voor woningen.

the actual use practice is within the range of his work, a limited amount of studies with real users are available.

Whereas Jelsma still focusses on energy, Shove focusses on the comfort that resource intensive technologies provide at home. Shove does not focus on the energy that such technologies consume, but offers insights into other aspects of energy, namely energy consumption patterns at home (Hand & Shove, 2007; Shove, 2003). Shove brings together the sociology of consumption of energy and technology to investigate the social meaning and realization of the practice that requires energy. The core set of concern are the interdependencies between (everyday energy consumption) practices and socio-technological devices. Shove understands energy consuming practices like bathing, heating, air conditioning and laundering as part of normal everyday life. To her, homes, domestic appliances and clothes play a crucial role in daily practices, and she questions how and why people perform their daily rituals associated with them. Shove (2003) interrogates the meaning and normality of such practices and weights them in light of terms like comfort, cleanliness and convenience. Shove (1998)is critical of the highly technological focused research on energy consumption, and addresses sociological issues of, for example, comfort (Shove, Chappels, Lutzenhiser, & Hackett, 2008). Shove (2010) argues that when energy consumption of technology is the focus, than so is comfort at home, because much of the energy in dwellings is devoted to keep people ‘comfortable’.

Although some examples of academic studies with a socio-technical perspective on dual purpose of energy and comfort innovations, socio-technical research on actual energy use behavior at home of users, the place where the innovations should fulfill their dual promise of energy efficiency and comfort is hardly available.

1.3 Purpose of the thesis and research question

The purpose of this thesis is to examine user-technology interaction in the actual homely environment from a socio-technical point of view, in a way that it can contribute to insight in differences in anticipated and actual energy use behavior in housing. This is relevant, because as mentioned earlier, a problematic issue for ECS is that calculated energy efficiency of building related systems in ECS research differs from actual energy performance of these innovations in buildings. This interferes with ECS goal to contribute to the realization of an energy neutral built environment. Awareness grows within ECS that the challenge lies in linking social and technical considerations of energy research. A socio-technical understanding of how users interact with indoor climate systems at home would be a way to bridge the gap between theoretical intentions of ECS research and practical outcomes. Academic research with a socio-technical perspective that investigates the dual purpose of energy efficient technologies in practice is hardly available. But, such work may inform further innovation on the way towards energy efficient technologies that support users’ comfort at home better, in responsible use of scarce recourses.

The central research question of this thesis is: *How do users realize a comfortable indoor climate at home?*

This question will be approached from two points of view, that of users themselves and that of ECS researchers. This requires two sub studies. The main study takes place at homes of users, the other takes place within the ECS research division. This is essential, because without reference data on anticipated use(r)behavior in ECS research, it is impossible to relate the findings of the actual users in practice to ECS expectation on energy consumption and deviated behavior. Therefore, ECS research will be analyzed as well.

For both sub studies holds that anyone who lives in a house with building related technologies for the indoor climate could be said to be a user. Of all indoor climate technologies, heating and ventilation systems are of main interest. As pointed out earlier, indoor climate systems have a dual purpose: energy saving and comfort. The energy saving potential of heating and ventilation systems will not be the focal point, but the *comfortable indoor climate* they aim at. Because in homing, users do not simply consume energy through indoor climate systems, but the *comfort* that the energy resources provide via heating and ventilation practices. At home users interact with indoor climate systems to heat or ventilate their indoor environment so that it results in a pleasant atmosphere. Therefore when comfort requires the use of energy intensive technologies, and energy savings are relevant, then so are the meaning of comfort and manners of provision. Comfort will not be conceptualized beforehand, but rather explored empirically in order to understand either users' own meaning of comfort and their behavior when they create a comfortable indoor climate at home, or ECS researchers' understanding of comfort regarding the indoor climate and its realization.

The main study that takes place at the homes of users has a socio-technical perspective on user behavior in creating a comfortable indoor climate in the home environment. So, the focus is not the direct re-actions of users on either one heating or ventilating system separated from the environment, but rather on user behavior that takes place within domestic setting. This means that the complexity and heterogeneity of the socio- technical setting at home are taken into account as well. At the same time, both social and technical aspects will be considered equally, as well as the whole dynamic of the complex socio-technical situation of the house and household.

This study will be explorative, since such research as well as its approach is relatively novel in the research field on domestic energy use practices. The empirical data for this thesis is collected via qualitative case studies and rely primarily on interviews with users at their own home. The goal is to provide insight in users' understanding of *comfort* and *indoor climate*, the realization of a comfortable indoor climate in their domestic socio-technical environment, and underlying social and technical dynamics that may explain the indoor climate situation as it is at home.

The second study that is set in the ECS department has a socio-technical view on anticipated users and use behavior with indoor climate systems, and projected provision of comfort in houses that are present in ECS research. Empirical data sources for this study are interviews with ECS researchers and documents created or used by ECS researchers. The goal is to provide insights in ECS understanding about users and comfort in ECS research and underlying motivations why research regarding users and comfort is done as it is.

The results of both studies will be compared in the end with the aim to shed light on dynamics underlying differences between anticipated and actual energy use behavior in housing. These insights may feed back into ECS research aiming at research that supports users well-being better in the in the home environment, in responsible of scares resources.

1.4 Scientific and philosophical relevance

The scientific relevance of this thesis lies in the application of socio-technical perspective on the problem of variation between anticipated and actual energy use behavior. Such an approach is relatively new for TNO. Usually research is focused on one single climate system and the reactions of users towards this technology are examined. These kind of user-technology analyses are usually isolated from the broader socio-material environment in which the studied reactions take place. It is uncommon for TNO to take into account the socio-material environment and the complex dynamics of the network within the house. My theoretical perspective helps to overcome the mainstream break between social and technical considerations in practice. Both social and technical aspects will be reflected at the same time by studying user-technology interactions.

The philosophical justification of this thesis lies in the conceptual framework that will be employed to reflect on the problem. In this reflection, the variation between predicted and actual use behavior will be approached with a socio-technical perspective. The socio-technical approach towards on energy use behavior is regarded a probe in this domain and therefore considered as an exploratory study to investigate and evaluate how this can be used in practice. This socio-technical perspective will be applied to study six cases empirically. This approach is already employed in the design practice by Ganzevles (2007). This thesis will study how such an approach can be deployed in the use practice and provide recommendations for further application. The application of this conceptual framework may also give empirical insight of how "the good life" is given form, in terms of how a comfortable indoor climate is shaped by the socio-material environment of the house.

1.5 Outline of the thesis

This thesis is outlined in seven chapters. After this introductory chapter, the structure is as follows: Chapter two gives and overview of the STS literature that is applied to build the theoretical fundament used in this thesis, and employs it to reformulate the research questions. Chapter three presents the two research designs for the ECS research domain and users at home. It details for both the research strategies, methods and sources applied, as well as further data analysis. The findings of the exploration of ECS research are covered in chapter four. The fourth chapter describes form the standpoint of ECS researchers the representation of users; the construction of comfort; and the design logic behind ECS research process. Chapter five introduces six cases of users and some of their typical (un)comfortable indoor climate situations at home. It highlights how users give meaning to a comfortable indoor climate, their negotiations with other household members and interactions with climatic interfaces at home. It explores the user logic behind the realization of a comfortable indoor climate and discovers that at home counts more than only user logics behind behavior. Chapter six draws an aggregate comparison between the outcomes of the studies of ECS research domain and users at home. Finally, chapter seven gives the conclusions of this thesis and provides a general, theoretical and practical discussion and provides recommendations for STS and ECS research.

2 Theoretical Framework

The purpose of this chapter is to develop a theoretical framework from which the research questions will be elaborated. Section 2.1 introduces the relevant theories from Science and Technology Studies. The research questions will be motivated and formulated in section 2.2.

2.1 An Science and Technology Studies approach

This subsection describes first *Actor Network Theory* as an approach to overcome the distinction between social and technical. The second theory presented is *script theory*, as a way to bridge design and use networks by means of the *script* of technology. The third theory, the *appropriation of technology*, serves as an analytic tool to explore technology in use in daily life. The fourth part introduces the the twin concepts *design and user logic* are described. These stem from a methodology for designing "moralized products" that aim to reduce unintended outcomes. Finally, the last part provides the concept of everyday 'practice' as a way to explore the dual promise of energy efficiency and comfort of technologies at home.

Actor network perspective on behavior

The core idea of Actor Network Theory is that human and non-human and their conjunctions should be treated equal in a network of people and artifacts. ANT is considered to be a promising theoretical framing for this thesis, because it makes no a priori distinction between the social and technical. Furthermore, ANT is considered relevant as being a material-semiotic method to for exploring the relations within networks and mapping outcomes brought about by networks of human and non-humans.

In this radical approach people and technology enjoy the same conceptual status and are treated symmetrically. Both humans and non-humans are termed *actants* by (Latour, 1992) as entities possessing agency having the ability to influence their environment. ANT scholars see technical objects as being made by social actors, but these objects push back on people, because of the specific material structure and design, and influence decisions that people make and affect the way they move through the world. *Actor-networks* are understood as alliances that necessarily always consist of both human and non-humans, who always are related to each other in dynamic and complex ways. Within networks people and technology interact and co-evolve with each other. As a collective, the network produces certain outcomes. Established sociotechnical networks may destabilize, change and re-stabilize.

Latour (1992) studied how artefacts can be purposely designed to replace human action and how things in interaction with human are allowing and limiting human's behavior. According to Latour, devices do often not receive the attention they deserve in social analyses and are often made invisible because of the focus on human behavior. When people behave moral, this is due to the social character of human, but as Verbeek (2005) interprets Latour, almost all our behavior is *mediated* by objects, devices and systems developed by designers. Behavior is embedded in mundane technologies and mirrors conceptions about behavior that are present in society. The ethics embedded in the material world is not taken into account. Latour (1992) calls that "the missing masses" in our society and social analyses.

Latour argues that technologies play such an active role in mediating human relationship that we cannot understand human behavior and the consequences, without an understanding of how technologies shape our everyday live at a micro level. Technologies are not neutral but play a mediating role, not simple as intermediary, but as a mediator that actively contributes to the way in which actions are realized (Verbeek, 2005). Division of action between human and non-human actors in carrying out tasks is referred to as *delegation*. Analyzing delegation is asking who is doing what, and where for whom and for what reasons in a certain technological set up (Jelsma, 2005). In this way, distribution of tasks, responsibilities and trust between human and nonhumans can be studied.

In this thesis the daily practice of shaping a comfortable indoor climate is understood as taking place within the dynamic domestic network in which users and technology are interwoven and continuously interact. I consider the outcome of these interactions of users as behavior. Household, climate systems and other technological artifacts are situated in the complex socio-technical set-up of the house in which human and non-humans act to create and maintain a comfortable climate. Human behavior is thus understood as resulting from the socio-technical interactions, rather than resulting from human motivation as most traditional behavioral studies do. The socio-technical organization of the household practice thus is constitutive for the users' energy behavior.

In the next section, I will elaborate more in detail how one can conceptualize the agency of the non-human, the artifacts. Madeleine Akrich (1992), another scholar in the ANT tradition, has developed the concept of *script* to describe the agency of technological artefacts.

THE SCRIPT-CONCEPT AS BRIDGE BETWEEN DESIGN AND USE

Madeleine Akrich's work is closely related to the network approach of Bruno Latour. Latour and Akrich show that design and use are remotely connected via technological designs. Akrich gives with the script theory (1992) an opening to connect the networks of design and use, and study relationships between designers of a technology and its users. According to her, designers materialize their predictions about envisioned use into the technical content of their product. Akrich calls this end-product a *script*. She drew the analogy between script and scenario of a film or play: "The technical realization of innovator's beliefs about the relationships between an object and actors is an attempt to predetermine the settings that users are asked to imagine for a particular piece of technology" (1992, p. 208). Thus like a film scenario, a script "define[s] a framework of action together with the actors and the space in which they are supposed to act" (Akrich, 1992, p. 208). A script forces user actions, while counteracting others: it has a facilitating force on behavior. Users need to read, decipher and interpret the script for themselves in order to act accordingly.

During the design stage, designers and other technical experts work on new technologies that have to be functional in an envisioned future practice of use. They *in-scribe* their visions about this future in the design of their new technologies. Designers "configure the user" (Woolgar, 1991). Akrich (1992) suggests that engineers anticipate deliberately and unconsciously when they define interests, skills, motives and behavior of *future* users and use settings which become materialized in the shape of the technology. Designers construct *user representations* (Akrich, 1995). This means that they have to imagine specific users of the technology and analyze what needs these users have. User representations are often defined with reference to market surveys and tests and/or based on designers' first hand experiences or visions (Akrich, 1995). Technologies are then designed in accordance with constructed *user representation*s with certain needs and competencies. Designers do not only inscribe their vision of users into the artifact, but also about use. Designers develop a *program of action* for the combined intentions of humans and functions of artifacts (Latour, 1992). They delegate actions and responsibilities to technical objects, by inscribing the program of action into the object, which then becomes materialized and objectified in the technology.

The result of the design stage is a material object like installations and devices that point to a presupposed end-use for which they have been designed. Akrich (1992) argues that the material form of technology, *the script,* has a facilitating force on user behavior; it *pre-scribes* users' actions when they use it. Scripts give technological artifacts agency by inviting certain actions while inhibiting other types of action (Verbeek, 2005). According to Oudshoorn and Pinch (2003) technologies have scripts that attribute and delegate specific capabilities, actions, responsibilities to users and technological artifacts.

When the material object enters the use setting, *real* users need to decipher the *inscriptions* inscribed in the hardware by the designers in order to use it. For the deciphering of original intentions of the designers, the term *de-scription* was introduced (Akrich & Latour, 1992). *De-scription* can happen consciously or by routine. The reaction of the user gives body to the designers' project. However, a script can never determine users' behavior completely. Users have a degree of freedom to "read" and interpret the script in different ways than was originally envisioned by designers. They have a broader range of options for embedding an object in use practice than just describe and follow the materialized intentions of the designers.

The script theory provides methods for the interaction of designers, technology and users of indoor climate. However designers and users are separated, they communicate indirectly via the script of the design of indoor climate systems. The designer sends his design to the world of users and they "communicate" via the script of the design. In this way, the script approach allows taking into account the active role of indoor climate systems in constituting shaping a comfortable indoor climate in a non-deterministic way. It zooms in on action, addressing how humans act in their world and shape existence. The script approach shows that agency and responsibilities are distributed and delegated over various actors in networks.

The script concept thus bridges design and use practices of indoor climate. It allows for transcending the dichotomy of either technological or behavioral approaches on energy consumption and is therefore a suitable conceptual basis for a socio-technical analysis. On the design side, the concept of script invites to think about the material "messages" that a device should communicate and how to take account of heterogeneity of envisioned use practices. On the use side, the script concept invites to study user-technology relations in a symmetrical way. Insights from these latter type of studies, can feedback into the design practices and further the development of technologies that better fit within user practices.

In my study, I focus on how users in interaction with their material environment, create a comfortable climate in their homes. The use of indoor systems studied in this thesis is thus located in the users' houses. A house is a highly scripted environment which contains more than one technology. Clearly, the physical structure of a house consists of an interrelated set of material and (infra)structural elements and technologies that all influence the behavior of a user in creating comfortable indoor climate. The scripts of the indoor climate systems and material structure of the house encourage and discourage certain user behavior by specific elements of their design. Which technologies and material structures play a role cannot be determined a priory, but will become clear in the use setting. Most studies that use the script theory focus on the use of one specific technological artifact and highlight user-technology relations. My research addresses use in daily practice that is way much more complex: it involves both various human actors like household members, as well as a diversity of material climate technology actors. This allows not only for focusing on the study of user-technology relations, but also user-user relations and technology-technology relations can be studied. Perhaps new types of "mismatches" come to the fore: e.g. mismatches of involved scripts (counteracting scripts) or counteracting human actors. Akrich (1992) suggests that by going back and forth between design and use activities of technology and reconstructing conditions and mechanisms that define relations, understandings of the role of technology will be enriched. Mechanisms for appropriation and acceptation of technologies by users are not fully explored within the script approach. Therefore I will combine script theory with domestication theory.

APPROPRIATING TECHNOLOGIES IN DAILY LIFE

Domestication theory focuses on the world of users, particular the cultural and social processes that enable or constrain the users' agency in relation to a new technology. It offers an analytic tool to capture how users "tame" new technology (Silverstone & Haddon, 1996). Central in domestication approach is that technological development does not end when a product is launched, but that a technology can only become fully functional, through the process of cultural appropriation. Then users give meaning to the technology from their own socio-technical background (Oudshoorn & Pinch, 2008). Domestication theory describes various dimensions of the process that a new technology has to go through, before it fits into the routine and practices of everyday life of users. Most useful for the purpose of this thesis is the *appropriation* dimension, which refers to the particular way(s) of active *appropriation* in which users accept, reject or change the script of technology in practice (Lie & Sorensen, 1996; Silverstone & Haddon, 1996).

Appropriation of technologies in everyday life is "the practical as well as emotional adaption of technologies": it is to make an object meaningful into one's life (Lie & Sorensen, 1996, p. 17). Appropriation involves *objectification*, whereby the technology becomes finds it physical place into the life of users. The use and the integration of the technology into a pattern of daily life are central. Appropriation also concerns a process of *incorporation* when the interpretative flexibility of a technology allows the ordinary user to find new functions and meanings. This includes both practical and symbolic aspects of adaption and use of technologies into everyday routines and patterns. It takes into account the collective effort on the part of the household; at the same time it is individual work as well as collective outcomes of negotiations, challenges to power and control and rule-making.

When a design enters the use world, users have to perform certain interaction with the technology in order to meet its designers' goals. It is not always the case that the script of technology is understood. For instance this can happen if embodied user representations are inadequate, thus when designers envisioned the user and use practice insufficient or inappropriate. But even once the script is understood; there is no guarantee that it will be followed by users. The script of an object is not totally inflexible: there is considerable room for other interpretations and actions of users. Users are not powerless, but active actors. Detailed empirical investigation showed that depending on users' context and background, they may put the technology aside or find out forms of unintended use. Wyatt(2003) shows that resistance and non-use of the internet includes voluntary aspects[12]. Norman (1988) shows that users struggle with everyday things and use technologies accidentally different as intended. Kline and Pinch (1996) demonstrate that users also deliberately deal different with technologies. Users can read and the script in their own way as never was envisioned by

[12] Non users are somehow inferior and difficult to locate, but can explain us about avoidance behavior and active resistance. Wyatt (2003) identified four different types of non-users: "resisters" who do not want to use a certain technology, "rejecters" people who no longer use technology, because they find it boring, expensive or have alternatives, "excluded" who cannot access the technology and "expelled" who do not longer use a technology because of loss of access.

designers. Lie and Sorensen (1996) consider users as “tinkerers[13]”, who shape actively their life trough creative manipulations of objects in relations to their practical needs and competencies. They may develop *anti-programs:* unforeseen ways of use or non-use that mismatch designers program of actions (Latour, 1992). If appropriation of technology does not occurs as expected by its makers, undesirable effects may take place.

For my thesis it is important to emphases on the qualitative understanding of the complexity of interactions that produce certain effects. Stories in which users appropriate those technologies in unforeseen ways, may explain why unwelcome effect of over and/or underestimation of energy consumption takes place. Detailed insight is needed on how current systems function in the hybrid daily practice, in other words, how the users interact with existing scripts inside the house and what they do to realize a comfortable indoor climate. The study of indoor climate systems in everyday life is an effort to look at *technology in use*. The daily use of indoor climate systems is more than just the use of only indoor climate systems; its use is associated with other home and household activities. The everyday use practice denotes routines of human existence and what we do over and over again (Lie & Sorensen, 1996). These ‘social practices of use or cultural meanings of artefacts cannot be fully anticipated in the design phase and only developed during the implementation of technologies (Rohracher, 2005). Therefore, users’ re-actions on scripts should to be anticipated by analyzing how the division of competences between the material structure of the house and users can be located, which part of behavior is caused by technological components and what is left to the user. This distribution depends on the positioning to existing technologies and practices and, how this positioning affects the meaning and status of the indoor climate systems in questions.
This cannot be determined a priori. Jaap Jelsma (1999) suggests that in such cases, empirical insight is needed in the use practice. According to him, designers should learn about the current use practice for which they design scripts. Jelsma suggest that the underlying *logic* of such use practices should be identified. In the next section more about Jelsma’s approach.

THINKING ABOUT BEHAVIOR IN TERMS OF THE DESIGN AND USE OF TECHNOLOGY

Jaap Jelsma offers a conceptual background in which the different perspectives from both designers and users are integrated. It serves as a design methodology for designing “moralized products”, which aims to reduce unintended outcomes. He builds further on ANT perspective and script approach. Figure 1 illustrates how Jelsma connects script terminology with design and use networks. It shows the force and directions of scripts on the scale of an artifact.

[13] They understand a ‘tinkerer’ as a *bricoleur* in Lévi-Strauss’s terms (1966). A bricoleur is adept at many tasks and at putting persisting things together in new ways adapting his project to a finite stock of materials and tools. Lévi-Strauss says that the universe of the bricoleur is closed, and he often is forced to make do with whatever is at hand. The bricoleur approximates a ‘savage mind’ in contrast to engineers, who approximate a ‘scientific mind’.

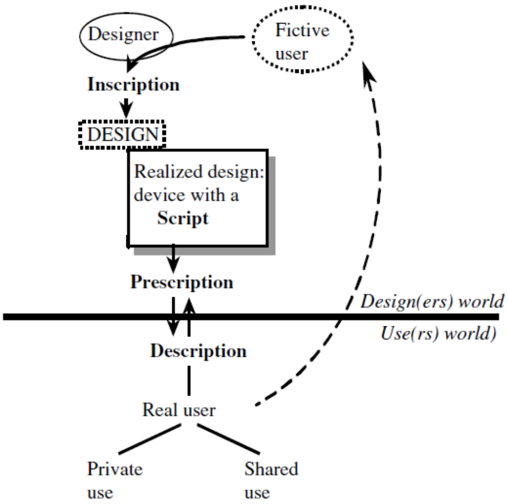

Figure 1: world of designers and users connected via script terminology (Jelsma, 2006a, p. 224).

In this situation, the fictive user is implicated by designers. According to Jelsma, empirical insights about use(rs)world should inform designers, otherwise this framework would suffer from technological determinism and to avoid design/use processes being perceived practically as linear (Jelsma, 2006a).

Jelsma (2005)argues that the material view of human action is clarifying, but one-sided, because the mind reflects on these entities. Material objects develop in a hybrid environment: partly material, partly mental. In the practice of design and use studies, analyses would be incomprehensible without representations and studies of the related mental reflections of designers and users (Jelsma, 2005). Jelsma uses insights from other fields to overcome the break between material objects and social processes. He introduced the twin concepts *design logic* and *user logic*.

Design logic is the driver that guides the process of inscription and principles of a local design practice. The development of technologies occurs never in empty social space, but takes always place in networks with certain design practices. The consistent whole of ideas, views, values and intentions in the design stage of technology are covered by the concept *design logic* (Jelsma, 2005). Often design logic is *blackboxed*[14] in work routines, according to Jelsma (2006a), and accordingly has a taken for granted status. Jelsma (2006b) reasons that for successful design thorough understanding is required of the drivers of action of use. Designers should know the underlying logic of the respective use practice. *User logic* is based on a complex, but for users consistent, mixture of values, preferences, intentions, and conventions (Jelsma, 2005), which are being "shaped and driven not only in social and cultural context, but also by material (dis)stimuli" that are part of the use practice (Jelsma, 2006a, p. 94). Many actions are carried out by routine, and users may not be aware of underlying reasons of their behavior. This does not mean that (s)he does not know these reasons. In most cases, if you question them, they will be able to explain why (s)he uses and object as (s)he does. They often are able to open the blackbox of their daily routines.

Jelsma suggest that the use practice should be represented. Such representation should be based on a reconstruction of the underlying logic of human-technology interactions. According to Jelsma

[14] Adapted by STS studies, a black box is a technical artifact that appears self-evident and obvious to the observer. Technologies as mundane as a seat belt (Latour, 1992) can be considered complex black boxes that depend on techniques, materials, thought processes and behavior. Opening the black box of technology leads the way to an investigation of the ways in which a variety of social aspects and technical elements are associated and come together as a durable whole, or black box.

(1999) such reconstruction cannot be derived from current theoretical behavior models, but should be based on empirical data of the use practice. For the reconstruction and representation of the use practice Jelsma suggests a set of methods and techniques for data collection that are central to User-Centered Design.

Although Jelsma was initially directed at optimizing only energy efficient appliances (1999, 2006a), he applied his methodology in the meantime for designing a complex service system for textile maintenance (Jelsma & Knot, 2002) . Thence complexity increased due to the increase of scale: the number of actors, relevant interaction mediated by technologies, and material infrastructures increased drastically. The researchers were not only concerned with core activities related to the service system, but also with activities in other domains. These activities of users in other domains may intervene with and influence core activities, and should be included in the analysis of user logic of core activities, because it increases the future "fit" in broader use practice. This means that more user logics have to be reconstructed.

My research will not be focused on a specific technology, feature or service, but on the daily practice of shaping a comfortable indoor climate. It is not a priori clear which technologies and material infrastructures will contribute to this indoor climate practice; so this has to be studied empirically. I expect that Jelsma's theory can be used to examine a research and use practice without a clear focus on one concrete technology and that in terms of complexity it seems similar to the reconstruction of design logic and user logic for service systems. However, a system may have competing script logics, and in the case that more human actors are involved (more person households) the user logics may also differ for each human actor. In other words, conflicting user logics may exist too in a daily practice.

What makes the twin concept of logics interesting for this thesis is that (Jelsma, 2005) argues that design and user logic are logics in motion. Design logic may change while developers struggle with resistance outside the scope of development of technology. The researchers of ECS struggle also with a mismatch between calculated and actual energy consumption. They consider social issues as part of the problem, but these are presently outside their scope. This may be an opening for change of design logic. User logic may change when something in their socio-material environment changes.

Everyday practice as concept to explore the dual promise of technology at home

Sociologist Elisabeth Shove offers a way to think about everyday practices (Hand & Shove, 2007; Shove, 1998, 2003, 2010). Shove builds upon conceptual resources from science and technology studies and from social theories of consumption and practice. Her work is directed at sociological versions of (energy) consumption of everyday practices and explores relational aspects between use, design, ordinary technologies, material cultures and conventions of comfort, cleanliness and convenience.

At the core of work of Elisabeth Shove is the concept of 'practice'. The concept of 'practice' embraces aspects of five concepts of acquisition, scripting, appropriation, assembly, normalization (Ingram, Shove, & Watson, 2007). These concepts do not fit together in a seamless theoretic whole, as Shove argues, because they all have their own intellectual ancestry. Nevertheless they all contribute to insight into co-constitutive relation between the symbolic significance of technology and realization of practices. Most of these concepts are already explained above, here follows in short Shove understandings of the five concepts that make up the notion of 'practice'. The first concept of a*cquisition* has different strands, but according to Shove is generally about the reasons why people acquire new goods. The second concept of *scripting* is derived from Akrich, and is for Shove the territory in which technology are accorded as a measure of agency, depending upon how they are designed, technologies permit and present certain courses of action and 'configure' their users. She explains that in the concept of 'scripting' the focus is on technologies as material entities, the symbolic side of technologies is explored with the third concept of *appropriation*. She takes this concepts from work of Silverstone[15]. For Shove what matters of 'appropriation' is the relation between technologies and the actions of the users, and that it makes a point of that the nature of meaning, use and purpose depend on context and situation. Whereas the concepts 'scripting' and 'appropriation' are used to describe interactions between people and disconnected technologies, with the notion of *assembly* Shove follows Latour in the way in which complexes of technology and users relate to each other in networks. The term assembly highlights to Shove the dynamic nature of technologies in use. For example, that technologies interdependency develops in the processes involved in organizing materials in the domains of, for example, domestic use practices. She uses the term *normalization* to refer to the process through which new technologies and arrangements become stabilized. Again, Shove does not claim that these concepts can be immediately plugged into a methodology for 'practices', but she suggests that these help together to light up the dark side of cycles of design and consumption.

Shove puts the 'doing' – that is the practice itself- at the center. Shove finds it important to understand technology as part of the practice that they make possible. Shove mentions that that practices develop from, establish and make sense of forms of bodily and mental activity, technologies and their use, and agrees with Jaap Jelsma that use logic and background knowledge in the form of understanding, knowhow, states of emotion play a role. She argues that practices cannot be reduced to any of these elements alone.

Shove focusses on the sociology of consumption of energy and technology. She does not focus on the energy that technologies consume in daily practice, but highlights other aspects of resource intensive user-technology interactions at home. She explores the comfort, cleanliness and convenience that technologies provide in everyday practices (Shove, 2003). Everyday practices that consume energy are normal household practices like bathing, laundering and cleaning. All sorts of socio-technical (f)actors at home play part in everyday practices and Shove investigates how and why people organization their daily practices as they do. She interrogates the normality, social meaning and realization of the practices that require energy.

This way of thinking is helpful for this thesis, because it allows placing the everyday practice of 'shaping of a comfortable indoor climate' at the center of research. The practice of 'shaping a comfortable indoor climate' can be considered as an energy consuming practice. In the indoor climate practice at home, play all sorts of socio-technical (f)actors at home a role. Shove's works helps to highlight comfort issues that are related to energy consuming practices of the indoor climate. Shove (2010) would argue that people at home do not simply interact with climatic technology to consume energy in the normal household practice of indoor climate, but do so for good reasons. For example, much of the energy used at home is used to keep people comfortable. In other words, people interact with heating and ventilation systems to realize a comfortable indoor climate. Seen from this perspective, what matters at home is the service of "comfort" that the energy efficient technologies provide in practice. Shove argues that if saving energy is the focus and the goal is to stimulate energy efficient use behavior of indoor climate systems, then so are users'

[15] For example: Silverstone, Hirsch, and Morley (1992) and Silverstone (1993)

meaning of comfort and the way how this is facilitated by the technologies (Shove, 2010; Wilhite et al., 2000).

In conclusion

In the previous sections, relevant STS approaches were presented. At the start, ANT was introduced as a relevant perspective for this thesis, because it understands behavior as resulting from dynamic socio-technical interactions. Also, ANT treats humans and non-humans equally, in the sense that both possess agency: technology has an active role in shaping users' behavior, as well as designers and user play an active role in its shaping. However, this is not to say that all (non)humans have the same power and/or role in technological development. Further theories were proposed to describe the specific roles and types of agency technology, designers and users. The design and use networks were connected by means of the script theory. This theory focuses on the specific agency of designers and technology. The agency of users was explained by means of studies about the appropriation of technology in daily life. An important consequence of the application of these theories is that understanding of technology varies when studied from the perspective of makers or from the perspective of users. Finally, to complete the theoretical frame the twin concepts design and user logic were introduced. These concepts are remarkable as tools to study mental drivers behind specific behavior in research and/or use practices.

Rooted in the foregoing, an integral approach to study use behavior in daily practice of shaping a indoor climate at home can be reconstructed. This approach does not only support bridging the gap between social and technical, but it also enables to analyze how agency and responsibilities are delegated and distributed over the socio-material design and use network. This is important for the analysis of underlying drivers of users' behavior in daily life.

As mentioned earlier, the house will be considered as a socio-technical environment in which household members, material and other technological artifacts that all individually influence behavior of users in shaping an indoor climate. The physical infrastructure of a home is a highly scripted environment that plays a core role in producing the experience of the user. Scripts encourage and discourage certain forms of use by specific elements of its design and have an effect on user behavior. But, in practice also values, preferences, intentions and conventions of users are part of indoor climate practice and contribute to user logic.

In this thesis, user logic will be examined without a focus on one concrete technology, but with an emphasis on the core practice of shaping an indoor climate at home. This daily practice at home is complex and dynamic: it involves many actors, and relevant interactions mediated by technologies and material infrastructures. The core practice of the indoor climate may intervene with, and may be influenced by other household practices in everyday life. However these other doings should be taken into account too, because they may indicate underlying reasons for doing the core practices as it is done.

This thesis does not focus on the energy consumption of user-technology interactions, but explores users' meaning and realization of comfort within the indoor climate practice at home. Comfort will not be conceptualized beforehand, but rather explored empirically in order to understand either users' own meaning of comfort and their behavior when they create a comfortable indoor climate at home, or ECS researchers' understanding of comfort regarding the indoor climate and its realization.

The final remark is about the specification of the user. The various authors are referred to in developing this theoretical framework, have used the term *user* in relation to several types of users. In this thesis, anyone who lives in a house with indoor climate systems could be said to be a user. I will refer with the term 'user' to an individual household member as end-user of indoor climate systems at home. In the next section I will divide the central question into six research questions.

2.2 Research questions

Having established a theoretical framework that allows applying a socio-technical perspective in this thesis, this section turns to the actual research questions. The central goal of this thesis is to find out underlying issues that can explain differences between calculated energy consumption in ECS research and actual energy consumption at home that is related to indoor climate practice. The study aim is to compare how researchers envision that users create a comfortable indoor climate at home' in *Energy & Comfort Systems* division with what actually happens at the homes of users in order to identify underlying causes for differences in energy consumption. In order to fulfil the goal, the following research question and six corresponding questions were formulated:

What underlying dynamics can be identified for the difference between calculated energy use and actual consumption by comparing (a) how actual users shape a comfortable indoor climate at home and (b) how researchers anticipate users, their behavior and comfort in research on indoor climate systems?

The following three research questions are formulated for the empirical investigation of the ECS research domain:

1. *How are users represented in 'Energy & Comfort Systems' research on indoor climate systems?* This research question aims to identify how ECS researchers anticipate the future users of indoor climate systems.

2. *How is "comfort" regarding indoor climate constructed in 'Energy & Comfort System'-research on indoor climate systems?* This research question purposes to discover ECS construction(s) of a *comfortable indoor climate*. It aims i.e. to identify how ECS researchers define and understand categories like 'comfort' and 'indoor climate'; what kind of materialized concepts of comfort are available in the ECS department on indoor climate systems.

3. *Which design logics lay behind "user representation" and "comfort construction" regarding to the indoor climate in 'Energy & Comfort System'-research on indoor climate systems?* This questions aims to provide insight into the rationalizations of ECS researcher that legitimize for them and explain the ECS research situation as it is, regarding user representations that were identified in question 1, and the construction(s) of a comfortable indoor climate as recognized in questions 2.

The next three research questions are expressed for the empirical study of indoor climate practices at homes:

4. *How is "comfort" regarding the indoor climate constructed by users at home?* The goal of this research question to discover commonalities in users' interpretations of *comfort* and

their experiences of the *indoor climate* in the socio-technical environment of their own home.

5. *How do users realize a comfortable indoor climate in at home?* This research question focusses on actual user technology interactions in the socio-technical home environment in order to create a comfortable indoor climate. The focus is on how agency is distributed in user-technology interactions, as well as how responsibilities are delegated over the socio-technical home environment in realizing and maintaining comfortable indoor climate.

6. *Which user logic(s)lay behind the realization of a comfortable indoor climate at home?* This sixth questions aims to present motivations of users that lay behind the domestic practices of creating a comfortable indoor climate, regarding their construction(s) of a *comfortable indoor climate* that were identified in research question four, and the actual user technology interactions that take place at home as presented in research questions five.

Taken together in the end, the findings of the ECS research domain and indoor climate practices at home will be put side by side for a comparison. The comparison will be about how both actor groups construct 'comfort', as well as anticipated user behavior with indoor climate systems in ECS research and actual use practices at home. Reasons and considerations behind the research and daily practices will be analyzed. Similarities and differences in constructions of comfort and anticipated and actual behavior will be highlighted in order to check the findings of ECS research for inconsistencies in the quality of user logics it incorporates. The assumption is that mismatches between comfort constructions and unforeseen use interactions may cause unexpected energy efficient effects of indoor climate systems. This comparison aims to shed light on dynamics underlying the differences between anticipated and actual energy use behavior in housing by focusing on comfortable indoor climate.

In this way this study hopefully provides useful insights about an area that, as of yet, is not well-known. In addition, the findings may form a foundation for further studies. The insights gained through this thesis may also feed back into ECS research, aiming to improve research and develop indoor climates systems that better fit the actual complex and heterogeneous energy use practices at home.

3 METHODOLOGY

The purpose of this thesis is to gain understanding of processes underlying the differences between anticipated energy consumption in *Energy & Comfort Systems* research and actual energy use behaviour in housing by focussing on the comfort regarding the indoor climate. Consequently, the research domain of 'Energy and comfort Systems' should be compared with actual indoor climate practices at homes of users.

The specific theoretical framework and research questions have led to embrace a qualitative approach. The ECS research domain and cases at homes of users were inquired in depth. The empirical inquiries were done with a socio-technical perspective. Both social phenomena as well as material objects were considered to contribute to indoor climate systems research as well as to daily practices of indoor climate at homes. Since a socio-technical perspective is relatively new in the field of energy performance research, this thesis has an exploratory character to develop initial insights and a sound base for further decision making.

The structure of this section is as follow: section 3.1 presents the research design for ECS research. Section 3.2 provides the research design of the actual indoor climate practices at home. Both research designs include an account of methods, sources, and the data analysis. Section 3.3 briefly described the comparison that is made between results of ECS research and indoor climate practices at homes of users. Finally in section **Error! Reference source not found.** some limitations on the methodology are explained.

3.1 RESEARCH DESIGN FOR THE ENERGY & COMFORT SYSTEMS RESEARCH

The purpose of this research is to inquire from a socio-technical perspective *how users are represented by ECS researchers and how comfort regarding the indoor climate is constructed in ECS research* on indoor climate systems, along with underlying *design logic(s)* of research that motivate for ECS researchers the current research situation regarding users and comfort. To answer these questions, it was necessary to inquire in detail social phenomena as ideas, opinions and motivations of ECS researchers and technical objects like methods, tools and further written knowledge that are applied in ECS research on indoor climate systems in regard to users and comfort[16]. For that reason was opted for two qualitative research methods: semi-structured interviews and content analysis. These data collection methods and corresponding sampling strategies will be described below, and afterwards follows how collected data is sorted, processed and analysed.

SEMI-STRUCTURED INTERVIEW

The first method used in this research was in-depth, semi-structured interview. This type of interview is open and allows new ideas to be brought up during the interview as a result of what the interviewee says. So the interviews gave access to personal views of ECS actors from different positions, climate systems specializations and location within the institute. Individual interviews clarified personal ideas, opinions and motivations on what type, and how *comfort* and *users* are

[16] During this research, I was an intern at TNO. This position allowed me to talk to various ECS researchers and observe the daily course of affairs within the ECS research domain; information was easily accessible. Furthermore, I received supervision from TNO. Being an intern was useful to familiarize with the ECS setting and to understand vocabulary, concepts, technologies and related issues in research practice. Initial insights were used to determine the research strategy and were integrated in the interviews. At a later stage, my experience of ECS practice was valuable in interpreting the collected data.

present in the ECS research. The collection of interviews was used to uncover shared trends in thought and routines.

The semi-structured interviews organized were as suggested by DiCiccoo-Bloom and Crabtree (2006). An interview schedule was built upon broad and open-ended questions. The interview schedule helped to focus on topics at hand, without being constrained to a particular format. Questions were asked that touched upon research activities on indoor climate and related systems, in general and more specific with respect to comfort and users. The freedom of the semi-structured interview helped to tailor the question to the interview situation and to the particular researchers. Further questions emerged from the dialogue, in following the interviewee's responses. Also, the order of questions was led by the response of the interviewee. To make the interview as non-directive as possible, I replied with prompts that repeated the words used by the interviewee. Annex A contains a generic version of the interview questing for ECS actors.

The selection of respondents was based on 'purposeful sampling' (Creswell, 2013). The aim was to select ECS researchers that represent a range of variation in dimensions of the interests at stake: comfort and users. The sample of ECS actors included researchers who were all involved in indoor climate systems and who have been working at the institute for a long time. To capture maximum potential richness of the data and perspective, the respondents vary regarding function, specialization and location. The sample of ECS actors was realized in collaboration with a TNO supervisor. The selection of the four respondents was based on researchers who are considered to have valuable input about comfort and users. Table 1 shows the ECS participants.

name	**function**	**specialization**	**location**
Edo Wissink	project leader 'refrigeration'	heat pumps	Apeldoorn
Piet Jacobs	advisor 'Energy, Comfort and Indoor climate'	ventilation, heating	Delft
Roel Brand	project manager *Energy &* Comfort Systems	collective systems	Apeldoorn/ Delft
Jan Ewoud Scholten	scientific assistent / consultant	heat recovery, thermostat	Apeldoorn

Table 1: overview of ECS respondents

The interview meetings took place at locations within the research practice during December 2012. The Interviews were prepared to complete within 60 minutes. The conversations were conducted in Dutch, recorded and transcribed verbatim. Quotes provided in chapter 4 are translated by the author into English

CONTENT ANALYSIS

The second method used was content analysis. A basic methodological assumption was that it would be beneficial to complement performing interviews with content analysis. Content gives access to a kind of 'official' image of the research heuristics, including more or less straightforward facts about how comfort and users are handled in practice. Furthermore, the written material may help to discover hidden aspects or inconsistencies in what actors say about the research practice. The mute evidence in the texts supports and enriches the findings of the interviews and the combination of both methods is likely to produce a fuller picture of comfort and users in ECS research practice.

The sample of content was based on materials that have been provided by the actors involved in research on indoor climate systems. These materials share the fact that the researchers consider them as representative examples of their research activities or ECS research. From these materials, a sample was selected based on relevance with the themes of comfort and/or users. The sample of the content includes TNO publications meant for an audience existing beyond the institute, TNO documents for internal use only, external sources used by ECS actors in research activities, and materials of personal interest of ECS actors. Annex B gives an overview of the ECS data collection. Some of the content is written in Dutch. Quotes from this material have been translated into English.

DATA ANALYSIS

The data collected in the ECS research department was prepared for further analysis. Data has been digitalized and stored into a computer data base. A commonly used approach for structuring data relies on using codes from a codebook for tagging segments of text and then sorting text segments with similar content into separate categories for a final distillation into major themes (Miles, Huberman, & Saldaña, 2013). Coding was also a crucial step for the conceptualization of data, by going from the descriptive level to the conceptual level and develop an approach for understanding the ECS research practice. During analysis, both list-coding and open-coding were applied. An initial list for the list-coding was derived from concepts in the research questions, and complemented during analysis with more specific codes by means of open coding. Coding helped to break down data and to gain new insights. Conceptually similar data samples were grouped together in categories and subcategories. The process of coding was organized with help of the program 'Atlas.ti 6.2'.

The data was first analysed against the background of the research questions about *constructions of comfort* and *user representations*. Certain underlying concepts of the research questions were brought into play when examining the data. For constructions of comfort, it was important to find out about interpretations, definitions, and concepts of comfort present in the ECS practice. Central for user representation was to learn about techniques for generating user representations, constructions of users and (anticipated) interactions of users with indoor climate systems employed in the ECS department. Therefore, attempts were made to adapt the experiences of informants and ECS practice into the main thought behind each of these dimensions. Furthermore it was also necessary to examine the general practice of ECS to be able to relate constructions of comfort and user representation to the *design logic* of ECS and in order to understand why the current research situation in regards to users and comfort is as it is. The analysis of *design logics* was focused on reasons and motivations that ECS researchers gave for dealing with users and comfort as they do in the ECS research domain.

3.2 RESEARCH DESIGN FOR INDOOR CLIMATE PRACTICES AT HOMES

The aim of this case study research is to provide a more thorough analysis of how users realize a comfortable indoor climate at home. The purpose of research is to inquire *how users construct comfort regarding the indoor climate*, how *a comfortable indoor climate is shaped and negotiated at home and along with underling user logic(s) of users* that motivate for them the indoor climate practice at home as it is.

This research was conducted with a socio-technical perspective on the home, in which the home was considered as a socio-technical environment that includes both material and human actors. Six empirical cases were explored on users' understandings of comfort; and interactions that take place at home with other household members, technologies, and material objects in relation to the realization of a comfortable indoor climate at home; and reasons that users gave for explaining the situation as it is. This qualitative research relies on in-depth semi structured interviews with people at their own home[17]. The interview method will be presented below, as well as sampling strategies. Afterwards follows a description of the analysis.

SEMI-STRUCTURED INTERVIEW

The main data source is in-depth semi-structured interviews as described earlier. For the interviews was a guideline prepared, with a series of broad and open-ended questions. The questions were organised around predetermined topics. Point of departure for the interview was to establish a profile of the interviewee, in terms of personal details, daily schedule, household, technologies and material housing situation. Secondly, *comfortable indoor climate* [18] was discussed starting with a broad view regarding their general housing situation towards indoor living atmosphere, and from indoor climate at home to more specific their heating and ventilation practices. Those interviewed were encouraged to give their own meaning to each type of domestic conditions and express freely their own opinions about comfort and discomfort in relation to their socio-material environment. In this way, the terms 'indoor climate' and 'comfort' became clear during the interview, without explicit explanation or direction to a specific definition of 'indoor climate' from the side of the interviewer, but interviewees were stimulated to clarify their 'comfortable indoor climate'. Finally, interviewees were encouraged to tell their stories about everyday situations and interactions with ventilation and heating systems. During the course of the interview questions were modified based on responses of interviewees. A generic version of the interview schedule for respondents at home is provided in annex C.

Again a purposeful sampling (Creswell, 2013) strategy was employed for information-rich cases. The selection of respondents was based on convenience sampling, which means for this research that the sample was being drawn from that part of population which is close at hand and available at the time of data collection. For this research the sample was selected from friends, family, and colleagues. The main criterion was to select participants that reside in a house built between 1970-1990. This criterion ensured comparable physical conditions and indoor climate systems in mutual cases. A second criterion was to select study units which represent variation in dimensions of interest, like type and size of the household, gender, tenants or owners, and type of house. This criterion was used to find diverse cases and multiple perspectives. The sample size was set at six. This decision was based on consideration of the exploratory intent of this study and limited time frame. According to Creswell (2013) six case studies in a single exploratory study should provide ample opportunity to identify themes of the cases. Table 2 shows the respondents[19] that were interviewed at home.

Name(s) & age	type of household & number of individual household members	Owner/ tenant	Type of house & year built
Tineke (57)	married couple with out-home children (2)	owner	semi-detached (1984)

[17] In preparation for the case studies, I talked with various people about the themes of research. I conducted three pilot interviews with persons that did not suit the sample criteria. These insights were included in the method and its application for data collection.

[18] During pilot interviews, 'comfort regarding the indoor climate' turned out to be difficult to study empirically without introduction or reference to the general housing situation. From scratch, the term 'indoor climate' was for most respondents too specialized. They often needed further clarification before they were able to say something about their indoor climate. 'the indoor climate' in these stories turned out to be narrow kind of interpretations and they rather general told about general aspects of indoor climate that they find comfortable or not.. Limited association with conditions in their own environment came to the front during pilot interviews. Since the goal is to capture users' point of view of their own indoor climate at home, this approach was to directive and restrictive. Therefore, a more workable approach was developed to investigate users' ideas about comfort regarding the indoor climate at home.

[19] The names of the user-respondents are feigned out of privacy reasons.

Tamar (27)	family with young children(4)	tenant	terraced (1970)
Sanne (28)	Commune (8)	tenant	canal house (1981)
Emiel (29)	single person household (1)	owner	apartment flat (1970)
Brenda (29) & Marieke (27)	cohabiting partners (2)	owners	apartment flat (1970)
Karina (28) & Edwin (28)	cohabiting partners (2)	tenants	apartment flat (1975)

Table 2: overview of 'user'-respondents

Four interviews were held as individual face-to-face conversations, two interviews were carried out with two persons. The interviews were prepared for 60 minutes and were performed in December 2012 and January 2013. The interviews were conducted in Dutch, recorded and transcribed verbatim. Quotes provided in chapter 5 are translated by the author into English.

The interviews were conducted during a visit at participant's own home. Meeting the respondents in their natural setting creates opportunity for direct observations (Yin, 2009). Some relevant socio-technical environmental conditions and behaviour were available for observations. The condition of the house and household, heating and ventilation systems indicate something about comfort and indoor climate at home. Such observational evidence was useful in providing additional information about the themes being studied. Furthermore observations at home were invaluable aids for understanding and interpreting the actual stories of the respondents, and any potential issues being encountered. The observations were recorded by making field notes, sketches and taking photos. Annex D provides an overview of further empirical data collection of observations at homes of respondents.

DATA ANALYSIS

The collected data of real indoor climate practices at home were prepared for further analysis. Data was digitized and stored in a computer database. A general approach for analysing cases is to rely on predetermined theoretical propositions that led the research (Yin, 2009). For instance, the shaping of a comfortable indoor climate in the socio-technical set up of the house and household, as a basic proposition in this research, was traced in the cases. For each case, the purpose was to determine how respondents behave and interact with the socio-technical environment in order to create and maintain a comfortable indoor climate. Consequently, it was also necessary to identify their interpretation and meaning of comfort and experience of the indoor climate at home.

Theoretical orientated guiding helps to focus attention on certain data and to ignore other; to organize the entire case and to define alternative explanations to be examined (Yin, 2009). The analytic strategy was to analyse the case study data by building an explanation about the cases. This was relevant because of the explanatory character of this research and to develop ideas for further study. Explanation building has occurred in narrative form. The focus was on the particularities and specifics of each case, especially the unexpected issues and happenings. Through stipulating *how* and *why,* underlying user logics could be explained. The explanations are a result of a series of iterations and gradually build up. After treating the individual cases as independent research studies, a cross-case synthesis was performed with replicating logic. The process of analysing and building explanations was done with the help of Atlas.ti 6.2.

3.3 Comparison of Energy & Comfort Systems research and daily practices at homes

After the two studies had been completed, the results of the ECS research domain and use practice have been compared with each other. The results of how both actor groups construct 'comfort' as well as anticipated use behavior with indoor climate systems in ECS research and actual indoor climate practice at homes are compared. First were the main elements and characteristics of the 'design logic' in 'user logic' or comfort and interactions identified. Once the 'design logics' and 'user logics' were mapped, they were compared to highlight similarities and differences. Inconsistencies in ECS logics and users logics were used as underlying processes that may cause unintended use and unforeseen energy efficiency effects.

3.4 Limitations

This study has several limitations due to its explorative character, time frame and availability of study units of this research. The main limitation is related to the samples of this research. The samples are small, and do not represent the populations at a whole, which makes it difficult to draw strong conclusions. Furthermore, for convenience sake the study units were selected that happened to be accessible and willing to volunteer at the time of data collection. A drawback of conveniences sample is that it suffers from a number of biases. Personal biases crept into the data. Because the particular selected researchers were suggested by my supervisor and the potential users were selected from my own relatives and acquaintances. Personal (un)conscious prejudices about certain researchers and potential users made that certain researchers and users had a higher chance of selection and other were not approached. This led to skewed data collection. Another drawback of conveniences sampling is that the sample may be biased by over or under representations of particular volunteers. For example, in the sample of potential users the age group of people of around 30 is over selected, while other age groups are under selected or missed all together. To get a good impression of how diverse users shape a comfortable indoor climate, it is necessary to study a wider variety of age as well. Furthermore, the volunteers may also differ in unknown but important ways from other potential users.

The inherent bias in conveniences sampling means that the samples are unlikely to be representative of the studies population of researchers and potential users. This undermines the ability to make generalizations from the samples about the entire populations. However, I wanted to study specific dimensions of interest and it was impossible to observe all researchers or potential users. Therefore it was more convenient to select specific samples, than to take a random sample of all researchers or potential users. The samples were useful for this explorative, pilot kind of research and the cases provided sufficient information to create insights and presumptions for mismatches between research and daily practices.

4 SHAPING A COMFORTABLE INDOOR CLIMATE IN ECS RESEARCH: USERS, COMFORT AND DESIGN LOGIC

This chapter presents the analysis of the study of the research group 'Energy and Comfort Systems'.
The purpose it to identify how users are represented and a comfortable indoor climate is constructed in ECS research and the design logics behind ECS research process. The empirical data for this analysis consisted of qualitative interviews with ECS researchers and some core technical documents that are produced and used in the ECS research practice. The sources were analyzed firstly on how researchers anticipate users and their behavior in ECS research; then on how they conceptualize the concept of comfort in relation to the indoor climate; and finally their reasons why current ECS research practice regarding users and comfort is as it is. The results of this study of the ECS research domain serve as reference data for a comparison with what actually happens in homes of users. The results will be related later in this thesis to findings of actual users and their behavior at home, users' constructions of comfort and user logics behind actual interactions in realizing a comfortable indoor climate at home.
The format will be based on a short introduction in section 4.1 of the general logic of ECS research on indoor climate systems. Section 4.2 presents the analysis of user representation, and section 4.3 provides the construction of comfort. Finally the research logics behind standards as method to apply users and comfort in the ECS domain are described in section 4.4.

4.1 PORTRAYAL OF CORE PRINCIPLES OF ECS RESEARCH

This section analyses briefly some core principles of ECS research on indoor climate systems. Questions like 'What is position?'; 'Where is it about in your research?'; and 'What are your research specifications, and how about comfort and users?' were answered with similar responses. These responses are grouped under *core principles* of ECS research. These principles describe the core of ECS research, but at the same time, these core principles were regularly brought into discussion to justify why 'users' and 'comfort' are treated as they are in ECS research. The ECS researchers use the core principles as arguments. Directly and indirectly motivate these core principles the scripting process of users and comfort in ECS research. This portrayal helps to place further analysis of user representation, construction of comfort and design logics of research into context.

A first principle is that ECS research is directed at the development and delivery of indoor climate systems. The main goal is to investigate systems and realize that they are energy efficient and improve the quality of indoor environment; the goal is thus twofold. This work is carried out by researchers that are specialized in technical sciences.
The core of their work is *technical* development of systems according to the researchers.

> *"I am involved with actual technological development (...), what matters in the end, is that a system has a certain return (...) and that is what I can improve." (E.Wissink)*

The researcher means with 'return' a measurable quantity and refers to the extent to which energy consumption of the installation is converted into effective heat. 'Effective heat' implies comfort. This suggests that the ECS researchers motivate their work as the *technical* development and delivery of indoor climate systems that perform measurable better regarding energy consumption, in which comfort functions as a value for the required energy, than previous systems. Thus although the purpose is dual, energy efficiency gets more priority than comfort in research practice due to technical nature of research.

A second core principle is that the technical development of measurable energy performance concentrates on the improvement of the functionality of technologies. The researchers tend to translate matters that influence climatic installations, like comfort, into technical features, and specify requirements that should be reached by the systems. This allows them to focus on functions of the systems:

> *"We check for functionality"(E.Wissink)*

This type of research inclines to investigate if systems work according to predefined technical features. This means in practice that the researchers must technically ensure that intended functions are carried out properly under controlled circumstances and result in certain performance i.e. specified energy outcomes. In such research is technology at the center of interest. At the same time, other matters i.e. future users and environment fade into the background in technical research of ECS.

A third core principle in ECS research process: social and technical phenomena approached separately. The researchers are aware that technology and people together contribute to a certain outcome, but approach technology and users independent. Researchers argue that they have influence over the technical performance of the design in relation to energy, but cannot control the social impact of users on the system. When the researchers speak about social impact of users on a system, they seem to mean users' behavior that influences the energy efficiency of the system:

> *"If you test a device in a house, eh with residents, this means, eh in practice, that you cannot control the experiment. [...] I want to measure the energy performance (of the device). But whether those residents shower one or ten times a day, that is something beyond my influence. [...] The quality of operation and, eh what those people actually do, we cannot take that into account during experiments. "(E.Wissink)*

As a consequence, ECS researchers feel responsible for technical performance and do not consider users' impact on the outcome of energy consumption. They focus solely on technical improvement:

> *"It makes sense to enhance technology, because it makes always a difference." (E.Wissink)*

They try to keep any deeper analysis of the social worlds to which their technology has to relate for becoming really 'functional' at distance.

DISCUSSION

The three principles explain in general the core of ECS research. However, what also becomes clear is that researchers are involved in the *development* stage of indoor climate systems. But, the researchers do not *design* systems. They rather *study* the new systems that were made by others. The researchers study new technologies that have to be functional in future practice of use. This means that the researchers are rather involved in *research*-development, than *design*-development of indoor climate systems.

This has implications for the analysis of design logic of ECS research. The concept of design logic of Jaap Jelsma is based on the *design*-development of a technology. Jelsma follows Akrich in the sense that he considers the design stage of a technology as a process of scripting, where designers inscribe their ideas into the design of a technology. However, the ECS researchers do not materialize their predictions about users and comfort into the physical layout of indoor climate systems. The researchers rather study inscriptions of technology that are made by the designers. Therefore, the concept of design logics does not work well for this analysis as it is considered as a design-development concept.

Therefore I want to consider design logics as a research development concept in this thesis. Because, a process of scripting takes also place in the research development but in a different way than in design development. Also researchers work with a coherent plan with underlying logics in the research practice on which the research team agrees. Researcher inscribe (and reproduce) the consistent whole of their core principles into the research process in order to deliver 'functional' research products. Their logics about how research should be done becomes objectified and mirrored in research content, methods, tools, and strategies. Research can be accorded as a measure of agency, depending upon how it is arranged; it permits and presents certain courses of actions. For example, ECS research is directed to check systems on functionality and energy efficiency.

The core principles of research have implications for the scripting process of users and comfort in research. These do not become materialized in indoor climate systems, but in research on indoor climate systems. ECS research is driven by a technical viewpoint; the researchers feel highly responsible for technical development and investigate the functionality of indoor climate systems. This has implications for social side of research on technology. The researchers believe that they cannot control social considerations and therefore concentrate solely on the technical side of indoor climate systems. It seems that social issues related to users are not explored actively and disregarded in research. Furthermore, it also has implications for the dual purpose of indoor climate systems. The indoor climate systems have a dual purpose of energy efficiency and comfort in theory, but in practice energy efficiency seems to get higher priority than comfort consideration. As result the indoor climate systems are explicit assessed and judged on 'energy efficiency'-grounds.

4.2 User representation

This section provides an answer to sub question: *How are users represented in 'Energy and Comfort Systems' research on indoor climate systems?* The purpose of this section is to provide insights in the generation, articulation and the role of specific user representations that are present in ECS research domain. The user representations will be compared later with actual users and their behavior at home.
In advance, some introductory remarks on the analysis of user representations need to be made. Soon became clear during interviews that end-users are not directly involved in the ECS domain. Users, their behavior and comfort preferences are not analyzed within ECS research. Interview questions about how users, their behavior and comfort preferences are involved in ECS research, were usually answered by ECS researcher with remarks like:

> *"User interactions are not examined."(J.E.Scholten)*
>
> *"We investigate the needs of users too little; we are not concerned with this."(P.Jacobs)*

These answers confirm the previous findings about a core principle of ECS research that at least social features of users are not explored actively.

Nevertheless the ECS researchers did exemplify intended users throughout the interviews[20]. These examples clarify much about the kind of end-user and use that they actually have in mind. Such examples in the interviews with ECS researchers and core technical document were analyzed for user representations in the ECS research.

The analysis was done in line with Madeleine Akrich' approach in *User Representation: Practices, Methods and Sociology* (1995). Following Akrich' approach, this analysis considered the mere fact that an example was introduced into the discussion in the name of the user makes it relevant to the purpose of this project. This analysis also follows Akrich in that she did not distinguish beforehand between methods that can be justified on scientific and conceptual grounds, and more empirical techniques that miss a formal base.

Akrich (1995) classified the methods that she had observed for generating user representations into two categories: *explicit* and *implicit* techniques. Explicit methods can be interpreted as techniques via which potential users are consulted direcly as sourses. She identified three explicit methods: marktet surveys, consumer testing and feedback on experience. Implicit methods have in common that 'real users' are adressed indirectly via i.e. spokespersons of users. Akrich defined also three implicit techniques: 'I-methodology', the experts, and other products. Her classification of explicit and implict techniques will be used as well in this research.

The interviews with ECS researchers and further empirical sources were analyzed against the background of Akrich's approach towards user representation. This resulted in the identification of four different kinds of user representation methods in ECS research process. During the process or research these four methods result into the articulation of three specific user representations. Each of these three user representation plays its own role in design logics of ECS research process.

The findings are presented in four steps: subsection 4.2.1 introduces the four user representation methods. Subsection 4.2.2 presents the three user representations and subsection 4.2.3 elaborates on the role of each representation of the user. Finally, subsection **Error! Reference source not found.** summarizes the findings about user representation in the ECS research domain.

4.2.1 FOUR METHOD FOR PRODUCING USER REPRESENTATIONS

This first sub section presents the four methods that are observed in the ECS research domain. These methods are: 'standardization', 'I-methodology', 'referring to family members', and 'using complaints'. These four methods are defined below and discussed in line with Akrich's approach.

STANDARDIZATION

The first method that ECS researchers use to generate user representations is 'standardization. This user representation technique takes standards as representative for users. The next example shows how users' needs are represented by standards.

> *"A resident needs tap water (...) but we are not going to question users 'how will you use it?'. Tap water is based on a standard. This is a specific tap pattern. For example, for a tap in the kitchen, this is just long-short-long-short and this pattern is simply standardized. Based on such pattern you basically evaluate the systems." (E.Wissink)*

[20] During interviews, ECS researchers have used the term 'user' loosely for all kinds of users. They brought in the term 'user' to refer to households, installers, maintenance and repair workers, concierges etc. However, this analysis focused only on one specific kind of user, viz household members who live in mechanically cooled, heated or ventilated house as end-users of indoor climate systems. With this type of end-user in mind the interviews were analyzed for user representations that the researchers use in the ECS domain.

Users' needs, i.e. hot tap water as being rapid available, are seen by ECS researchers as typical for all users in general. Researchers consider it normal to retrieve such kind of 'comfort' needs from standards and norms.

The method of 'standardization' was formulated (Jelsma, 2005) and not expressed in the study of Akrich (1995). Jelsma prefers to call this methods 'parameterization', because in standards are "the whimsical needs of heterogeneous users reduced to (re)settable parameters" that fit the "experimental setting designed for gathering data about technical performance" (Jelsma, 2005, p. 78)of indoor climate systems. Standards are used by ECS researcher as information sources that express potential users' behavior and reactions. Potential users do not speak for themselves. So, the method of standardization may be categorized in as an implicit technique.

Standards seem to be important sources for the ECS researchers, because they motivate that the resulting user representation can be justified as formal and scientifically based. Not only did all ECS researchers mention this methods regularly throughout the interviews; when mentioned this method was always surrounded with comments like 'normal', 'everybody uses them', 'common to use standards', 'why use something else if information is ready available'. The comments together with the frequent use of this method suggest that 'standardization' is a highly accepted and obvious in ECS research pracice and influential way to create user representation during the research process.

I-Methodology

The second method that came to the fore in interviews is the 'I-methodology'. ECS researchers use their own experience with indoor climate systems to capture real users. Some anecdotal quotes are provided that demonstrate how researchers refer to their own personal situation at home.

> *"By chance, I programmed my own heating curve[21] last year, because I thought that it was too high and I wanted to bring it down."(R.Brand)*

> *"This overhang [which the researcher sketched to explain a typical situation] is of course my own [situation at home]. I always draw my own house of course; I am not familiar with other houses." (P.Jacobs)*

> *"I just thought, 'let me connect a wattmeter [to the pipes of the floor heating] to measure its electric power' (…) and what did I see… '220 watt!' Well, in that case it is better to turn the heating off [instead of leave it on at the 'standby-option']." (P.Jacobs)*

In most personal stories the researchers present themselves as spokesperson for potential 'real users' that have the technical skills that are required to examine their home situation in search for improvements.

The 'I-methodology' was formulated by Akrich (1995). Akrich suggested that this method is an easy and influential option when there are hardly other means available of bringing in the end-user. This seems also to be the case in the ECS domain. Throughout the interviews, all the researchers made frequently statements on behalf of users. Real users and their behavior not directly involved or studied in ECS research environment, and it looks like that ECS researchers turn to first their own experience when they want to exemplify real user experience, because their personal stories are easy available.

Akrich categorized this method as implicit. Referring to themselves allows the ECS researchers to form implicitly a "mental model" of a user. The concept *mental model* is an explanation of someone's

[21] In Dutch: 'stooklijn', spoken language for a heating control system.

thought process about how something works in the real world. One of the TNO documents (Spiekman, 2010) elaborates on this concept:
the mental model of users is influenced by their *experiences* of a technical device, in contrast to developers, whose mental model is based on their *technical insight* in a system. Via the I-methodology, *researchers* use their own technical insight to form a mental model of a *user*. Although these type of representations lack a formal academic base, personal information can carry a certain amount of conviction and is often treated as valid arguments (Feng, 2005). This also seems the case in the ECS research practice as the researchers quite often referred to this way of representing in the interviews. Therefore, I consider that the 'I-methodology is a powerful method as well in the ECS domain to represent users.

REFERRING TO FAMILY MEMBERS

The third method that was observed among ECS researcher for creating user representations is 'referring to family members'. Instead of using to their own experience, ECS researchers refer to daily situations in which family members play a role and take this as characteristic for real users.

> *"But once I switched to the 'fireplace'-setting, I go to bed at night and my wife still remembers 'hey, I have to turn it down' and she can do that without any problem. (…) But what she does not know is that the temperatures in the other rooms remain more or less the same."(R.Brand)*

> *"When my mother visits our home (...) she might say 'gosh, it's a bit stuffy, I want some fresh air', and fresh air means for her 'an open window so that cold air inside can come inside'. (…) and well that's true, or better was true 20 to 30 years ago, then it was the standard. But now of course, that does not matter anymore, because now we have a heat recovery system that also provides fresh air at home."(E.Wissink).*

In these types of stories, the – often female - relatives are portrayed as 'typical' users with wishes, ideas, and skills that are inappropriate in interaction with indoor climate system. By applying the method of 'referring to family members' their relatives act as examples for real potential users. These user representations are very often about women and are always linked to a form of technical incompetence. This means that in discourses about users in ECS research – an environment that is highly dominated by male researchers-, gender stereotypes are (re)produced.
The method of 'referring to family members' is closely related to the 'I-methodology'. They are similar in the sense that researchers bring personal situations into play. However, the researchers do not refer to themselves users, but to their – often – a-technical female family members. Again they form a sort of 'mental model' of a user, but now do the researchers not use their own technical insight as with the I-methodology, but rather interpret other real users' experiences of the working of technologies. 'Referring to family members' as method is easily available too, and also lacks a scientific basis. 'Referring to family members' may also be categorized as implicit, because "typical scenarios are acted out by people deemed to be representative real-life users" (Akrich, 1995, p. 173). The family members do not speak themselves, but are represented by the researchers. The method 'referring to family members' was not observed by Akrich (1995). However, Feng (2005) did recognize user representation based on female family members in the creation of technical standards. Feng (2005) argued that statements made to capture typical users based on one's mother and grandmother, are often treated as valid argument.
Referring to family members' was not used as much as the previous methods to exemplify user. Three ECS researchers made occasionally use of this method to exemplify users during the interviews. Therefore, to my experience it seems that 'referring to family members' can be

considered as an easy way to represent users in research practice, but it is likely to be less influential as 'standardization' and the I-methodology.

Using complaints

The fourth method for producing user representations that was observed among ECS researchers was 'using complaints'. Complaints of real residents are occasionally used by ECS researcher to represent actual users' housing situations.

> *"Complaint lists consist of an inventory of opinions, [for example] someone complains that his energy consumption is too high or too low. In such cases are we going to figure out how the situation is at their neighbors' or we look at similar houses. So, in that way we check the complaints. But what we don't do directly is to check the opinions of the people that complain; rather we investigate and compare their situation with the similar technical set ups in the neighborhood."(E. Wissink)*

ECS researchers do not compose complain lists themselves, but receive these from their clients. Clients, like housing corporation or producers of indoor climate systems, can approach ECS for independent advice when they have a conflict with residents about their housing situation and need a solution. A conflicting housing situation could be i.e. that the building is to cold or that more energy is used after the installation of a new heating system. Usually, the caretaker of the building collected problematic issues of residents by means of surveys, which are organized afterwards in complaint lists. Via such complaint lists inform clients ECS researchers about the problems of residents and; ask ECS to investigate the conflict housing situation and give advice to improve the circumstances[22].
The complaint lists cover according to the ECS researchers comments like: 'the system does not work', 'it is too complex', 'I do not understand why it is always too cold here', or 'the energy costs are too high'. ECS researchers use such complaint, as being real-life scenarios, to represent users in their housing situations.
'Using complaints' as a method to generate user representations was not formulated by Akrich. However, this methods shows similarities with "feedback on experience " (Akrich, 1995). The methods have in common that real users' feedback information about real-life situations. But differ in the sense that the 'feedback' is used directly by the developers to eventually improve a product. Here the 'complains' serve more as a base for clients to take action in a conflict and consult a third group, in this case ECS.

> *"A list of complaints is something you cannot ignore [...] Usually, I will have a quick look at the list, but I try to approach problem from the perspective of functional needs. […] I am not going to ask 'how do you use it?'."(E.Wissink).*

It seems that the package of complaints is handed over to ECS researchers as a sort of evidence for the conflict that cannot be neglected. But the complaints are hardly consulted during research. Furthermore they have in common that the information of users' side is filtered. For 'using complaint' i.e. may apply that users are pressed for specifics by means of surveys and may only tell those issues that they consider relevant.

> *"In proportion to good stuff, we observe more bad things, because the good things won't return to us."(E.Wissink)*

[22] ECS researchers usually research the situation by studying the technical set up of the building and find logical causes why the particular situation does not match the expectations of residents and provide recommendations to improve the current situation.

Moreover, the body that collects and organizes the complaints can filter only that users' information that is relevant to their opinion. In short, the complaint lists are manipulated. Nevertheless, the complaints are derived from actual resident about real life situation, the methods 'using complaints' can be categorized as an explicit method.

All interviewed ECS researchers used at least once complaints to picture real users. The complaint legitimizes consulting research activities. Furthermore, the interests of ECS clients make the lists relevant. Complains are considered as the only official link with real users:

> *"An official list with complaints is the foundation [...] without such lists, people become not involved in our research." (E.Wissink)*

The formal base of the complaint lists makes that the ECS researcher can refer officially to the complaints as being representative for users. The complaints of users have to be interpreted by researchers. In this way, these interpretations contribute to a 'mental model' of the user which is based on researchers' interpretations of complaining real users' experiences of the workings of technologies. Taken together, 'using complaints' may be a powerful method in ECS research, however it was not mentioned as much as the former methods to exemplify user representations. Therefore, this final observed method is considered as potentially influential method in ECS research.

4.2.2 ARTICULATION OF THREE USER REPRESENTATIONS

Which user representations are articulated via the methods elaborated above? This second sub section presents three specific user representations that are produced through the four methods. The user representations of the 'standardized user', the 'smart user' and the 'incompetent user' are defined below.

THE STANDARDIZED USER

The first user representation that was observed in the logics of researchers is the 'standardized user'. The 'standardized user' is generated through the method 'standardization'. The 'standardized user' is a conceptually molded version of users that fits with the ECS research principles. Because the term 'user' in standards usually represents a large and highly heterogeneous group of people (Feng, 2005), it is difficult to point to a specific group of people as key stakeholders. The heterogeneous group of users and their capricious behavior and needs are represented by means of one consistent and uniform representation of the standardized user in ECS research practice. Using standards was identified as a common and influential way to generate user representations in ECS research division. Therefore, the resulting 'standardized user' may be considered as a common and influential user representation in ECS research.

The researchers motivate that the 'standardized user' allows them to articulate and define users in interaction with indoor climate systems. The two examples imply how variation and diversity of user behavior and needs are reduced what is supposed to be appropriate in interaction with indoor climate systems:

> *Eight o'clock breakfast, nine o'clock leave home, and back at five o clock. According to the standard, people leave their windows closed [in the meantime]. "(P. Jacobs)*

> *"[In standards is recorded that when people have] controlled ventilation, they will not open their windows in winter."(E.Wissink)*

It appears that the 'standardize user' serves as a theoretical guideline for social considerations, which prescribes heterogeneous users behavior and their average preferences. One ECS researcher described in a discussion the formula behind the 'standardized user' as a 'the sum of good use and behavior and average preferences'. This representation suits the type of research done at the ECS department because it ensures researchers with quantitative values for users. The 'standardized user' helps researchers to focus on the technical side of research and discourages to investigate actual users. But the 'standardized user' is far from perfect: It is abstract user representation with an over simplified behavior and preferences. This representation fails to convey the diverse needs and desires of 'real' heterogeneous users.

THE SMART USER

The second user representation that is present in the ECS research domain is named the 'smart user'. The 'smart user' follows from the 'I-methodology'. By means of the I-methodology, individual researchers form empirically their own 'mental model' of a 'smart user' based on their personal experience. The individual mental models of smart users share typical characteristics. The shared characteristics of the mental models of the 'smart user may be considered as the user representation of the 'smart user' that is present in ECS department. The 'I-methodology' was determined as common and strong for bringing in real users into ECS research. Therefore, the user representation of the 'smart user' is likely to be influential, however cannot be justified of a formal base because it is empirically formed by ECS researchers.

By using the 'I-methodology', ECS researchers consider their own expert assessment of the indoor climate as a measure of how end-user will think of it. An example was provided by Jacobs, one of the researchers: He is involved with a community platform for house owners who have the ambition to (re)build their house into a zero-energy house. This platform facilitates energy-pioneers to meet and exchange experiences. Energy efficiency, saving money, and increasing comfort are important motivations for the house owners to improve their homes. Jacobs seeks actively as a user for innovative improvement possibilities in his own house and shares and discusses his ideas with the other house owners via the platform. Jacobs actively uses this private experience as input at his ECS work and he is not the only one. Also the other three ECS researchers told about their home improvements. One of them showed pictures of his housing projects, another researcher provided excel sheets with energy saving calculations and the third reported about the comfort problems he had solved at home by replacing systems. These personal experiences allow ECS researchers to motivate the representation of a 'smart user': a user that behaves 'smart' in interaction with indoor climate systems.

A smart user is characterized by possessing technical knowledge and skills that are required for good interactions with indoor climate systems. Although that the interviewed ECS researchers do not literally say so, to my experience researchers consider *technical* as *good*. This is more concrete highlighted in TNO article *bedieningsgemak: luxe of noodzaak?* In this article explains Spiekman(2010) deviant user behavior with indoor climate systems by highlighting differences between the 'mental models' of users and engineers. Without going too much into detail, in this article are developers and engineers characterized as having a mental model that is based on technical understandings of the world. In contrast to users, which are characterized with a mental model that is based on their own experience and perception. In parentheses mentions this article that the *technical* mental model is *right* model, as well as that users' model may deviate from the "right" model of engineers. To my opinion, it seems that *the technical outlook* (or skills, approaches etc.) towards interactions with technology is considered as being *the best understanding* among other options underlies also the reasoning of researchers during research process.

They seem to consider that technical understandings results in appropriate skills and attitudes that are required for, as frequently mentioned by ECS researchers, 'logical' and 'rational' interactions. The researchers motivate that logical and rational interactions can be controlled and result in predictable outcomes. They motivate that they are in charge to control and predict the efficiency results of technologies and therefore rational and logical interactions are considered as good in their logics.

Also typical is that the smart user explores actively the indoor situation for improvements that reduce energy, and so comes across many innovative possibilities in use. Main motivations for innovation at home are foreseen benefit to save energy or money and increased level of comfort. In my view, ECS researchers consider that as ideal because it underlines the dual research goal of energy efficiency and comfort increase. The 'smart user' does not just behave good with indoor climate systems, but moreover improves the situation in such way that it has a supposed positive effect on the energy and comfort performance of indoor climate systems. The 'smart' user stimulates core research goals of ECS.

The 'smart user' representation shows similarities with 'lead users', a term introduced by Eric Von Hippel (1986). Lead users are real users who "are ahead of the majority of users in their populations with respect to an important market trend", and "they expect to gain relatively high benefits from a solution to the needs they have encountered there"(Von Hippel, 2005, p. 4). Lead users can be seen as pioneers that may discover new needs of general interest and they are strongly encouraged to create innovative solutions that suit their own needs.

These characteristics of lead users also yield for ECS researchers. They investigate their own indoor climate situation at home and improve it with creative solutions that satisfy their own need, these solutions should be beneficial to many in future. These lead user characteristic become via mental modelling of researchers embedded in the smart user representation.

The logics of researchers seem to underlie that they find it promising as they (as lead users) are professionally involved in innovative research on indoor climate systems. However, when ECS researchers implying themselves (as being lead users) as potential smart users is also complicating, because it leads to a one sided user image in research practice. The I-methodology leads always to a representation of a user that mismatches with other real users on the level of knowledge and skills. This mismatch underlies the reflections of researchers about users during the research process and their drive for energy efficiency and comfort considerations.

The incompetent user

The third user representation observed in the logics of researchers can be labeled as the 'incompetent user'. The core of the 'incompetent user' representation is that this type user is not able to handle indoor climate systems in a good way. This means, in line with the underlying research principles behind this representation, that seen from a technical point of view of researchers, users interact irrational with technology. This user representation is generated through 'referring to family members' and 'using complaints'. So, the 'incompetent user' is partly formed empirically by individual researchers and partly based on official grounds. The methods 'referring to family members' was recognized as less influential than 'standardization' and 'I-methodology' in generating user representations, and 'using complaints' as potentially powerful. Therefore, the resulting user representation of the 'incompetent user' should be less dominant than the 'standardized' and 'smart' user representations in the logics of research.

ECS researchers consider the representation of the 'incompetent user' as a measure of how typical lay people behave in a bad way with indoor climate systems.

Despite that the situation is technically correct, the user complains. In that case you have to find out if just that person is at the wrong place, or that everybody in the neighborhood complains. Is it a logical complain? […] But then, it appears that the person is frustrated and dissatisfied because of incorrect use of the system."(E.Wissink)

Core principles of research allow ECS researchers to focus on the technical side of user-technology interactions: they give priority to technology and its efficient operation. They reasons unconsciously that nothing is wrong with technology, seen from a technical point of view, but that the error should be at the side of users of the context in which interactions take place. The logics behind this more contextual kind of research activities are that researchers assume that users do something technically wrong in cases of conflicts with technology in use.

When the ECS researchers use complaints or refer to -mostly female- family members to exemplify users, they focus on incompetent use behavior. Typical remarks about incompetent use behavior are: 'my wife cannot set the thermostat properly', my mother opens windows while it is not necessary', 'those households do not maintain the system correctly', and 'those elderly cannot deal with the interface'. In line of the research principles, users that play a role in these kind comments do not interact efficient or rational with technology and confirm the assumption of researchers that users do something technically wrong in cases of conflicts.

Furthermore, ECS researchers believe that the incompetent users are barely interested in technological development and do not move along with innovation:

"Systems improve continue, and eh, users do not move along [with technical progress]. "(E.Wissink)

"More and more new features are built in […] But in terms of new features, residents still live in the Middle Ages." (R.Brand)

Incompetent users have difficulties with adjusting their habits to new technologies. This is difficult to reconcile for researchers with their own logics. One researcher reasons that these type of bad habits are similar to the habit of smoking:

"ja ja, users ... [...] It's actually comparable with smoking. Everyone knows already for a long time that it is not good, but just recently people begin to quit smoking."(P.Jacobs)

In his reasoning he implies that everyone, including the users themselves, should know better. According to him it is for users own good to get rid of bad habits like disinterest in and refusal to comply with technology. For him it seems incomprehensible that it takes generations to change. The anticipated characteristics of incompetent users form a strong mismatch with the logics of research.

The researchers seem to agree that incompetent use behavior is a result of a lack of understanding.

"The lack of knowledge brings the user in a position that he or she acts in certain ways, which the developer probably did not thought about.[…] That is just the whole principle with understanding [technology], and it just does not happens with users. "(R.Brand)

In line with their research principles, they aim at a specific kind of understanding: incompetent users lack technical capabilities[23]. Therefore, researchers reason that 'incompetent' characteristics are inappropriate during research process.

[23] Although that the interviewed researchers do not explicit mention what kind of knowledge incompetent users miss, this was more explicit formulated in the article of Spiekman (2010) that was highlight in the part about smart users. In this article was described that users form their mental model based earlier on experiences and this deviates most of the time from the correct 'technical' mental model of engineers. The incompetent user representation is very often about woman and residents that complain and are always linked a lack of understanding about the working of technologies. This representation of users is a-technical, and to my opinion, the researchers suppose that incompetent users therefore misses

The ‘incompetent’ user representation seems to be an implicit element in the ECS research process, since research is focused on indoor climate products that are meant to be used by ‘everybody’, both male and female users, as well as technical and technical users. Real users of the type ‘incompetent users’ are not involved in the ECS research process – an environment that is highly dominated by technical competent male researchers. However, representations of incompetent users are present in the research practice of ECS. The representations are present in the researchers’ gender stereotypes and technical biases towards interactions with technology. In their reasoning the technical biased and gendered representation of the user is merely invoked by ECS researchers as constraints to be ignored in ECS research process. Because the ‘technical shortcomings of the ‘incompetent user’ results in irrational and illogical behavior, which is difficult to reconcile with their own logics. The underling difficulty is that ECS researchers cannot control or predict incompetent behavior and therefore cannot calculate the behavioral effects on the performance of indoor climate systems.
As with the ‘standardized user’, this representation too fails to convey the needs and desires that ‘real’ lay people have for indoor climate systems. Taken together, this last representation of ‘incompetent user’ also is characterized by a strong mismatch real users and it fails to take their preferences into account.

4.2.3 Role of user representations in design logics of ECS research process

This third sub section presents in which way of the three user representations are scripted in the design logics of ECS research process.

‘Standardized user’ representation as obvious and official tool for heterogeneous users

ECS researchers demonstrate a taken for granted attitude towards ‘standardization’, the methods for generating the ‘standardized user’.

> *“You cannot easily observe human behavior [...] that is why we turn to simulation and calculation.” (J.E.Scholten)*

Using standards as source for information about users is obvious in the ECS research domain, and thus is its resulting user representation. The ‘standardized user’ is not only present via standards, but also in common research applications that are based on these standards, such as simulations and models. ECS researchers consider standardization as ‘professional’ and ‘official’ way to represent users. Furthermore, the researchers argue that the standardized user ensures them with quantitative values for all kinds of users. Quantitative data is seen as a prerequisite for doing technical research on the energy performance of indoor climate systems.

> *“What we need are solid facts and strict values […] that is what is required for the measurements." (E.Wissink)*

ECS researchers prefer the ‘standardized user’ above real users in technical research. They suggest that real users would disturb technical measurements by bringing in too much variation, but that the ‘standardized user’ allows them to deal with users in a systematic way. This is in line with core research principles of the ECS research domain. The researchers described the ‘standardized user’ as ‘reliable’ and ‘trustworthy’ because it helps to gather accurate data about technical performance of

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the right knowledge, skills and attitudes that the researchers consider appropriate for interactions with indoor climate installations.

indoor climate systems and calculate energy consumption of the system. Clearly the ECS researchers value the 'standardized user' as an appropriate user representation for the ECS domain.

The 'standardized user' is not so much seen as a type of real user, but merely as an official tool to bring in the heterogeneous user into research. It is a means to treat heterogeneous users as a function of indoor climate systems. The 'standardized user' allow researchers to realize one of their main technical goals: to gather accurate data about users' preferences and behavior that is required for the *technical performance* of indoor climate systems in experimental setting. This is one of the core principles of the research. The 'standardized user' is embedded in standards and also incorporated in the technical applications in ECS research setting and is therefore inscribed as a dominant tool to represent the heterogeneous user in the design logics of ECS research.

DUAL ROLE FOR RESEARCHERS VIA THE 'SMART USER'

ECS researchers seem to embrace the 'smart' user' in the ECS domain. This user representation is brought into the research arena by means of the I-methodology: researchers rely on their own personal experience to represent potential users. The researchers approach the 'smart user' in a positive way: they use words like 'good', 'correct', 'best way', 'clever' to describe smart use. This gives me the impression that the 'smart user' is welcome in the ECS research domain.

By bringing in the 'smart user' representation, ECS actors script for themselves a dual role in research setting. Their dual role becomes that of 'ECS researcher' and at the same time 'expert user'. The actors are, as ECS researchers, involved in the technical development at work, and at the same time, as expert users, involved in daily use situations at home. In test setting, for example, researchers bring in the 'smart user' as a measure of how users will deal with indoor climate systems.

> *"During experiments, we assume that people deal in an intelligent way with the devices out of convenience."(P.Jacobs)*

The researchers mobilize their own smart user experiences, as a sort of encouragement to support intelligent use. In doing so, they inscribe unconsciously their own masculine and technical biased interests on future users in research process. In addition they use these as an argument of how users are supposed to behave smart with indoor climate systems. The dual role makes it difficult for researchers "to realize that the smart relation to the product at stake is different form the way the majority of end-users perceive it from their own context (Jelsma, 2005, p. 79)". Nevertheless, the inscribed dual role of ECS researchers in ECS research process appears unconsciously as normal logic

'INCOMPETENT USER' AS ARGUMENT TO KEEP TECHNICAL INCOMPETENT USERS AT DISTANCE

The researchers have a negative approach towards incompetent users. ECS Researchers do not seem to favor to inscribe direct user involvement of this type of users in research process. They mentioned about user involvement that 'user research is too expensive', 'users are too impulsive', 'users have a negative impact on the functioning of the systems', and 'when users are involved it is difficult to get precise results'. Furthermore, they demonstrated a skeptical attitude towards users of the user representation 'incompetent user'. During interviews they regularly made comments like: 'it is impossible for users to do it right', 'users just do whatever they want to do', they often do something without any intention'.

Researchers agree that is difficult to work accurately with real users and make reliable predictions in regard to the performance of indoor climate systems. It appears that it is not easy for researchers to deal with users and realize goals in ECS research setting. In practice, the 'incompetent user' is inscribed in ECS research process as an argument to keep (all) real users at distance in research. They utter about incompetent users as constraints to the technical performance of systems that be ignored during research. Incompetent users are not much consulted as they are, but rather are invoked by ECS researchers via female relatives or complaining users. The incompetent user's representation is present the technical bias and gender stereotypes that are (re)produced in the ECS research domain. The researchers' image of users represents only a selective set of competences, interests, attitudes and values that are inappropriate in interaction with the technical performance of indoor climate systems. These images of users are on purpose "outscribed" of ECS research process.

This approach becomes problematic when ECS research process regarding on indoor climate technologies mirrors the exclusion of technologically incompetent women and other laymen users; and at the same time the research assumption is that the systems under investigation will be used by 'everybody' in the future, without taking notice of the gender and other incapability's. Given the heterogeneity of users, when ECS researchers privilege consciously or unconsciously the user representation of the smart user over incompetent user, in future certain users have to work harder than others to interact with indoor climate technologies and make the use of those technologies comfortable to them.

SUMMARY

This section was concerned with user representation in 'Energy and Comfort Systems'-research on indoor climate systems. Users are not involved in directly according to ECS researchers. Nevertheless they exemplified intended users during interviews. These examples about users in interviews served as main sources. These were analyzed on the generation, articulation and the role of specific user representations in the ECS domain.

An inventory of methods that ECS researchers use to envision intended users was drawn up. The four methods were analyzed in line with Akrich research about user representations (1995). Three implicit techniques were observed: 'I-methodology', 'referring to family members' and 'standardization'. The first two methods support ECS researcher to address empirically themselves and family members as spokespersons for real users, but lack any formal base. Standards are put forward in the name of 'typical' use behavior and average preferences, and can be justified on the base of scientific research. Also one explicit method was identified: 'using complaints'. 'Typical' complaints are provided by people deemed to be representative of real-life users and have an official feedback information status.

Only one of the four methods observed among ECS researchers was previous expressed by Akrich. She formulated the 'I-methodology' (1995). The method of 'standardization' was already described in work of Jelsma (2005) . The other two methods may be added to her record of user representation techniques. Need to note that 'referring to family members' was observed by Patrick Feng (2005), but he did not formulated it as a method yet in his work. 'Using complaints' seems to be a remarkable method in ECS research.

The four methods for generating user representations do not have similar influence in the ECS domain. 'Standardization' seems to have a taken for granted status, and is most powerful. The second most influential technique is the 'I-methodology'. The other two methods seem to be less dominant. This is in line with Akrich's argument (1995) in which she considers that implicit methods seem to be more dominant than explicit ones.

The methods are employed by ECS researchers to develop, promote and impose user representations. Three specific user representations are articulated. The first user representation of the 'standardized user' is a result of the method 'standardization'. The standardized user is a conceptually molded user defined as (re)producible parameters that represents use behavior and

preferences of heterogeneous people. The researchers expressed a taken for granted attitude towards this ‘neutral’ user representation. Furthermore, it is an authorized representation for heterogeneous users in ECS department.
The second user representation ‘smart user’, is generated through the ‘I-methodology’. This user representation allows ECS researcher to use their own technical, explorative and innovative experience of daily situations into experimental setting. The researchers are highly positive about this user representation. Although that ‘the smart user’ is formed empirically, it is nevertheless a common and powerful user representation too. Especially, because hardly any other options are available to bring real end-users into the ECS research domain.
The third user representation of the ‘incompetent user’ is produced by a mixture of ‘referring to family members’ and ‘using complaints’. This representation is built upon on empirical and formal base and stands for technically incompetent lay people. This user representation is based on gender stereotypes that are reproduced in ECS research practice and technical biased. The ‘incompetent user’ is considered as unpredictable in research on indoor climate systems and approached in a negative way. This third user representation is the least influential in technical ECS research.

Each user representation is scripted in a different way into ECS research process. The role of the user representation depends largely on how it fits with the research goal to gathering accurate data on technical performance of indoor climate systems. The ‘standardized user’ is inscripted as an official tool to incorporate heterogeneous users into ECS research. The standardized user serves as a neutral theoretical guideline for the ‘users as a function’ of indoor climate systems. The ‘standardized’ user is not only embed in standards and but also in practical applications in technical research setting. The ‘standardized user’ is a dominant device to incorporate users as a function of indoor climate system in ECS research. This user representation is extremely suitable for the technical kind of research done in the ECS domain.
The other two representations of users are not so much pre-defined entities like the ‘standardized user’, but rather things to be defined and mobilized in support of one side or another (Latour, 1987).
The term ‘user’ is a malleable term that is mobilized by researcher in their attempts to investigate indoor climate systems that should serve ‘everybody’. The ‘smart’ and ‘incompetent’ user representations are invoked respectively to support users as useful sources for inspirations or as constraints to be ignored in research.
These two representations are built up from the experiences of the ECS researchers active in the technical research on indoor climate systems. These images of users seem to suffer from a systematic bias; they are biased towards a technical understanding of the indoor climate systems of ECS researchers. Furthermore, the user representations are based on stereotypes about technically incompetent women and complaining laymen users.
The ‘smart user’ scripts a dual role for ECS actors: they are researchers and expert users in research process. The ‘smart user’ is easy accessible and also convenient in order to operate a system correctly and benefits its performance. ‘Smart’ behavior and skills are promoted in ECS experiments. At the same time, the ‘incompetent user’ is scripted as a logical argument to keep common technically incompetent people at distance in technical research, because their influence on the performance on indoor climate systems is unpredictable. Incompetent users are in conflict with the research principles of ECS. So, wishes and desires of the majority of ‘real’ users are “scribed out” of the ECS research process. This approach leads to the research practice in which choices becomes attuned to the interests and skills of - mostly male -technical competent researchers, rather than

women or complaining residents groups. This makes it later difficult for 'everybody' to interact in comfortable ways with indoor climate systems.

4.3 Construction of comfort

This section elaborates on the sub question *how 'comfort' regarding indoor climate is constructed in 'Energy and Comfort System'- research on indoor climate systems?* The answer to this question should give the reader and insight into what ECS researchers perceive as reality for a comfortable indoor climate. This is relevant to appreciate how a comfortable indoor climate is inscribed into ECS research process. This construction of 'comfort' of ECS researchers will be compared later with the users' construction of 'comfort' regarding the indoor climate at home.

For the inquiry on the construction of 'comfort' in the ECS research domain, empirical data was analyzed. The interviews and some core documents, were studied with the aim to identify work-related ideas and opinions of ECS researchers about terms like 'comfort', 'indoor environment', and 'comfortable indoor climate inside a building'; how they understand and give meaning to 'comfort' in research on indoor climate systems, and what (kind of) definitions and materialized concepts of 'comfort' are available and used in the ECS research domain. These findings together give insight in how comfort is constructed in the indoor climate and embedded in the research on indoor climate systems.

Throughout the preparations of the study about the ECS research domain, several actors highlighted that the 'indoor environment' is approached and researched differently on the locations in Delft and Apeldoorn. Therefore, it seemed relevant to take these differences into account for the construction of 'comfort'. During the interviews were the ECS researchers explicitly questioned about their opinions about the research practice in Delft and Apeldoorn and the differences between the locations regarding 'comfort' and 'indoor environment'.

At the beginning of the actual interviews, the researchers gave their own interpretation of 'comfort'. These were all more or less general interpretations of 'comfort' and served as a basis for the remainder of the conversation. However, the more we spoke in-depth about their research activities, the more detailed and concrete they articulated about what notion of 'comfort' actually is inscribed in research. Thus although, researchers usually gave one interpretation, more specific interpretations of comfort could be identified.

This subsection is structured into three parts. Subsection 4.3.1 presents three interpretations of 'comfort' and deals with supposed differences between Apeldoorn and Delft. Subsection 4.3.2 elaborates on the construction of comfort in the ECS research domain. Subsection **Error! Reference source not found.** summarized the constructions of comfort that are inscribed in the design logic of ECS research process.

4.3.1 Three interpretations of 'comfort'

This sub section presents three interpretations of comfort that were observed in the ECS research practice. On questions like 'What does 'comfort' mean in research setting', the researchers replied with a general interpretation of *comfort as human experience of conditions inside a house.* This interpretation was given explicitly by the researchers themselves. However, during the analysis of the interviews, two more specific implied interpretations could be observed. These are: *comfort as experience that can be regulated with technology,* and *comfort as function of indoor climate systems.* The three understandings are defined below.

General interpretation of comfort as 'human experience of the conditions inside a house'

The first interpretation of comfort, regarding the indoor climate, which is observed among ECS researcher can be defined as 'the comfort experience of the indoor climate'. This is a general understanding of comfort that ECS researchers explain as 'how people perceive the conditions inside of a room or house'. Thus they interpret the concept of 'comfort' here as a subject-bound experience. Similar understandings are present in documents provided by ECS researchers, for example in a handbook for engineers (Van Tol, 1986): 'the conditions that a human being 'senses' or 'experiences' in his or her environment and which serve as criteria to review a room as being comfortable (or not)'[24].

The researchers from Apeldoorn and Delft differ in their opinions about what relevant 'indoor conditions' are. They are conscious about the differences and all needed to clarify what they consider as indoor conditions. Apeldoorn researchers sum up conditions that people experience like: physical layout and material buildup of the house; building related systems; indoor conditions as temperature, draft and humidity; the use of the systems; activity level of people and their clothing. Delft researchers also mention these conditions, but include more, like: interior and furnishings; indoor conditions like dust, odor, sound, lighting, viruses; age of people; personal needs and desires; upbringing; cultural traditions.

To my opinion the meaning of 'indoor conditions' differs between Apeldoorn and Delft. This can be explained by their previous research focus and areas. Before the merger, Apeldoorn was concerned with 'indoor climate' whereas Delft was occupied with 'indoor environment'. 'Indoor climate' is focused on only climatic conditions, whereas 'indoor environment' includes the climatic conditions and other environmental circumstances. The 'indoor environment' is a thus a broader approach to the inside conditions in a room or building.

Thus, the researchers share the general interpretation of comfort as a human experience of the conditions inside a room or house, but Delft and Apeldoorn researchers differ about the meaning of indoor conditions of this general interpretation, due to previous research scopes. Because of explicit different views on indoor conditions between Delft and Apeldoorn, I have the impression that researchers consider that they are involved with different kind of research in Delft and Apeldoorn.

In my experience, this general interpretation of comfort of *comfort as human experience of conditions inside a house* is mainly used in conversations. In particular in the type of conversations that do not need a specific definition of comfort, like casual chats between ECS researchers; social talks that ECS researchers have about their work with lay people, or more work related discussions with i.e. clients, which does not require going too much in detail about comfort. In such kind conversations the ECS researchers use this more shallow indefinite human oriented understanding of comfort that is easy to understand for others.

Specific interpretation of comfort as 'an experience that can be regulated with technology'

The second interpretation of comfort that could be identified may be defined as 'comfort experience that can be regulated with indoor climate systems'. This interpretation builds upon the former more general interpretation of comfort. The ECS researchers share the idea that the 'human experience of a room or house' can be increased when indoor climate systems improve the indoor conditions. Although that the researchers from Delft and Apeldoorn consider different indoor conditions on a

[24] The original Dutch definition of 'comfort'provided in the handbook is: "de condities die de mens in zijn omgeving 'voelt' of 'ervaart' en die als criteria dienen ter beoordeling van de behaaglijkheid van een ruimte" (Van Tol, 1986, p. 157).

general level, in this more specific interpretation of comfort exist agreement about the kind of indoor conditions: *climatic conditions*. Despite little variation between Apeldoorn and Delft, all researchers sum up the most important ones as: *temperature, air circulations, humidity and compositions of air.* The ESC researchers seem to agree on the assumption that when these indoor climate conditions are in proper balance, the indoor climate will be experienced as comfortable.

All ECS researchers consider that the 'comfort experience of indoor climate conditions' can be controlled with technical devices. Their focus is on technological devices rather than on the human experience:

> *"Binnenklimaat Installaties kunnen de condities van het binnenklimaat beïnvloeden, veranderen. Zo heb je de mogelijkheid om bijvoorbeeld de temperatuur te manipuleren en te controleren" (E.Wissink).*

ESR researchers argue that indoor climate technology needs to serve a comfortable indoor climate.

> *"Je kunt zeggen, installatietechniek is er ten dienste van het bereiken van een acceptabel binnenklimaat, in de praktijk betekent dat een installatie moet voldoen aan, in staat moet zijn om een bepaalde temperatuur te produceren" (R. Brand)*

ESC researchers mean that indoor climate conditions can be controlled with technological devices so that (a level of) comfort may be accomplished.

This understanding of comfort as something that can be regulated, is similar to the notion 'comfort as achievement' that was introduced by the sociologist Elisabeth Shove (2003). Shove states that 'comfort as achievement', "has to do with things, conditions and circumstances"(2003, p. 24). The sociologist emphasizes the physical turn that is given to comfort and explains that comfort is understood as an object-bound concept. This understanding of comfort implies, according to Shove, that technology can improve human well-being. The interpretation of 'comfort as achievement' corresponds with researchers' understandings that indoor climate systems can regulate human comfort. The improvement of comfort of users is thus considered a *technical achievement.*

This specific interpretation of comfort is used in discussions about research. These discussions are especially work-related and are often highly technical in nature. Although social factors play a role in such discussions, it seems to me that the decisions should be based solely on 'technical' considerations. Such technical discussions require a more precise description than the more social talks.

Whereas it on general level appears that the researchers seem to suppose that they are involved with different kind of comfort research because of focus on different indoor conditions, this more specific interpretation of comfort -which highlights climatic conditions- contradicts this idea. When researchers speak more *technically* about their work, their ideas and views appear quite similar to me. Therefore, at first sight it appears that researchers are involved in distinctively different research activities on comfort in Delft and Apeldoorn, but these seem to vanish when research becomes more technical.

PRACTICAL INTERPRETATION OF COMFORT AS 'FUNCTION OF TECHNOLOGY'

The third interpretation of comfort that was observed in ECS research practice can be described specific as 'comfort as a function of indoor climate systems'. This is the more practical application the second interpretation that the comfort experience can be regulated by means of technology. Standards play an important role in the operationalization of the concept of comfort as a function. Using standards allows ECS researcher to interpret comfort as a function of indoor climate systems.

The next quote gives an example of how that 'comfort' corresponds with the function of rapid available hot water.

> *"Ja, als dat met een cv ketel op zolder wordt gedaan, dan komt het er gewoon uit dat je heel veel water verbruikt, een deel van de warmte in de leidingen blijft zitten en dat de ketel qua comfort slecht presteert omdat je langer moet wachten op de warmte" (E.Wissink)*

The second quote indicates comfort can also be located in a house, by means of building related systems that can regulate indoor climate conditions.

> *"Wij kunnen helpen om de situatie, woning of systeem zo aan te passen dat de juiste omstandigheden worden aangeboden. Dat het automatisch in de woning ingebakken zit. In een nieuwbouwwoning heb je automatisch al comfort, omdat daar nieuwe voorzieningen aanwezig zijn" (P.Jacobs).*

In these examples is 'comfort' translated into as 'rapid hot water available' or 'provision of appropriate conditions' and understood as a function of a house or technology.

The interpretation of comfort as 'function of technology' is similar to what Shove (2003) termed as 'comfort as attribute'. Shove explains about the application of standards, when these are used "with a purpose of achieving conditions of comfort, [this] suggest[s] that comfort exist independent of the mind or means by which the conditions are produced" (2003, p. 24). Standards allow the ECS researchers so to say to treat human needs as feature of indoor climate systems. Jelsma (2005, p. 77) agrees with Shove, when he points out that 'comfort as attribute' can be understood as "located in technology as a function".

This last concept of comfort as a function of indoor climate systems is dominant in ECS research. Because, as Shove states it, once 'comfort' is "understood as attribute of technology, it makes sense for designers to enhance this feature" (2003, p. 24). That is precisely one of the core activities of all ECS researchers: manipulating and monitoring the build in comfort-function of indoor climate systems (or buildings).

The interpretation of comfort as 'comfort as function of indoor climate systems' is used in technical ECS research activities. These research activities include calculations, simulations, modelling, and functional testing and are highly technical in nature. Standards and other research tools play an important role in such activities. These are used for the practical application of the comfort function in ECS research. All researchers make use of comparable standards and research tools that are required for the investigation of the indoor climate of a house or indoor climate systems. The application of these research devices make that all researchers in both Apeldoorn and Delft use the same normalized interpretation of 'comfort as function of indoor climate systems' in the end.

4.3.2 Normalization of 'thermal comfort' as 'the function of technology'

This second sub section presents the normalization of the concept of comfort as *comfort as function of indoor climate systems.* This concept needs to be operationalized for technical ECS research. Comfort is applied in normalized manner in the ECS research domain by means of standards. An example of a comfort standards is ASHRAE standard 55 'Thermal Environment Conditions for Human Occupancy', but also other (inter)national authorized standards are used by ECS researchers. The diverse standards differ in minor details, but share the underlying preferences and assumptions of thermal comfort research. The use of thermal comfort standards ensure that a particular meaning of comfort prevails in the ECS domain and becomes embedded in ECS research.

The application of thermal comfort standards has as result that the meaning of the function of comfort can be defined as 'thermal comfort'. 'Thermal comfort' is defined as ´that condition of mind which expresses satisfaction with the thermal environment" (Fanger, 1970, p. 1). In this definition, comfort is reduced to thermal conditions.

According to the ECS researchers, several conditions impact thermal comfort. However in the ECS practice are just a few variables of main interest: air temperature, radiant temperature, air circulation and humidity. All interviewed researcher agree that temperature is the most important one:

> *"[...]De binnentemperatuur is bijna in 80 procent de indicator, Als het gaat om het karakteriseren van het binnenklimaat. Op het moment dat de vraagstelling wat dieper is, komt daar de vochtigheidsgraad en stralingstemperatuur bij." (R.Brand)*

> *"Het binnenklimaat, ja, als je dat absoluut bekijkt, gaat het om de temperatuur en een beetje luchtvochtigheid. [...]Als de temperatuur binnen een bepaalde range valt, bijvoorbeeld de temperatuur van 18 tot 22 graden wordt als aangenaam ervaren voor een kantoor, ligt het erbuiten, dan neemt het aantal klachten toe" (E.Wissink).*

Thus thermal comfort as a function of technology highlights mainly temperature and a few other climatic conditions in ECS research domain.

In standard is comfort normalized, which goes hand in hand with emphasizing certain preferences and assumptions. A few of these assumptions are presented here. In standards are the thermal conditions encrypted as universal necessary conditions for optimal comfort. This means that existing individual and cultural preferences and needs for comfortable temperature and a few other climatic conditions are standardized. By the application of thermal comfort norms, the researchers assume that human comfort needs are uniform in ECS research domain. Furthermore in standards are the thermal conditions like temperature are specified and quantified into abstract (re)settable parameters for comfort in standards. When researchers use resettable parameters, ECS research emphasizes the quantification of comfort, instead of the qualification of comfort. Also using thermal comfort to define users' needs and preferences for comfort as function of a technology makes that users essentially are constrained or constructed as passive recipients of thermal stimuli (Shove, 2003). This is also the case in ECS research domain. Finally, parameters may give the impression that comfort can be fine-tuned. This allows ECS researcher to manipulate and control comfort and makes possible to make predictions in technical research.

SUMMARY

This section was concerned with the construction of comfort regarding the indoor climate in 'Energy and comfort Systems'-research. Three interpretation interpretations of comfort were observed: *comfort as human experience of the conditions inside the house; comfort as experience that can be regulated with technology*; and *comfort as function of indoor climate systems.* The three interpretations are closely related and range up from a general view up to a concrete concept. The understandings do not only rise from a general view up to a concrete concept, but the applications of the three understandings also climb up from merely social talk to technical research. The more specific the interpretation of comfort, and the more 'technical' its application, the more researchers share one and the same construction of comfort in ECS research. This construction of comfort is 'thermal comfort' as function of technology'.

Although researchers from Delft and Apeldoorn seem at to believe that they approach comfort in different ways, this only holds for a general level, at the core of technical research work, they all use similar same constructions of comfort. The main reason that researchers make use of the same or at least similar constructions of comfort - despite supposed differences- is that that they all use standards and research tools based on standards in technical research activities. 'Comfort' in standards is strictly defined and gives no room for own interpretation.

The researchers use standards to implement the function of 'comfort' in technical research. Due to standardization, comfort is inscribed in normalized way in the ECS research proces. Furthermore, the content of thermal comfort standards becomes representative for the meaning of comfort. In the content of thermal comfort standards is the meaning comfort narrowed down a concrete definition: the condition of the mind which expressed satisfaction with thermal environment. In this definition, the term 'thermal environment' refers predominantly to climatic conditions and some other variables. In ECS research practice, temperature is the most important climatic condition. Also air circulation, humidity and composition of air are studied but other variables or climatic conditions are rarely taken into account. Moreover 'normalized comfort' as function of technology goes hand in hand with assumptions like: universal user needs and preferences; users as passive recipients; quantification of comfortable indoor climate environment; and comfort as resettable parameters that can be fine-tuned. The construction of comfort as 'thermal comfort as function of technology' produces a simplified picture of users' comfort needs and preferences for the indoor climate in the environment.

Since indoor climatic systems should meet standards, it is likely that similar notions of comfort are inscribed actively by the producers of the systems. Subsequently are these systems investigated in the light of the same standards in the ECS research domain, and thus evaluated on similar constructions of comfort. As a result, inscribed notions of indoor climate systems do not become visible in ECS research: ECS researchers do not critically question if the 'right' comfort notions are inscribed by the producers, but instead focus on the 'right' functioning of the inscribed comfort notions. Thus, inscribed notions of comfort pass the research domain, if the technical performance of the systems satisfies with the standards.

With the analysis of the construction of comfort became clear that standards are not only used to normalize user representation, but also for the normalization of the definition of comfort. The degree of standardization in technical research is high. Normalization of users and comfort is not only present in standards, but is also embedded in the technical research tools. Standardization seems to be extremely powerful and taken for granted as will be presented in the next subsection. The normalized representations of users and meaning of comfort are hardly questioned, taken for granted and become reproduced in ECS research domain.

4.4 Design logic behind using standards

This section provides an answer to the sub question: *which research logics lay behind 'user representation' and 'comfort construction' regarding the indoor climate in 'Energy and Comfort System–research?* The answer provides insight into the considerations of ECS that for the application of standards for users and comfort. The reasons of ECS researchers for standardization are relevant to understand the current situation as it is in regards to the physical (material) user representation of 'the standardized user' and the construction of comfort as 'normalized thermal comfort as a function of technology' in technical research.

Research logic can be defined as the logic behind the research process in which technologies are checked on their inscription. As such, it is the rationality behind a local research process. The concept of research logic is meant to cover the consistent whole of ideas, views, values and intentions in the research process of indoor climate technologies. Research logics are incorporated into the research practice in which technologies are evaluated. Research logic has it counterpart in the material world, which are i.e. research tools, schedules and texts. In this thesis study, research logic, is operationalized by looking at the motivations that the ECS researchers provide for using of standards - as being the physical representations of the normalized and standardized user comfort - in the research practice. The so called 'ECS research logics' do not become inscribed into indoor climate artifacts as design logic would according to Jelsma, but rather are incorporated into the technical research on technologies.

Later in this thesis will the 'ECS research logics' of indoor climate systems be compared with user logics. What makes research logics interesting for this thesis is, that it may be like design logics, which is logic in motion (Jelsma, 2005). It may change while developers struggle with resistance outside the scope of development of technology. Since ECS researchers wrestle with resistance outside the research lab, meaning that actual energy consumption of indoor climate systems in buildings deviates from calculated energy use in ECS research. In my interpretation of Jelsma's design logic applied to 'ECS research logic': this may be due to that 'ECS research logic' in the area of indoor climate systems clashes with user logics at home. To check 'ECS research logic' for inconsistencies of 'user logic' and provide recommendations to change 'ECS research logic' so that it better fits with user logic, may be an opening to solve the gap between anticipated and actual energy consumption. This will be discussed later in this thesis.

Here in this section, the consistent rationality of what is proceeding at the ECS research process on indoor climate systems at the work floor is presented. In the current research process are users and comfort included via standardization; and as 'the standardized user' and 'normalized definitions of comfort' incorporated into ECS technical research. The ECS rationality behind this research process is made visible during the in-depth interviews probing for their reasons and motivations to use standards. All these logical aspects are combined into a coherent research plan, which form the underlying logic on which the ECS research team agrees for using standards (and thus embedded 'standardized user' and normalized comfort definition).

This section consists of three parts. Subsection 4.4.1 presents the 'ECS research logics' on standardization. Then, subsection 4.4.2clarifies that the 'standardized user' and normalized comfort definitions are taken for granted in the 'ECS research logics'. Finally, subsection 4.5gives some conclusions and looks forward towards the study on users.

4.4.1 'ECS RESEARCH LOGICS' BEHIND USING STANDARDS

ECS researchers told that is not mandatory to use standards in order to represent users or comfort. But the researchers appear very reluctant to deviate from standardization and make use of other sources to include users and their comfort needs in ECS research. Six types of motivations are identified to apply standards in ECS research. These are presented below in random order.

A first type of motivation mentioned by ECS researchers is that standards are within close reach. Real users are hardly involved in research practice, and ECS researchers view usability tests as complicated and expensive. Standards are an easy alternative to consult for information about users. They merely have to take the information about users of the shelf. In the ECS domain standards are easily available and a practical solution to bring users into ECS research.

The second kind of motivation that ECS researchers gave was that they approach standards as a professional reference. They mean with 'professional' that standards are official, objective and have a scientific base. This 'professional' feature enables researchers that they can refer explicitly to standards in their work. This is important to gain recognition for their research in the broader world. Standards as a basis for ECS work give their research an authoritative status.

A third sort of reasoning is that standards are widely accepted. The content of standards is the result of earlier discussions that are closed now. The solutions are based on collective agreement and provided as common information:

> *"Waarom zou je nog discussie voeren, waarom zelf alles nog een keer doormeten en gemiddeldes berekenen?[...] Je hebt gewoon sommige dingen, die onder de norm vallen, daarover bestaat geen discussie meer, die discussie is al geweest"(E.Wissink).*

For example, one researcher explained that a contested area is human need for fresh air. Fresh air can be understood in different ways. However, in standards is 'fresh air' specified in terms of temperature, air circulation and humidity. In ECS research serve standards as a common accepted reference point for users and their comfort needs.

A fourth kind of motivation is that ECS researchers use standards as an instruction manual for complicated user and comfort issues. Standards prescribe how indoor climate systems should function regarding users and comfort.

> *Je moet gewoon harde gegevens hebben, harde waardes [...] die heb je nodig voor metingen." (E.Wissink)*

Standards provide guidance for making accurate predictions and guarantee the effectiveness of systems. Standards can be defined as rules and codes that commit the ECS researcher to particular technological research on comfort.

A fifth type of reasoning is that standards help to coordinate between actors in the 'built environment'. For example standards are authoritative in the regulation of indoor climate systems for the research institute, industry, and contractors. Standards organize guidance for assessment and labelling of competing systems:

> *"In feite, als iemand een heel slim apparaat op de markt brengt, maar die is niet volgens de norm getest, dan kunnen ze daar in de nieuwbouw niets mee. Want daar horen geen EPC punten[25] bij.[...] Ook al is het apparaat beter, als het niet volgens de norm is getest, dan zijn daar geen bewijzen voor." (E.Wissink)*

Without any official energy performance evaluation, it is impossible to grant an energy label to a device. Devices without a label will not qualify to be built into houses. The corporation within the 'built environment' depends according to the ECS researchers on standards.

A sixth kind of motivation identified is that standards ensure interoperability between various technologies. The indoor climate systems are not meant as stand-alone technologies at home. In a house, they require to function with other systems and networks like the electricity grid. The match with other technologies is accomplished through standards.

These six types of reasoning together form a coherent underlying logic to use standards in the ECS research domain for users and comfort. This 'ECS research logic' justifies for ECS researchers why standards are the main way to represent users and comfort in the current technical research.

4.4.2 'Standardized user' and 'normalized comfort' taken for granted in 'ECS research logics'

The 'ECS research logic' that underlies standardization go hand in hand with a taken for granted attitude towards the applications of standards for users and comfort. They rationalize that standards

[25] EPC stands for 'Energie Prestatie Coefficient'. 'EPC credits' give an indication for the energy performance of i.e. a climatic system, or in other words, its expected energy consumption.

provide the theoretical assumptions for users and comfort that they need for technical research. Using standards appears to be obvious to ECS researchers:

"Een norm pakken we zo uit de kast. Informatie over gebruikers is zo beschikbaar. "(R.Brand)

The researchers consider standards in terms of its input and output without critical reflection of its internal working:

"of de norm nu goed of slecht is, of wel of niet aansluit bij werkelijk gebruik, ja… dat is dan zo. [...]"Er zijn mensen die echt met norm ontwikkeling bezig zijn. Die stellen bepaalde normen voor, [...] daar ga ik niet over, ik vertrouw erop dat die mensen hun werk goed hebben gedaan" (E.Wissink).

This implies that 'the standardized user' and 'normalized definitions of comfort' that are embedded in standards come as durable wholes to the ECS researchers. The interviewed ECS researchers do not seem to feel responsible for the content and assumptions that are built into standards. In addition to this, some of the actors the ECS research group are involved with the development of standards. The interviewed ECS researchers trust that their colleagues do their work properly and that standard in general are *good*[26]. The above implies that the obvious application of standards lead to a situation in which users represented as abstract notions that are taken for granted in design logics of ECS research process.

4.5 Conclusions

This chapter was considered with user representation, comfort construction, design logics of the ECS research process in the ECS domain. The main conclusion is that 'shaping a comfortable indoor climate' is inscribed in design logics of ECS research process as a technical achievement of indoor climate systems and that users, comfort and energy are considered as functions of technology.

How are users represented in 'Energy & Comfort Systems' research on indoor climate systems?
This chapter explored user representation methods, articulation and roles of representations in design logics of ECS research process. Three representations were identified that ECS researchers use to anticipate future users: standardized, smart and incompetent users. The standardized user is inscribed on purpose, the smart user is inscribed unconsciously and the incompetent users is out scribed in ECS research process.

How is "comfort" regarding indoor climate constructed in 'Energy & Comfort System'- research on indoor climate systems?
This chapter explored how ECS researchers define and understand categories of 'comfort' and 'indoor climate'. Three interpretations of comfort were identified; however one construction of comfort, namely normalized definitions of thermal comfort, are explicitly inscribed in design logics of ECS research process.

Which design logics lay behind "user representation" and "comfort construction" regarding to the indoor climate in 'Energy & Comfort System'-research on indoor climate systems? In the final sections became clear that the researchers reason that standards are the best possible solution to the seemingly self-evident divide between technology and behavior in their engineering research approach on indoor climate systems.

[26] To my opinion, the indication 'good' usually equals 'technical', 'logical' or 'rational' etc. in the ECS domain.

Using standards into research process has great advantages, and ECS researchers are unwilling to shelve standards. Granting that standards are voluntary, the ‘ECS research logics’ seem to make their use seem ‘true’.

The ‘ECS research logics’ justify not only standardization as the ‘truth’, but also justify indirectly some consequences of standardization. Standardization allows technical investigation of indoor climate systems as a stand-alone object, detached from users and environment on neutral grounds in laboratory. Standardization ensures that all researchers do the same, which makes that the investigation becomes independent of the person performing the work. Furthermore, standards represent ‘the standardized user’ and ‘normalized definitions of comfort’. These are incorporated as detailed instructions and procedures and make that researchers can focus on doing things right, instead of doing the right things. The findings showed that the researchers do not question critically standardization, nor embedded content in standards or supposed benefits for using standards in the light of the potential users of the indoor climate systems under investigation.

The application of standard has reached a taken-for-granted status in the ECS research domain. The use of standards has as consequence that ‘the user’ and ‘comfort’ are treated as blackboxed entities in the ECS research domain. Thus, the ‘ECS research logic’ has an enormous influence on the users, their behavior and comfort needs that are embedded in the ECS research domain.

All these aspects are combined into a coherent research strategy with an underlying ‘ECS research logics’ on which the research team agrees. This logic determines the final arrangement of specific user representation and construction of comfort that guide the researchers in certain ways so that they can do functional research.

When one opens op the coherent research plan, it’s taken for granted status becomes less obvious, because it shows the action of ECS researchers that is required to make it appear logically ‘true’. Explaining i.e. the use and content of standards into ‘ECS research logic’ has certain benefits. It makes clear that standardization is not an objective property of the ECS research practice, but only one of more possible ways to arrange research. Moreover in my interpretation of Jelsma, ‘ECS research logics’ is a-deterministic in that it depends on the logics of the ECS research group members. If the research group would change, i.e. with TNO experts from behavioral science department or user involvement in research, the research logic and thus incorporated standardized values may change too. Another benefit is that the mapped design logics of ‘ECS research process can be compared for inconsistencies with the logics of related projects, like the energy consumption research of behavioral sciences. Do these logics i.e. define similar users and comfort preferences?

An important advantage of ‘ECS research logic’ for this thesis is that it can be checked for the quantity and quality of the user logic that it incorporates. Jelsma hypothesizes that “the less user logic a research logics includes, the less functional – e.g. in saving energy the resulting design will be” (2005, p. 102). The user logics will be explored in the upcoming chapters. Jelsma suggests a contextual approach, because that departs from the minds of developers, in this case researchers.

5 SHAPING A COMFORTABLE INDOOR CLIMATE AT HOME: MEANING, REALIZATION AND USER LOGIC

This chapter presents the analysis of the study of potential users of climatic interfaces that are studied by research group 'Energy and Comfort Systems'. In the previous chapter was analyzed how researchers anticipate the main question *how users shape a comfortable indoor climate at home* in ECS practice and how user representations and constructions of comfort are embed in ECS research logic. This chapter analyses the main question approached from the perspective of potential users and their vocabularies. The results give insight in what actually happens in homes of real potential users and what logics lay behind their meaning of comfort at home and shaping of a comfortable indoor climate.

The empirical data for this analysis consisted out of six qualitative interviews with respondents at their own home and records of observations about behavior and socio-technical environment. During the interviews[27], the respondents were questioned why they behave, use, act and interact with each other and/or objects in their environment as they do in the realization of a comfortable indoor climate[28]. The empirical sources were analyzed on how respondents construct the concept of 'comfort' at home in regard to their indoor climate; on how they shape a comfortable indoor climate at home; and finally what (element of) user logics lay behind their meaning of a comfortable indoor climate and if the concept user logics is enough to explain the realization of a comfortable indoor climate.

The purpose was to identify diverse (elements of) user logic at home that interfere with their energy behavior at home. The analysis brought about climatic practices and considerations of users, too many to deal with in this chapter. Therefore, it was necessary to make some decisions for further analysis. I took two criteria into account. The first criterion was to select from each case, those indoor climate situations and logic elements that seem, to my interpretation, important for the respondents[29]. The second criterion was based on the goal to highlight the diversity and variety of user logics. Therefore, I selected per case the most remarkable and unique circumstances in relation to the other cases. To my view, I managed to select those indoor climate elements and situations that are relevant for individual respondents and that together result into the widest possible variation among cases in regards to user logic of shaping a comfortable indoor climate.

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[27] Two remarks: first, I want to emphasize that the interviews were held during the winter. This has of course influenced the stories about indoor climates, heating and ventilation practices. Second, the interviews took place in the homes of the respondents. This gave opportunity to observe respondents in their natural environment. Although the interviews were leading for the reconstructions, in some cases observations were valuable contributions.

[28] The user logic of shaping a comfortable indoor climate was understood as a combination of values, preferences, intentions and conventions etc. in the home environment. This is a complex and dynamic mixture, but for respondents consistent. The mixture of user logic is being shaped and driven not only in social relations, but also by material (dis)stimuli that are part of the daily use practice at home.

During the interviews became clear that the shaping of a comfortable indoor climate at home is often carried out by routine. However, this does not mean that they did not know the reasons behind their actions. In most cases, the respondents were able to explain why their regular practice is as it is and was it was possible to discover underlying reasons and considerations of their daily indoor climate routines

[29] During the interviews, respondents emphasized certain issues of daily practices over others. For example, respondents went back repeatedly to certain elements in their environment or they had strong opinions about certain situations that deem to be comfortable or not for them. These were clues for me that certain issues of indoor climate practices matter more than others to them. With this in mind, I chose per case those aspects and situations that appeared most important for the indoor climate practices of respondents.

In the next chapter, these results of user logics will be compared for inconsistencies with research logic in order of ECS to shed light on dynamics behind differences between calculated and actual energy consumption in housing

The structure of this chapter is as follow: It starts in subsection 5.1 with a gallery to introduce six portraits of users and climatic interfaces at home; then subsection 5.2 offers in three gradual steps the users meaning of a comfortable indoor climate and discussions of users logics behind this meaning. Subsection 5.3 provides the realizations of a comfortable indoor climate at home. It highlights user negotiations with other household members and interactions with climatic interfaces in daily life. It concludes with that indoor climatic behavior of users cannot be understood only from the logics of the users. Section 5.4 identify and discusses that indoor climate practice at home is also subject to the household logics and the technical infrastructures. The final section gives the conclusions.

5.1 Gallery with six portraits of users and climatic interfaces at home

This section presents a gallery of six portraits of the respondents at their home. This gallery serves as an introduction of the six cases of users and their socio-technical environment in which indoor climate practice takes place. The portraits help to place further analysis of comfort, shaping a comfortable climate and the underlying user logic into context. The portraits describe briefly the respondents and some of their characteristics observed during the interview, the other household members and indoor climate interfaces of the house. Furthermore, each portrait is accompanied with a synoptic table of the main socio-technical characteristics of the environment, a picture of the front of the house, floor plans and occasional additional pictures. These can be found in annexes E up and including J.

Emiel

Emiel (29) is a PhD student Civil Engineering. Nearly finished, he puts a lot of effort in completing his thesis. Emiel appears as a calm, social and friendly young man. He lives alone and can go his own way at home. For example, he enjoyed that he could furnish his home according to his own preferences and did not have to make conventions. He describes his home décor as tuned, organized and tidy. Emiel prefers overview and orderly circumstances in general, because that makes him at ease.
In 2009, Emiel bought his apartment on top of a flat in 2009. The house owner has an investigative attitude and wants to know what goes on in and around his flat: he reads the papers of the owners association and attends the building meetings. Emiel is well informed about the status of his house and willing to tell about it. The building is provided with central block heating, the heat in his house can be regulated with individual radiators with thermostatic valves. Furthermore, the building has central block ventilation with ‘always on’ fans only in the bathroom. Other ventilation options in his house are the windows, (balcony) doors and some trickle vents. The engineer approached the material features of his home environment from a technical point of view and talked about those in jargon, but also clarified everything afterwards. Emiel seems to have technical insight and values logical functioning of matters. More details of this case can be found in annex E.

Brenda & Marieke

Brenda (29) completed the study Art and Technology and works as a traffic manager at a marketing agency. She appears as an extrovert person with a strong will of her own. Brenda told that she has the habit to take immediate action when something annoys her. Brenda admitted that she is

impulsive and stubborn, but also willing to listen to others for good advice. If she believes that another solution will lead to a better situation, she will adjust.
Three years ago, Brenda bought her house in an apartment building. The building has central block ventilation with 'always on' inlet and outlet fans in the toilet and kitchen. Windows and (balcony) doors in her apartment can be used for further ventilation. Her apartment has central heating which she can regulate with a thermostat and 'on/off' valves on the radiators.
For two years she lived alone in her apartment. But a year ago, Marieke moved in. Marieke (27) studied Educational Sciences and works as a pedagogue at an institution for children with mental disabilities. Marieke appears to be quieter than Brenda. According to Brenda, Marieke has a persistent attitude and is a natural authority. Marieke told that she, unlike Brenda, thinks twice before she takes action. Additional information is provided in annex F.

Tineke

Tineke (57) is married with Eise; together they have three grown up children. She has a background in mental nursing and assists young grownups with a mental disability so that they can live independent. Her part-time job is irregular in terms of working days and ours. This causes a variable weekly schedule at home. Household activities and leisure hours are flexible planned around her work hours, every week is different. Tineke appear as an insecure person and does not talk simply about her own needs and preferences. She is open and willing, seems to know what she wants, but cannot put that easily into words: they have to be pulled out. For example, Tineke was open about her wish for an environment that is clean and organized according to 'her standard'. But what 'her standard' entails, remained vague. Furthermore, Tineke admits that she has an almost compulsory urge for control over diverse kinds of household practices.
In 1986 Tineke and Eise bought a semi-detached house. In this house they brought up their kids. But they have moved out. So finally, Tineke and Eise live together again in their house. Their house has central heating; the radiators can be put on or of individually. During a renovation six years ago, the manually operable thermostat was replaced with a programmable thermostat. Their house is provided with mechanical ventilation with 'always on' fans in the kitchen, bathroom and toilet. Other features for ventilation are windows, doors and trickle fans. More details about this case are enclosed in annex G.

Tamar

Tamar (27) is a warm talkative person who has interest in the people around her. She appears as a ambitious and flexible all-rounder: she combines motherhood with a part-time study and job. Tamar studies Human Recourses and works two days per week as an information assistant at a housing cooperation. She has a relationship with Ties (26), and together they have two young children, a daughter (4) and a baby boy. Tamar feels responsible for her children and values quality time with her family.
Her household practice appears a bustling organization. It seems that Tamar has control over the situation and that her household functions as a well-oiled machine. Tamar told that it cost some effort: her household needs careful planning, management and clear structures, and everything happens in social harmony.
The young family moved three years ago to a terraced house. This house has several indoor climate features. For ventilation it has a mechanical unit with vents in the kitchen, bathroom and toilet. The vents can be set manually at three different levels. Additionally, windows, doors and trickle vents can

be used for ventilation. Furthermore, their house is provided with central heating and radiators which can be put on/off individually. In Annex H is more information provided about this case.

Karina & Edwin

Karina (28) appears as a calm and social person. She studied Legal Services and works as a municipal official that investigates tax frauds. Karina has an explorative approach to issues in general and wants to find out what lies behind. She told that if something is unclear to her, she will figure out how it works. Karina has already for nine years a relationship with Edwin. Edwin (29) has a background in Communications Studies and works as an online marketer. He seems and easy going man, inquisitive and is curious about the latest gadgets. Throughout the interview Karina and Edwin need little discussion and agreed frequently or quickly with each other just by giving a look at each other. They seem to be in an equal and harmonious relationship in which feelings appear as more important than rationality.

For two years they rent an apartment in a block. The block is provided with central block heating. In their house they have radiators with thermostatic valves. Furthermore, their apartment is featured with mechanical ventilation with vents in toilet and kitchen. The vents can be adjusted manually into three different degrees. Other options for ventilations are (balcony) doors, windows and trickle vents. More details are provided in annex I.

Sanne

Sanne (28) went to the art academy. She appear as an entrepreneurial, critical, flexible and open minded person. For matters that have her interest or are her responsibility, she is willing to put effort in. Like being a volunteer in an art shop. She told that she wants to achieve appropriate knowledge and skills that enable her to do her work properly. However, there are also issues that cannot thrill her, like filling in her tax forms. Rather she leaves them up an accountant. Sanne ensures that suitable people help her with such things. Altogether, it seems that Sanne has organized her affairs and controls it. According to Sanne, you do not have to do everything alone, in good consultation and with help of with others you can achieve a lot.

Recently, Sanne moved for a new job as graphic designer to another, to another city. She did not know anyone and therefore she chose to live in a co-operative living arrangement. The co-op group exist out of eight unrelated members, four men and four women. Their ages vary between 28-56. All of them are highly educated, six have a job, and two are unemployed. The group values social engagement and environmentally consciousness. The co-op group rents and shares a residential structure. The house comprises common areas: living room-kitchen, laundry room, storage spaces, guest room, cellar and a garden; and semi common or shared rooms: three bathrooms, four toilets. Furthermore, each member has its own private room, which serves as personal living room and bedroom. The house has several indoor climate features. For heating it has a central heating system. This system can be programmed on/off with respect to the outside temperature and time. If it is on, radiators can be put on/off individually. Furthermore the house has mechanical ventilation with vents in the kitchen, bathrooms and toilets. They can be operated manually in three different positions from a central place in the kitchen. Further ventilation options are windows and doors. In annex J can be found more information about this case.

The gallery demonstrated that the six cases are unique cases of socio-technical environments. The six portraits featured above have provided insight in the diversity and variety regarding type and size of household, gender, tenants or owners and type of houses which have been achieved by the sampling strategy. Furthermore, the portraits provided more analytical insights that each user has its own personality and each house has its own mix of indoor climatic features. The six unique socio-technical environments form the basis of indoor climate practices of users, which will be subject of analysis in the next subsections.

5.2 MEANING OF A COMFORTABLE INDOOR CLIMATE AND THE USER LOGIC BEHIND

This section answers the sub question: How is ´comfort´ regarding the indoor climate constructed by users at home? The interviews revealed that users do not so much construct but rather give meaning to a comfortable indoor climate. Therefore, this section provides the analysis of users' *meaning* of a comfortable indoor climate at home. The goal was to discover how they frame comfort, the indoor climate and what they consider important for a comfortable indoor climate at home.

The concept of 'comfort' was approached in three levels from wide to narrow in relation to the home in order to discover comfort considerations that may go beyond the indoor climate practice, but will have an impact on the indoor climate. These levels are ordered from wide to narrow: comfortable housing, comfortable living atmosphere and comfortable indoor climate. For each level of 'comfort at home' could be similar kind of comfort themes be identified that are important for users and influence the indoor climate, successively housing selection, feeling at home, warmth and fresh air.
This order is also used to present and discuss individually their impact on the meaning of a comfortable indoor climate. The presentations and discussions highlight those aspects that are important for users at home and at the same time probably outside the scope of researchers.

The outline of this subsection is as follow: The part 5.2.1 presents comfortable housing as housing selection. This presentation is followed by a discussion of user logics of housing selection criteria behind the indoor climate. The part 5.2.2 defines comfortable living atmosphere as 'feeling at home' and corresponding conditions. Afterwards will the user logics of feeling at home behind the indoor climate be discussed. The part 5.2.3 describes users' meaning of a comfortable indoor climate, how users interpret the whole indoor climate in which climatic conditions warmth and fresh air interplay. Subsequently user logics of a comfortable indoor climate will be talked over and emphasize especially those elements that are difficult to foresee by researcher. The final part **Error! Reference source not found.** provides some additional lessens for research about users meaning of a comfortable indoor climate at homes.

5.2.1 COMFORTABLE HOUSING IN RELATION TO THE INDOOR CLIMATE

The respondent tends to answer questions why their house is comfortable in general, with considerations why they have chosen for their house. In their replays they motivated that their house is an attractive place to live via descriptions of housing criteria's that imply comfort to them. Therefore, comfort at the level of comfortable housing will be discussed via the theme 'housing selection'.

HOUSING SELECTION

This section describes 'comfort at home' at the level of comfortable housing.
The respondents elaborated on many different kind of housing selection criteria. Four types of housing selection criteria could be identified in all six interviews. These four criteria contribute according to respondents to comfort at home and also were (un) consciously associated with the

indoor climate. This section describes these four housing selection criteria and how users relate each criterion (in)directly to the indoor climate.

A first criterion that respondents consider is the 'status and appearance of the house'. The descriptions of status and appearance of each respondent and their preferences were rather diverse. Sanne favors a house that has 'character'.

> *"I like it that the house has a lived-in look; it's not too new and has character. This canal house has a wooden beamed ceiling and wooden lived-in floor. The house has weird corners, not only in this room, but in the whole house. The floors are not leveled equally everywhere, there are many small stairs in between. Those kinds of things give it character. I was hooked immediately. "(Sanne)*

Whereas Emiel likes the opposite:

> *"What I like, just before I moved in here, that the house was renovated and everything is up-to-date. It is all finished perfectly, nothing is broken, and everything works. It's all new and modern. Otherwise, I don't believe that I would have bought it." (Emiel)*

The status and appearance of a house has an effect on the indoor climate. For example, Sanne related this criterion directly to the indoor climate by referring to draft:

> *"This house is of course rather old, thus it is a bit drafty. That is something that you know in advance […] that's part of the deal. I believe that you don't have to open windows constantly for fresh air here."(Sanne)*

One might expect that draft would be a general comfort issue, but it is not for Sanne. Sanne knew at forehand that it would be a drafty house, and accepts that it is a characteristic of the house. Therefore, she does not recognizes the draft at home as a problem, but rather explained that she wears extra clothes to be comfortable. She developed her own solution for the drafty old house. In contrast to Emiel, draft would be a serious issue for him. Yet he does not experience uncomfortable draft as he argues due to recent restorations at this house. He does not have to experience draft because he had chosen consciously a renovated house.

A second criterion is the 'outside view'. Also for the outside view applies that each respondent has a personal preference that makes him or her at ease at home, which resulted in six different descriptions of a comfortable outside view. Two example are provided:

> *"I find it really cool to live up so high ... the view, yes, that is the big reason why I bought it." (Emiel)*

> *"So far, since I live in Enschede, I always had a view on the church. And I've said each time, if I move, then I want again a house with a view on the church."(Brenda)*

For each respondent applies that their own comfortable outside view contributed to the experiences of their housing comfort.

The criterion outside view has in some cases impact on the indoor climate, because it contributes to the place of the house in a building. For example, Emiel's bought his apartment situated on the fourteenth floor, partly inspired by the beautiful view. But because his house is placed at the top of the building, he has to deal with the rising heat of neighbors downstairs, which lead to a situation that it is often uncomfortable warm at home. In contrast to Brenda, her house is built-in between that of her neighbors, which makes that warmth retains and less heating is required. She finds this a comfortable situation because she considers that she has to heat less herself. The choice for a specific outside view has impact on the location of the house, and therefore also indirectly affects the indoor climate.

A third criterion is related to surrounding safety in the neighborhood. All respondents associate a calm neighborhood with being safe. That resulted in similar descriptions about interactions with their neighbors, like:

> *"Live is quiet here [...] the neighbors in the flat, it all very jovial, people do not have conflicts with each other […]we feel safe here, that is important."(Brenda)*

Good relationship with their neighbors is an important condition for comfort, because it provides a safe feeling. Although that all users consider their neighborhood as safe, Brenda and Karina consider another safety aspect: the possibility of burglaries, which has an impact on their experiences of the neighborhood. Even though they perceive it as safe, these users want to prevent from intrusions of thieves. When users bring up the riffraff in their in their neighborhood, they link it in a practical way to the indoor climate. The prevention of intrusions influences how they deal with their windows: they leave windows never open unattended during the day to prevent burglary. Also the other users were questioned about this kind of safety issues in their neighborhood, but do not experience it or see it as uncomfortable. Those users leave windows slightly open during the day, whether locked or not, for fresh air all day. The households of Brenda and Karina would prefer fresh air too, but are in a practical way hindered by ideas burglaries in the neighborhood which affects their indoor climate. The idea that they keep intruders outside by closing windows makes them comfortable with their neighborhood.

A fourth criteria to consider a house attractive is 'incidence of daylight'. For daylight in home, windows are important according to all the respondents. They take the degree of sunlight and windows into account when they select their home. The descriptions were comparable with the following illustration:

> *"And I believe that it is actually very light at home. I like that […] that is also part of why we choose this house. Of course, the light is due to the large window at the backside. I really enjoy the light in this room." (Karina)*

The respondent explained that daylight has a positive effect on comfort because it improves their daily performance and mood at home.

All users understand light as an indoor climatic phenomenon. In their words, (sun)light in home is an indoor climatic condition by itself. Furthermore, they argue that sunlight influences the indoor climate not only as light source, but also contributes to warmth, another important climatic conditions in their perspective. Users see light consciously as an indoor climatic condition and at the same time the sun as influencer of the indoor climate.

The four presented housing criteria are important for all users to select a comfortable house. In addition to these criteria, all users revealed that they found it important that they were able to choose consciously themselves a house that fits their own criteria. That they could make their own selection contributes highly to their experienced housing comfort.

Discussion of housing selection as logics of users behind a comfortable indoor climate

This section highlights what user logics of housing selection criteria underlie a comfortable indoor climate. Comfort at home for users at the level of comfortable housing was defined via four housing selection criteria that are important for users to qualify their house as an attractive place to live and that they (in)directly relate to the indoor climate.

In the rationales of users applies that when they can deliberately select themselves a house that matches personal housing criteria, they will consider that house as a comfortable place to live. In the logics of users it is obvious to consider among several criteria a consistent mix of four criteria that also impact the indoor climate. However, the content of the individual criteria in the mix differs among users rationales. Each user has a personal interpretation for when a criterion applies as comfortable. Especially the comfort descriptions for the appearances and status of a house and its outside view varied. This implies that each user has its own preferences for these two housing criteria, and thus differs among user logics. For the other housing criteria neighborhood and daylight via windows, are their qualifications for comfort more alike. This indicates that in user logics the preferences for these criteria are more or less similar. Although those users consider the same mix of criteria to consider their house as comfortable, the qualifications for comfort differ per user. Therefore, the meaning of comfortable housing differs per user logic.
In addition, since each user gave a different meaning to comfortable housing because of diverse mixes of preferences for housing, it seems reasonable that users select different kind of houses. This means that a selected house may be considered comfortable for a user, but would not necessarily be comfortable to other users. So even though major differences between the houses in this study, each user reported to be comfortable in his or her own house. At the same time, different users have diverse 'points of departure' for giving meaning comfort at home.

In users rationales, the four presented housing selection criteria related (in)directly to specific indoor climate conditions. This means that users either directly or indirectly also take indoor climate aspects into account when they assess the status and appearance of a house. In users reasoning a newly renovated house or an old house will result in dissimilar indoor climatic conditions. In user logics is it also normal to take windows into account because they find sunlight comfortable. Their stories revealed that they also keep in mind other technical factors like doors, indoor climatic systems and the arrangement of the house in their housing selection.

This implies that indoor climate conditions are (in) directly part of their housing selection. Users seem to expect a certain indoor climate as a characteristic of the house that they choose. This means that in the logic of users the indoor climate does not completely appear out of the blue when they live in the house, but was part of the choice that they made themselves. As they made a conscious decision and the indoor climate matches their expectation, they will consider this specific indoor climate as a normal condition that is part of daily practice. Apparently users understand the indoor climate as dynamic characteristic of (technical setup of) the house. And since users have diverse preferences, each user will consider another characteristic indoor climate as normal.

However, other housing selection criteria contribute in daily practice to the indoor climate. The outside view determines partly the location of the house in respect to other houses. In daily practice the location of the house can affect the degree of dependence of indoor climate practices of neighbors. Those users that are 'built in' between their neighbors believe that they can benefit from their heating practices and that they can heat less themselves. However, a user in the top of a flat has to deal with the rising heat with the neighbors downstairs. This resulted in an uncomfortable warm situation at home. Furthermore, people in a flat building are usually connected via collective ventilation systems to the ventilation practices of their neighbors. All users experience that as a disadvantage. The comfort of the outside view and the location of the house can in daily practice interfere with the comfort of (in)dependence of their neighbors indoor climate practices. If the dependence results in daily practice to an unfavorable situation, users consider that simply as uncomfortable. Also the housing criteria of a safe neighborhood, might be experienced differently in practice as expected. Users that feel not safe in their neighborhood due to (ideas about the possibility of) burglaries in the area prefer to prevent insecure situations. They are comfortable is they can keep intruders outside, for example, by closing windows during de day. Although that they prefer fresh air all day. In such cases safety issues interfere with their indoor climate practices: their definitions of safety are in conflict with a comfortable indoor climate.

5.2.2 Comfortable living atmosphere in relation to the indoor climate

This subsection defines 'comfort at home' at the level of comfortable living atmosphere. The respondents inclined to answer questions about what a comfortable living atmosphere at home means to them, only with answers under which conditions they feel at home in their house. It seems the respondents understood 'a comfortable living atmosphere' as feeling at home. Consequently, comfort at the level of comfortable living atmosphere will be presented via 'feeling at home'. The first part presents the shared of 'feeling at home'-dimensions that users tend to focus on when they give meaning to comfortable living atmosphere.

Feeling at home

It appears that all users, once they have chosen a house that they find attractive, want to turn it into their home. 'Feeling at home' has a very positive connotation and was described by respondents in terms as: 'feeling at home in your own house', 'a homely atmosphere', 'coziness', 'being at ease', 'a safe environment', 'familiar', a sense of security'. Respondents talk in different ways about feeling at home. However, five similar types of 'feeling at home' conditions were discovered in all interviews. Respondents give meaning to a comfortable living atmosphere conditions by linking them to other factors in their socio-material environment. Feeling at home cannot be reduced easily to individual conditions without losing its qualitative character, because it appears that respondents experience feeling at home as a dynamic whole. Nevertheless, the five 'feeling at home' conditions and socio-material will be presented individually to present how users give meaning to a comfortable living atmosphere at home. Afterwards follows a short explanation how 'feeling at home' affects the meaning of a comfortable indoor climate.

A first condition to feel at home is privacy. The home is often compared to workplace, university and other public areas as a place to relax and be alone. Most respondents give comparable descriptions, like:

> *"But 'home' also entails a feeling that it is nice to be back again, anyway, it is nice to come home after a day at work. Here I can be myself […] Here I have no obligations, I feel no stress[…] the sphere is good and that gives a sense of harmony."(Karina)*

Feeling at home implies that respondents do not feel the pressure, obligations or responsibilities from outside. At home they have their own rules. This results in calmness and the possibility to be yourself, which is very comfortable for the respondents. Furthermore, privacy is also associated with having an own room:

> *"I have privacy in my own room. Here, I can close up from others and have personal freedom."(Sanne)*

Most respondents expressed the need for having an own room for some privacy. They explained that they need to separate themselves from the rest once in a while, in order to come to senses. Privacy in this sense, means that they can linger around without being hindered by others including household members. Privacy is a strong must once in a while for feeling at home.
A second condition that the respondents link with feeling at home, are their own home décor and personal belongings. They view home décor as a significant means to turn a house into a home. They all made many comments along the line of:

"You adjust the house as much as possible to your own style, for example, we have painted all the walls in colors that fit our taste […] Not only the colors, also the materials, you choose the furniture and stuff for the walls and curtains for the windows […] you fine-tune and combine it to your own preference."(Karina)

The respondents have a strong need to compose their own interior, and to do it in such way that it fits their personal preferences. Karina and Edwin feel comfortable when they achieve a cozy and warm atmosphere; Tamar favors the calm look of white and Tineke wants that everything is aligned. It seems that respondents attempt to create a home environment that mirrors their personality.
A third condition for feeling at home is the 'freedom of choice to do what one likes to do'. Throughout all interviews, respondents made regularly comments along the line of: 'at home am I free to do whatever I want', 'here do I have a say in how I want it', and, 'in this room I can decide to do it like that'. In regards to comfortable living atmosphere, all respondents refer to their home décor, for example Tineke:

"Fortunately, at home you can decorate the rooms, i feel at ease when i can decide how i want to do it. Here I can do whatever I want, and I do not feel the need to take others into account."(Tineke)

The interior is just one of many concerns of respondents to demonstrate their need for being able to do what they like to do at home. It could be about anything and everything that happens at home. From watching a certain television program to what is on the menu; and from when and how to clean to how long one will be under the shower. As long as they can freely decide themselves, it provides comfort.
A fourth condition to feel at home is to good relationships with other social actors at home. Certain people are frequently mentioned as most important to have a good relationship with at home: their partner, children, and other household members. Also other people were mentioned: further family members, neighbors, and friends. Being together with these people is important for means for respondents:

"Being together with my family gives me the feeling that I am complete"(Tamar)

"Feeling of togetherness, that you belong to them."(Sanne)

It is nice when friend come over to our house, because then you are not alone."(Brenda)

A good relationship and being together implies solidarity and avoidance of loneliness. Being together with other people seems to be in conflict with feeling at home conditions of privacy and freedom of choice. But the specific people mentioned are part of their socio-material environment. The respondents do not consider that as problematic but pleasant. That they have to take into account the needs and preferences of other people in exchange for less privacy and less freedom of choice are just part of daily experience of comfortable living atmosphere.
As fifth conditions for feeling at home as to do with certain types of activities done at home. These activities are frequently discussed in relation to other people at home. Common activities that are

often called are cooking, enjoying dinner or a drink and playing. During these activities, communication is important. For example, Brenda and Marieke like it to talk about the past day while they cook, in order to hear how the other is doing. These activities are comfortable moments to find out find out how the other is doing.

Relaxing at home is for all respondents another important activity at home. After a day at work, they enjoy to 'watch some television', 'read a book', or 'fiddle around'. Such activities have a 'do something for myself' caliber, and need no conversation. However, most respondents clarified that they find it comfortable that other people are there: nearby and easy accessible at home. Respondents also like t, activities in which they can create something themselves or they can develop themselves, like crafts or studies. Such activities are usually done alone, but also for these kind of activities applies that it is comfortable that the others are around at home.

DISCUSSION OF FEELING AT HOME AS USER LOGICS BEHIND A COMFORTABLE INDOOR CLIMATE

This section discusses the user logics of 'feeling at home' behind a comfortable indoor climate in daily practice. 'Feeling at home' is in the rationales of all users extremely important to experience comfortable living atmosphere. Throughout all the interviews, users frequently considered feeling at home considerations to explain why they do, act and behave as they do at home in their daily practice. Thus, it seems that 'feeling at home' in the logics of users is considered as a strong need for comfort at home in general.

According to Shove (2003) comfort can be understood as a 'state of well-being' that they experience or want to achieve in their social-technical environment. The findings of this research also revealed that users seemed to be guided by their feelings, experiences and common sense at home to realize comfortable living atmosphere at home. Users qualify, rather than quantify comfort as 'feeling at home'. 'Feeling at home' in the considerations of users has to do with their mental and social welfare. When users explain what feeling at home means to them they take their socio-technical environment into account. Comfort for users appears as a comprehensive feeling of satisfaction that has to do with themselves, other social actors, the house and other technical factors and circumstances at home. Thus, comfort at home can be understood as a subject-bound concept in which users correlate themselves to the dynamic relationship with their socio-technical environment.

Let's see what can happen when feeling at home considerations are applied to the indoor climate in daily practice. Since the socio-material environments are diverse and varied, it has varied effects among users. However, similar patterns can be identified in the logics of users.

User wants to experience privacy, which means that they do not want too much interference with the outside world and that they can go their own way at home. If external values or rules are imposed on the users that wring with their own comfort ideas, there is a big chance that they do not comply. For example, the vents of the central ventilation system of Brenda and Marieke are adjusted according to the neighbors by a service man from outside for optimal ventilation comfort in the flat. However, this setting results in uncomfortable sound in their house. They do not accept this noise and attempt to realize a comfortable situation, which means that they manipulate the settings of the vents. Although that they are rational aware that it is better to adhere, and it is not common interest that they go their own way, they do it, because their private comfort is more important for them. Similar kind of situation can also be found in the other interviews. In the logics of users their own comfort appears to weighs higher at home than external guiding.

The users organize their socio-material environment to their personal taste and style. This was explained by the home décor that people shape according to their personality. But this can be extended to the indoor climate practice. For example, Karina and Edwin leave the door from the living room to the kitchen open while one of them is cooking, because they want to talk to each other. Or Tineke, she prefers to set the thermostat manually, because so she can control the heating practice. Users attempt to organize the windows, doors, vents indoor climate interfaces to their personality and preferences. If they are able to organize it so that it fits their will, they will experience the situation as comfortable, if not, it makes users frustrated.

Users want to experience the freedom of choice to do what they like to do at home. This also applies for the indoor climate. For example, Karina and Emiel would like to attach burglar claws on their windows so that they can leave them always secured open. However, they are hindered by their housing corporation. Therefore, they experience that they cannot freely ventilate as they want. Or Emiel, he is hampered because his own heating practice depends highly on the heating practices of his neighbors'. Therefore, he does not experience the freedom to organize warmth as he wants it. If users do not feel that they can make a free and conscious choice in relation to their indoor climate, they will experience that as very uncomfortable.

At home users want to maintain a good relationship with other social actors at home. This means that they have to take their preferences into account, thus also their indoor climate preferences. Different preferences for example a comfortable temperature may conflict, but users have diverse and various strategies in daily practice to overcome the differences. Users do not consider different preferences of users as problematic, but rather as part of daily experience.

Finally, certain activities have an impact on their heating practices. Cooking for examples interferes with warmth, and users may open a window or lower the heating. Or cleaning makes them warm, and they will take of some clothes or leave doors open. When they relax they prefer it to be warmer, then when they study. Communication and being accessible to each other also has an impact on the indoor climate. When users are in different rooms, but want to experience that they are close to each other or being able to communicate, they prefer to leave doors open, like Karina and Edwin.

5.2.3 The meaning of a comfortable indoor climate at home

This part explains 'comfort at home' at the level of the indoor climate. For most users the 'indoor climate' is not a taken for granted concept. They needed some room to clarify the meaning of 'indoor climate' for themselves. Once they understood the 'indoor climate' in their own terms, it was possible to discuss what a *comfortable* indoor climate means to them. The interview questions were directed to their daily heating and ventilation practices. When a comfortable indoor climate is discussed in light of heating and ventilation, two important indoor climate phenomena could be discovered in all interviews: warmth and 'fresh air'. In the vocabularies of users are 'warmth' and 'fresh air' important climatic conditions for a comfortable indoor climate. Therefore, comfort at the level of a comfortable indoor climate, will be discussed via the two climatic indoor conditions of warmth and fresh air.

However, this section starts with a short introduction with users' way of giving meaning to the concept of 'indoor climate'; and then elaborates on the climatic conditions warmth and fresh air as seen from the perspective of users and corresponding important socio-technical factors in their environment.

USERS' INTERPRETATION OF THE CONCEPT OF 'INDOOR CLIMATE'

During the interviews it appeared that 'indoor climate' was not a usual concept for the respondents. Before they were able to explain what 'a comfortable indoor climate' means to them, they had to determine how they understand 'indoor climate'. This happened in similar ways. To questions about what they see as 'indoor climate' respondents reply with a list of several indoor climate phenomena. Frequent mentioned phenomena were: warmth, temperature, fresh air, damp, humidity, draft, light, smell, sound, dust, etc. When respondents were encouraged to describe what these climatic phenomena mean to them, they elaborate by linking them to various other socio-material factors in their home. Some similar factors that were associated frequently with indoor climatic phenomena could be identified; building technologies as windows, vents, and heating and ventilation systems; interior, furnishings and personal belongings, other people, their clothes, personal needs and preferences etc. However users do not give such a list with associations, they rather explain how they experience and organize the particular indoor climatic condition in daily practice. For example when respondents give meaning to the climatic condition 'humidity' they associate it especially with the bathroom after showering. Humidity is explained as damp, and appears as a layer of moist on the mirror and windows. Ventilation is required to get rid of the humidity and avoid the formation of mold, and therefore they open windows or doors etc. Thus when respondents attempt to interpret 'indoor climate' during the interviews, they are able to sum up a few indoor climatic phenomena and subsequently gave meaning to those conditions from their own context. This (way of) interpretation of the indoor climate forms the basis for the climatic conditions warmth and fresh air that are presented in the following parts.

USERS' MEANING OF WARMTH

Whereas engineers tend to talk about heating and temperature, in users vocabulary 'warmth' is the associated with the practice of heating. Users consider 'warmth' as an indoor climatic condition. Users consider 'heating' as to make something warm. In this understanding of 'to heat' they focus rather on the quality of 'warm' as a characteristic of a room or their body, instead of the action of 'making' or a certain temperature. Hence this theme is called 'warmth'. 'Warmth' was mainly discussed in relation to the living room and bed room. The interviewed users spend most of their time at home in these spaces and prefer these rooms be comfortable warm. Other rooms are rarely associated with 'warmth'. During the interviews, other rooms were hardly associated with the climatic condition 'warmth'.

Users give meaning to 'warmth' and the organization of 'warmth' in relation to other circumstances and factors in their socio-material environment.

Users associate warmth with temperature. User tends not to talk about just 'temperature', but as a qualifier for a circumstance that warmth is comfortable to them. Temperature was described as:

> *"Steady 20 degrees with fresh air." (Karina)*
>
> *"Somewhere between the 19 and 21 degrees is nice depending on what I do." (Tineke)*
>
> *"Always 20,5 degrees with a blanket." (Tamar)*

It seems that a temperature in the range of 19-21° C appears to be comfortable warm for users. But their descriptions about temperature to define 'comfortable warmth' circumstance were always accompanied with further information about other factors like fresh air, activities, and clothing.

Users do not consider temperature as a singly qualifier to define 'comfortable warmth': also other factors in the environment contribute at the same time to comfortable 'warmth'.
Users link the organization of warmth to 'heat sources'. Most mentioned heat source factors are central heating and block heating. But also other factors were brought up. The sun was mentioned by multiple users:

> *"We have a large south-facing window and the sun shines in all day [...] you can really notice that. If it freezes and the sun shines in all day, at the end of the day, we have a warm room, we do not have to turn on the heating. When we come home after work, it is actually warm here. Perhaps later at night we will to turn on the heating system." (Brenda)*

Furthermore, the some users talk about 'candles' and 'cooking' as factors that contribute to warmth. Karina told that they eventually lower the heating once they have lit candles in the evening. Brenda lowers the heating when she cooks. Various 'heat sources' at home influence together the daily heating practice. They adjust the main source for heating according to other sources in their environment; otherwise it will become too warm. The factors like the sun, cooking and candles contribute not all at the same time, but vary throughout the day. Furthermore, these factors have in each practice a different influence on the heating practice. Thus, users coordinate the various sources throughout the day in order to balance warmth at a comfortable level and the coordination practice of heat sources differs among households.
Users associate their own practice of 'warmth' with that of their neighbors. Factors like 'the location in the building', 'isolation' and 'pipes' make that they are related to their neighbors. Karina, Tamar, and Brenda emphasize that their house is isolated between their neighbor's houses. In this meaning of isolation, they imply the place of their house as being built-in between neighbors. The location of their home in relation to that of their neighbors' makes that they 'gain' heat of their neighbors.

> *"And what probably contributes as well, is that we are completely in between our neighbors. Built-in between the other houses and yet we get heat from our neighbors. [...] as a result, I believe that I have to heat less here."(Brenda)*

The location of their home in the flat compared to other neighbors gives them the impression that they get warmth from them. Brenda, Tamar, Karina consider that as comfortable, because they have to heat less themselves. In contrast to Emiel, who lives at the top floor of a building and does not have to heat at all. Emiel focuses on the technical setup of the pipes of the central heating system and material construction of isolation of his roof that connect him to the heating practices of others in the building. The warmth of neighbors' downstairs rises and lingers in his apartment. Through this, is becomes too warm in home and Emiel considers this as extremely uncomfortable. As a counter action he leaves his windows open to get rid of the surplus warmth. According to users the heating practices of neighbors contribute to their indoor warmth, and their comfort thus depends on their neighbors.
Users associate warmth also with the speed at which a room can be heated and how the warmth can be kept in a room. Factors like the size of a room, doors and windows play major roles: most users expressed that they close doors and windows in order 'make the room smaller' and 'to lock up' the heat inside. Emiel however does usually the opposite, in order to get rid of all the warmth. The possibility to play with the speed of heating and hold the warmth inside by means of doors and windows is extremely important for the users. They consider it as uncomfortable if they would lack these options. Doors and windows serve as extra tools that they can use to control their indoor climate. Also further solutions were mentioned to realize a higher speed and retain heat.

“This extension made the living room rather large. We had to place an additional radiator, because otherwise it would take too long to heat the room.”(Tineke)

“When I’m cold, then I set the thermostat on 30 degrees, because I believe; well, now I just want to become warm quickly, and afterwards it will be suffocating hot and then I will turn it off again.”(Brenda)

Factors like (additional) radiators and thermostats encourage users in their strategies to control the speed of heating. All users have their own strategy to increase the speed and hold of heat, and make use of the available ‘control factors’ in their own environment in quest for comfort.

Users related warmth to certain activities. They mentioned mainly intensive physical activities like tiding up and vacuum cleaning, that heat up their bodies. Furthermore they also pointed to other activities that release heat to the room, like cooking. During such activities, there is less need for a warm environment. Usually they take steps lower the warmth by turning the thermostat lower, open doors and/or windows, and otherwise they take off some clothes. Moreover, the users describe activities that require sitting, like watching television or computer work. During such activities, most participants need more warmth. Sometimes they heat the room a little more, but most participants prefer extra clothing. What comfortable warmth means to users varies among various types of activities. Users have different strategies and make use of various factors in their environment to lower or higher the warmth of the room or body so that it is comfortable in line with what they are doing at home. When users associate warmth with activities, they usually make a distinction between body warmth and a warm environment. Apparently, there exists a kind of limit what the participants experience as a comfortable warm environment; above a certain temperature it becomes discomfortble in combination with some activities. I.e. if the environment is too warm, some participants clarified that this makes them drowsy; this is undesirable in cases that have do work that requires concentration, like Sanne:

“If I have to work at home, the environment should not be to warm. It makes me sleepy. I’d rather snuggle into a blanket, which makes my body pleasantly warm.”(Sanne)

In such cases, the users choose often to put on some extra clothes or a blanket to tune their body heat with the environment and activities in such way that they experience comfort. Clothes are also used by the participants as a means to overcome differences between variations between people’s preferences for a comfortable warm environment.

“I am the shivery one of us, I get easily cold in this room. But well, I also adjust myself to him. I wear extra socks and a warm sweater. Because, I see that as the first solution to overcome differences between preferences for warmth.“ (Karina)

Users told that they use clothes to adjust to the environment and become comfortable warm. In conclusion, clothes clearly are an important means for these them to adapt themselves to the environment and tune their individual preference for warmth.

Users’ meaning of fresh air

Users associate the practice of ventilation immediately with ‘fresh air’. In users’ vocabulary, ‘fresh air’ is a climatic condition. They understand ‘to ventilate’ as ‘to let fresh air into the room’; instead on the action users tend to emphasis the quality of fresh air. Users describe ‘fresh air’ as new, cold, healthy, oxygen-rich air. The interviews demonstrated that the respondents have a strong urge for fresh air at home. Emiel and Tineke calls their need for fresh air ‘a habit’ and Tamar, Karina and Edwin have a ventilate routines, in order to ensure that the air at home is fresh throughout the day. It seems that fresh air is an obvious requirement for a comfortable indoor climate at home. Fresh air

is frequently associated with certain rooms, such as the living room, bath room and bedroom. Especially in these rooms is fresh air necessary, in the other rooms fresh air seems less important.
Users describe fresh air as air that comes from outside inside the house and circulates in the house or a room. According to five participants fresh air is natural.

“Fresh air is just natural, it flows literally from outside to inside, and not via an air conditioner or some ventilation unit. That is no fresh air. I really do not want that, I would never consider that. It would be a doom scenario for me.”(Sanne)

For some, fresh air consists out of natural elements, including pleasant smells:

“There is nothing like the smell of freshly cut grass. That smell makes the experience of fresh air 10 times stronger.”(Sanne)

Users prefer windows and vents to let in natural fresh air. Most interviewed have a strong urge to leave windows slightly open on a daily base. Also the vents are usually open in the homes of the participants, unless it is really cold outside. By doing so, they ensure that there is always a flow of fresh air. Karina also leaves doors inside open during the day, so that the fresh air can circulate in house.
Natural fresh air was in the interviews regularly contrasted with artificial ‘fresh air’ produced by means of technical systems. Artificial produced ‘fresh air’ was rejected literally by users as real fresh air. Users consider that technology cannot mediate fresh air. According to users, available ventilation systems at home can refresh, extract, filter or clean the indoor air, but this type of air is by no means similar to natural fresh air as described above. Thus, users do not see ventilation systems as alternative means for windows, doors and ventilation vents to achieving natural fresh air at home.
‘Fresh air’ has a counterpart, which users described as ‘musty’, ‘stuffy’, and ‘cramped’. Unfresh air do users considers as extremely discomfort able.

“I hate it when no fresh air is coming in, I cannot stand that. I need fresh air.”(Emiel)

Unfresh air means actually that fresh air is absent to users. They associate the lack of fresh air with enclosed spaces and environments that lack ventilation possibilities for natural fresh air.
The absence of fresh air has according to users a negative impact on their health and causes irritations. Headache was frequently brought into discussion.

“I find it easily stuffy, especially when we lay there with the two of us. And sometimes, I imagine that, when the windows are closed, I get headaches.”(Tineke)

But participants also thought about a pale skin, fatigue, cough, a dry throat, and dry eyes as consequences of absence of fresh air.
Users associate unfresh air, with uncomfortable odors. Some say latterly that ‘unfresh’ air stinks. It appears that air that stinks is a strong indicator for users that a room lacks of fresh air. Users refer to stinky odors that they ‘produces’ themselves at home like toilet smells, cooking odors and the smell of sleep.

“This morning we had breakfast with fried eggs and if we don’t open windows afterwards, then lingers that smell here all day. That is not fresh.”(Tamar)

Those users with collective ventilation, complained about unpleasant odors of neighbors. They mention smell of toilet, cooking odors and smoking as disturbing, like Emiel:

“And then suddenly, I notice that someone is smoking cigarettes, because I smell smoke in my bathroom […] I suppose that someone else is smoking at another toilet in the building […] or… I don’t know that if

he or she is sitting on the toilet, or that the smoke comes from a living room […] that is an issue for me, I believe that is it not necessary that I know when my neighbors are smoking."(Emiel)

Due to collective ventilation they are related to the ventilation practices of their neighbors. Whereas most users see a collective heating system as beneficial, collective ventilation systems are by all considered as negative. The main disadvantage is that collective ventilation systems make that they can smell unfresh air of their neighbors. Furthermore, users do not consider ventilation systems as alternative for fresh air, and even though the system may also filter their own indoor air, they mainly experience the unfresh air of their neighbors in their own homes. Therefore, collective ventilation systems make their own daily fresh air organization depends in an uncomfortable way on the ventilation practices of their neighbors.

Users develop different strategies to reduce the effect of the collective system. For example, Emiel closes often his bathroom door to keep the smell of cigarettes out of his living room. But Brenda often tries to manipulate the system, yet without any comfortable result. Others would prefer a different situation, but have no options other than to accept the present situation. If it really starts to smell bad, they all open their windows. Thus, users make use of various factors in their own environment to reduce the dependence of ventilation.

INDOOR CLIMATE AS AN INTERPLAY OF WARMTH AND FRESH AIR IN THE LOGICS OF USERS

This section discusses the meaning of a comfortable indoor climate in the logics of users. It highlights elements that differ from the construction a comfortable indoor climate or marks aspects that are outside the scope of researchers or elements that researchers do not anticipate. These aspects on users side have in common that they are difficult to forsee in the ECS research domain.

In the rationales of users the 'indoor climate' is not a familiar concept and its definition and meanings are not fixed. Users did not submit to a predefined term for the indoor climate, but it took effort to define their own term for the indoor climate. Apparently, the indoor climate is not a taken for granted concept for users .

Nevertheless, all users have a strong preference for two climatic phenomena: warmth and fresh air. In their vocabularies these phenomena appear as indoor climate conditions, whereas researchers would rather prefer to call these conditions temperature and quality of air. The notions of warmth and fresh air mean nothing as standalone for users; they become meaningful in relation to the home environment. This is another difference between users and researchers: users qualify in relation to their environment when the climatic conditions count as comfortable to them, while researchers quantify temperature and the quality of air. The quantifications of researchers for temperature are rather strict, but the descriptions of comfortable warmth vary among users. Nevertheless, but they share some common dimensions that are important for their interpretations of comfortable warmth.

Comfortable warmth is more than only a temperature that they can realize with their heating system at home. When users interpret comfortable warmth, they think about their practice of heating at home. Most users prefer a temperature between 19-21degrees as comfortable. But in their heating practice, they look further than only heating systems: it depends on further factors and practices at home. First of all, there are the other heating sources that contribute to comfortable warmth, like candles, sunlight, the stove or oven. Secondly, their particular doings at certain moments guide what they consider as comfortable warmth. For example, different activities like vacuum cleaning, computer activities for work or chill on the couch watching TV matters. Their comfortable warmth preferences vary if they are physical active, need to concentrate or relax. Thirdly, in some cases depends their comfortable warmth depend on the practices of their neighbors. The effect of heating sources, activities, dependence of neighbors heating practices on comfortable warmth vary and have to be coordinated throughout the day at home. Finally, for all users are clothes and blankets means to fine tune their personal preferences comfort with the warmth in the environment. Thus when users think about their heating practices at home to define comfortable warmth, heating systems are just one of the means to achieve comfortable warmth, and warmth is more than only temperature.

Whereas the description of comfortable warmth varies among users, their interpretations of fresh air are rather alike. Users describe fresh air as new, natural cold, healthy, oxygen-rich air. Their descriptions differ from the qualification of air of researchers that focus on technical aspects of humidity, air circulation and composition of air. Furthermore, users think about how they organize fresh air and call that ventilation. The lack of fresh air is a strong motivation to ventilate, because it causes problems for health, concentration and mood. For users it is important that fresh air comes from the outside and flows through their house. They prefer to use vents, windows or doors to let fresh air in. That is because the observable openings ensure them that it is actually fresh air. In contrast to researchers, ventilation systems are explicit rejected by users as means to let in fresh air. Users understand ventilation devices that can clean or filter the indoor. The result is a kind of artificial air. For users, ventilations systems do not produce fresh air that corresponds with their descriptions. Moreover, in the case of collective ventilation systems, users notice only the negative influences of the ventilation practices of their neighbors the systems that interfere with their own fresh air conditions at home. The meaning of fresh air and ventilation practice are shared among users.

The indoor climate appear as a whole to users. Although that warmth and fresh air were presented as two individual indoor climate conditions, users did not discuss these two and other conditions like draft, humidity, sound, smell and light as isolated conditions. In users rational they are closely related to each other: users told about the ‘total phenomenon’ of the indoor climate. In their reasoning is the indoor climate a whole in which several climatic conditions like warmth and fresh air are involved in a dynamic interplay. The indoor conditions of warmth and fresh air can wring with each other in daily practice. For example a room is comfortable warm, but lacks fresh air, which causes an unhealthy situation; should the user open a window or not, because it will be at the expense of the temperature etc. When there are tensions between climatic conditions at home, users attune the indoor climatic conditions to each other with help of the possibilities in their environment, so that the indoor climate as a whole will be perceived as comfortable. The indoor climate has a comprehensive meaning for users.

5.2.4 In conclusion

The previous sections presented and discussed the meaning that users give to a comfortable indoor climate at home. Above all, it showed the diversity and variety among different users. This makes that no common meaning of users could be observed. Nevertheless. It showed common themes of how users frame comfort at home at three different levels from housing selection to living atmosphere to the indoor climate and what these different degrees of comfort at home mean for the indoor climate. Furthermore, it was possible to isolate and identify dimensions that are important for users regarding a comfortable indoor climate: housing selection criteria, feeling at home conditions and indoor climate conditions warmth and fresh air. The findings were discussed in light of user logics behind their meaning of a comfortable indoor climate. Many of these dimensions are outside the scope of ECS research and therefore difficult to foresee by researchers. The presentations showed above all that a comfortable indoor climate means much more to users than heating and ventilation systems that can control temperature and composition of air. This section provides some closing comments about a comfortable indoor climate.

Individual users and different contexts matter

Users give actively meaning to a comfortable indoor climate. It is remarkable that users think in a different way about a comfortable indoor climate than ECS researchers: users do not submit themselves to some ECS definition of a comfortable indoor climate. Users rather they give their own interpretation according to their own preferences, values, intentions and convention. Users play an important role in making sense of the indoor climate at home.

For users, a comfortable indoor climate becomes meaningful in relation to the context of home. The interpretations of a comfortable indoor climate were typically described with reference to the situation at home from which the data was drawn. They link a comfortable indoor climate to the circumstances and sociotechnical elements of the house and household. It seems logical for users that a comfortable indoor climate depends on their home environment. Users give actively a personal meaning of a comfortable indoor climate from their own home context.

Comfortable indoor climate as a broad and human bound concept

Users' meaning of a comfortable indoor climate is broad concept. For users counts much more than only the four indoor climatic conditions those researchers incline to focus on. Users consider many more home conditions that influence a comfortable indoor climate. Their personal ideas about status and appearance of their house, outside view, neighborhood, daylight, but also their interpretations of autonomy, safety, health, coziness and being together and many other conditions at play a role in their meaning of comfort. Thus, the meaning of comfort at home reaches far beyond the indoor climate.

To determine an indoor climate as comfortable a few conditions are necessary for users. It is essential that they make a deliberate choice for a house and so can accept the indoor climate as a consequence of their choice. Another essential condition for users is that they 'feel at home'. Many of their interpretations about a comfortable indoor climate were motivated out of a 'feeling at home'. This means that users prefer specific conditions for a comfortable indoor climate at home. Privacy as being free from interferences from others outside their home, the organization of home that mirrors their personality, freedom to do what one likes to do, good solitaire relationship with other people at home to avoid loneliness. These conditions weigh rather heavy in meanings of a comfortable indoor climate.

In their logics, comfort is all about human well-being in relation to their environment, other people and circumstances at home. When users give meaning to a comfortable indoor climate they focus on a certain mood that they have or want to experience in the home context. Their feelings relate to their own aspirations, needs, contentment and disappointment. Comprehensive experiences of satisfaction, calmness, relaxation and contentment are leading in judging the indoor climate as comfortable or not. Thus, users consider comfort as a subject bound concept of wellbeing.

A comfortable indoor climate as a characteristic of the socio-technical home environment

In the meanings of users a comfortable indoor climate appears as a comprehensive characteristic that is inextricably linked to circumstances at home and their socio-technical home environment. All while choosing a house they take (in)directly elements into considerations that will affect the indoor climate. Technical factors like the location and arrangement of their house, doors, windows, building related technologies are taken into account. For users it is normal to expect a certain indoor climate as a characteristic of the technical context of their house. It appears normal in the rationales of users a comfortable indoor climate manifest itself as a dynamic relationship that depends not only on indoor climatic phenomena, but also wider socio, technical factors and circumstances at home. A comfortable indoor climate is a double sided process: the indoor climate of home works on well-being of the individual and conversely individuals project their comfort meanings, feelings and experiences on the indoor climate on the home.

Users live under remarkable different conditions, but all reported about a comfortable indoor climate. Users make themselves a comfortable indoor climate at home. For users it is common that different meanings of comfort, meanings of indoor climatic conditions and socio-technical environment interfere with each other at home. That is part of regular daily life. As long as the socio-technical environment offers varied, flexible and socially as well as technical viable means users be well with their indoor climate at home.

5.3 Realization of a comfortable indoor climate: interaction and negotiation

This section answers the sub question: *how do realize shape a comfortable indoor climate at home?* The previous section dealt with how users' gives meaning to indoor climate comfort, this section elaborates on their indoor climate practices. It analyses the creation and maintaining of a comfortable indoor climate in daily household practice and user logic behind. The focus is on the negotiations between household members about the organization of warmth and fresh air; and the socio-technical interactions with 'official' heating and ventilation interfaces. The goal is to elaborate on the complexities of technology-in-use, for example the distribution of agency and delegation of responsibilities over the socio-technical home environment, in realizing a comfortable indoor climate. Due to the complexities that are part of daily life at home, the question rises if the concept of user logic is enough to understand the dynamics behind the realization of an indoor climate. This question provides a point for further discussion of difficulties that arise in daily life because further socio-technical causes at home. This section presents and discusses remarkable elements of the realization a comfortable indoor climate of the six individual cases.

5.3.1 Six ways of realizing a comfortable indoor climate: users' interactions with climatic interfaces and their negotiation s with other household members

This section presents six different way of realizing of a comfortable indoor climate. It highlights significant user-technology interactions and negotiation of each case and gives insight in complexities of technology-in-use at home. In additions was examined if the resulting behavior may be supposed as energy (in)efficient, and can be understood by their user logic.

Emiel behaviors is at odds with his user logic

One of the first things you notice at Emiel's home are the open doors in his apartment.

> *"They are actually always open, because it seems larger […] at the university office I never close my door too […] if doors are closed, the space seems much smaller, I feel imprisoned and it makes me short of breath."(Emiel)*

His intention behind the open doors is that this situation contributes to a sense of 'spatiality'. Emiel said that at his parents place, at work and at home, he always leaves doors open. Apparently, Emiel has a strong preference for ’open indoor spaces and open doors have become part of his habit to realize indoor comfort at home.

But, the doors are also open for another more disturbing reason: usually Emiel finds it too warm in his apartment. He explains that it is due to the heating unit of the central block heating is on top of the roof, and hot water flows downwards trough pipelines to make thermal heating accessible to all neighbors. These pipes cross his house and spread more than enough warmth in his home. Moreover, the roof is too well insulated. If neighbors below heat their room, warmth ascends, and lingers in his place. This technical set up of his house and central heating system makes him depend on heating practices of his neighbors and contributes to uncomfortable warmth at his home.

Situated in this domestic socio-technical network, Emiel attempts to create and maintain a comfortable indoor climate in his own house on a daily base.

Since it is usually too warm at home, there is no reason to make use of the heating facilities in his own apartment. He considers this very uncomfortable because he cannot interact with the heating facilities with the intentions to regulate the warmth at home during the day according to his own preferences.

> *“It bothers me, because I believe that it is silly that you have to open the [balcony]door while it is winter. […]it would have been better if it was a system that gives you control. That you can freely decide yourself how and when you want to heat.”(Emiel)*

The only way to realize comfort is to open doors and windows and gets rid of the surplus warmth.

Latour would argue that his behavior cannot be explained by his own motivation. For instance, he opens windows and doors to get rid of the surplus warmth. But the script of the isolation is to keep the warmth inside and the setup of the technical heating system is to benefit from each other’s heating practice. The scripted environment encourages energy efficient behavior. Emiel said that he understands this. As PhD Civil Engineering, he has technical understanding and values efficient working of technology. But according to Emiel the material home environment is too perfect in carrying out this task: it becomes too warm. This is at odds with his own user logic. Emiel also understand that he cannot change the situation. This encouraged him to develop an anti-program to open doors and windows to get rid of the surplus warmth. The specific material structure and design of the central heating system makes him a non-user of the heating facilities in his own house; and pushes on Emiel to behave energy efficient in the context of the building.

Brenda and Marieke battle with each other and their ventilation system

The ladies expressed that they argue a lot about how to organize their indoor climate in daily practice. They have different views on a many issues. So have both their own preferences, and ideas about how to realize comfortable warmness. Brenda prefers higher temperature than Marieke. She also has intentions to heat a cold room real quickly and therefore is it logical for her to set the thermostat at 30 degrees at home[30] when she comes home. Brenda motivates her behavior by saying that she inclines to act impulsively and immediate towards her intentions and that she usually focuses on one single interaction - in this case Brenda-thermostat - and its outcome – warmth- .

According to Marieke, this is not a proper way to deal with the thermostat to heat the room and she ‘teaches’ Brenda that she should be more patiently. Moreover, as Marieke reasons, other factors at home like individual radiators, candles, the oven or cooking hobs, influence a pleasant temperature.

[30] She follows the same strategy in her car and at work, therefore it seems that technology - at least in her environment – encourages this interaction.

According to Marieke, the temperature will rise too quickly with Brenda's strategy, and then they have to open the door afterwards to dissipate heat.

"It is just too bad to open the door or window to lose heat […] that is really a waste of energy […] then you just keep the fire going for the birds outside."(Marieke)

Marieke also values financial and energy consequences of heating interactions. It appears that Marieke has a broader picture of the heating practice in mind than Brenda, and opts for optimal comfortable result at home. And therefore, Marieke considers Brenda's behavior illogical within the socio-technical context

During their negotiations about preferences, intentions and strategies, the two women stand their ground and try to convince each other. The ladies have both rather competitive attitudes and approach negotiations in terms of 'battles'. This makes that their discussions appear as games and agreements as victories. Marieke often 'wins', as they call it.

"Thereupon I say: 'no, we are going to do it just like this.'[…] I just stick with it for longer, turn the knob back continuously […] But it also comes about by itself, you just listen carefully to me eventually. "(Marieke)

According to Brenda, Marieke was able to persuade her to try to deal in another way with the thermostat, because it will have benefits too, like saving energy and paying less. Such 'prize' is an important condition for Brenda to be open to other ways of using technology. If it works both actually win and therefore their 'fights' are not really an issue. Final score: both accept the outcome.

They made a convention for their heating practice. Their behavior for heating is particular driven by the characteristics of the logics of their negotiation process and material stimuli that are part of their home environment. For instance, they have established a daily routine that entails a combination of several interactions in their environment: that they set the thermostat at 19 degrees after coming home from work; one makes dinner, and the other creates cozy sphere at home: she closes curtains and lit candles. These dynamic interactions will lead to a temperature of 20,5 degrees, which is acceptable warm for both in the end. This behavior tends to be more energy efficient than the previous situation in which Brenda interacted with the thermostat according to her user logics. The energy savings can be mainly understood from the 'household logics' of negotiations, since the material environment did not change. Both are comfortable with this heating practice.

Less satisfied are they with the functioning collective ventilation system. Their house is connected to the 'always on' ventilation of the block. Brenda explains it as a kind of closed system with an inlet and outlet for air. When Brenda moved in, the serviceman of the block tuned the adjustable cores of the fans with great precision, so that its script is to provide optimal ventilation is available to all the residents in the flat. However in practice, the settings of the fans have a side effect: it leads to an annoying whistle sound.

"Ssss... that is what you hear all day, it really drives you completely crazy. […] I notice it at night, when I'm in bed. We closed the bathroom because of the whistling, but now we can hear it coming from the toilet too. I really cannot sleep because of the noise."(Brenda)

In the socio-technial background of their home the meaning of personal discomfort of the noise conflicts with the scripted the comfort of ventilation for all. The discomfort noise of the fans is so dominant, that it hinders Brenda and Marieke to appropriate the ventilation device as a meaningful technology for optimal ventilation comfort for all. In their everyday life the actively try to change the scripted settings of the technology in practice. The fans allow them a certain degree of freedom to deal in another way the settings. On purpose they manipulated actively the fans in different ways with the intention to get rid of the noise. For example, Marieke opened the vents, and closed them, Brenda scoured them off and put a pen into it etc. But in return their actions caused other undesirable effects: they get the stink of neighbor's actions, like smoking and toilet visits. Apparently, the system cannot properly ventilate, filter and clean the air when the vents are not tuned well. Thus when she tries to obstruct the workings of the ventilation system, she becomes depend of uncomfortable aspects of ventilation practices of her neighbors. Brenda asked the technical manager of the building for advice, but without any satisfying outcome for her: she should accept the technical settings as they are. She struggles already for three years now with the technical systems and is stuck with this uncomfortable ventilation conditions.

Their ventilation behavior cannot be explained from their household logics, but should be seen as an outcome of the socio-technical environment. They understand that it would be better to leave the settings as they are for optimal ventilation comfort, but for them it is more important to realize another form of comfort: to reduce the noise. Wyatt (2003) would identify them as non-users of the collective ventilation system: as 'resisters' because they resist the envisioned script on purpose, but also as 'rejecters', because the environment offers alternatives to ventilate (doors and windows) and therefore they also reject the ventilation system. Against their logic to compete each other, they have teamed up and battle together against the working of the ventilation system. A very inefficient practice for all: the technical device is hacked, cannot ventilate properly and creates new negative side effects for Brenda and Marieke: dependence of bad air of ventilation practices of their neighbors, the sound is not completely gone and the device still uses energy. Their energy wasting ventilation behavior can be understood as a result of the socio-technical interactions.

TINEKE LOST CONTROL OVER THE HEATING PRACTICE DUE TO PROGRAMMABLE THERMOSTAT

Tineke told about their renovation plans for the house six years ago; when also adjustments to the central heating were required. Tineke told that she as well as her husband felt insecure; and doubted if they had appropriate knowledge to make a good decision, and feared new technologies because they do not know what to expect. Tineke prefers that others help them in such situations: that others give advice and tell them what they should do. She admits that she has no critical attitude and just follows advice. Experts recommended them to get a programmable thermostat, and so they did, without questioning.

The new programmable thermostat was connected and programmed by an installer. However, the device does not fit their daily practice. The thermostat is set to maintain every day a consistent temperature of 19,5 degrees from 7:00h till 23:00. Previously it was the conscious task of Tineke and Eise to organize a comfortable temperature during the day, but now this is delegated to the thermostat. The thermostat is responsible for a stable heating pattern at their home. However this pattern wrings with her variable time schedule due to work. Moreover, Tineke lost control over the heating situation:

> *"I would prefer to operate by hand. Now, the only advantage is that when you enter the living room in the morning, it is comfortably warm. But actually I would like to determine myself when it is warm."(Tineke)*

The present heating practice is rather uncomfortable for Tineke because the thermostat dominates: its scripts does not grant much agency to Tineke because the program prescribes an automatic organization.

Although that she fears the thermostat because of its complexity, she would like to reprogram it, eventually with help of others. But her husband prevents her from doing that, because he does not trust the system and is afraid to mess up the system.

"Perhaps, I should change its settings, but… I'm being inclined to make it a bit warmer, but my husband always raises his voice and shouts: don't do it, don't do it!'."(Tineke)

Although she knows that it would be better to reprogram the thermostat so that it matches their daily schedule better, but she cannot do it because she considers it as too complex. She is not able to appropriate the device in a suitable way that fits her own preferences and needs. According to Els Rommes (1999) the appropriation of a device is an activity: it takes time and energy. Tineke should put effort in it and has to usurp knowledge about the thermostat. But her own user logics and social context at home discourage her to turn it into a meaningful device. She believes that she misses the capacity and knowledge to understand the difficulties of the system, her husband hinders her to investigate or ask for help to others because he is afraid that the settings will be ruined. And so she becomes an 'excluded' user, because she cannot access the technology (Wyatt, 2003).
She prefers the former heating situation in which they could operate the thermostat manually. She was more aware of her interactions and behavior in relation to the indoor climate practice.

"In the past, I turned it down deliberately. But now I think, oh well, never mind. Because I do not want to disrupt the system. […] because my husband is afraid that the system will fail. […] That makes me more insecure and hinders me to do something about it."(Tineke)

Tineke told that she gradually got accustomed that she has no influence anymore and the thermostat has become in charge of their heating practice.
Their dissatisfaction also appears to roll over to other their energy behavior. She told that she does not longer worry about the energy bill anymore as is it used to be:

"Oh, I would not know. I no longer occupied with that, since I cannot control it anymore. I really have no interest in energy savings anymore. But I believe that we use more and pay more after the renovation."(Tineke)

Previously, when she could operate consciously the thermostat by hand, she was also more aware of the energy consumption, and engaged in energy saving at home. But since the heating organization was delegated to the thermostat, she also started to lose her interest in reducing energy. For Tineke, the thermostat took also that responsibility over. But since the strong mismatch between the program of the thermostat and her work schedule, and the fact that the living room is heated regularly when nobody is at home, is appears as an inefficient energy practice.

TAMAR DEVELOPED CONSCIOUS VENTILATION AND HEATING PROGRAMS

Tamar is mother of a young family; this entails responsibilities to her children. She believes that her children will copy their parents behavior, and is aware of her role and behavior.

"We are aware that we should be good examples for our children. We cannot afford it to abstain from it."(Tamar)

Tamar expressed that they find it important to be responsible for the environment and energy efficient, and want to raise their children with this value. They fitted this value into their household routines in practical ways:

"[...]We have a tray especially for paper, separate plastics and organic waste, that is good for the environment. We return empty batteries to colleting bins at the supermarket, and bring our own bags

with to the store. That stuff. We also try to be efficient with energy. Altogether, it are quite some extra actions, but if you do it structurally, than it's not too bad."(Tamar)

It is not easy to be a good model to her children. Tamar admitted that, if she would be alone, she would behave less strict. But she cannot afford that, since she is a parent. Thus her social environment motivates her to behave energy efficient.

Tamar expressed that it takes effort to organize the household practice and to be good parents. The 'secret' according to Tamar, is that she and Ties take time to negotiate about every detail of their household practice and make clear agreements. For example, they had open discussions about aspects of their indoor climate and energy behavior. They made clear rules about how to set the thermostat, what a good temperature is, when to heat room, to wear some extra clothes, to close doors etc. If new issues arise, they deal with it as soon as possible. This prevents real problems according to Tamar. Furthermore, the needs of their children are very important in these discussions. Practical rules that are result of their negotiation over the indoor climate, energy behavior and their parental role make the realization of a comfortable household practice much simpler.

Tamar and Ties have developed 'ventilation program' for the rooms of their children. Tamar can easily explain the considerations and motivations behind their plan. For example, the ventilation plan is about how and when to open inner doors (at night, because open fans and windows would be too cold for her children, and with open doors she can eventually hear if her children are awake), close doors (during the day, because her son can sleep without being disturbed by other people at home) open windows in the morning for an hour (when they are still at home, so that air of sleep can go and fresh air can come in), close windows during the day and open fans (to prevent burglary)etc. This practice is according to her comfortable and as energy efficient as possible with young children.

They also have heating rules for the living room. In the morning, they heat it for an hour so that they can have breakfast together in a warm room. Afterwards they go to daycare, school, work and study and make sure that the heating is of. Around five, when they come home again, they heat the room again, but a little less than in the morning. Because one parent will play actively with the kids and the other prepares dinner. Therefore they need less warmth. After dinner, the parents bring the kids to bed. Around 20:00h, Ties and Tamar spend some time together, they chat or watch TV. At 22:00h they lower the temperature said Tamar, because:

"We have to study in the evenings, which mean that we have to concentrate till late. So then we don't want the room to be so warm, otherwise you may get a headache or consider going to bed […] because that is what you get and want if it is too warm and stuffy at night."

Because their kids are not around, these late hour are ideal to study. To study they need fresh air and a cold room to concentrate.

Their heating and ventilation behavior can be explained from their motivations and 'household' logics. Especially the social context of the family and the process of negotiation at home enables agency to Tamar and Ties over their household practice. For them it is logical to make their environment meaningful in relation to heating and ventilation practices. They have a particular way of appropriating the facilities at home: they accept them as they come[31] and try to make the best of it.

[31] Tamar was the only respondent that brought no technical distimuli into discussion in the interview. Their way of appropriation gives the impression that they are always able to find a way to deal with technology that suits them.

They incline to tackle issues before they become big problems. Both have an open and flexible attitude and are willing to put effort in finding a good solution: they investigate and try out at home in order to create and maintain comfortable warmth and fresh air. They adjust themselves to the environment, and also attempt to adapt elements of their environment to their own preferences, needs and intentions. They constantly and consciously interact with their socio-technical environment in a practical and meaningful way so that it fits their everyday routines and household practice. Therefore Tamer and Ties can be considered as 'tinkerers' who actively shape their household trough creative interaction with the limited objects at hand in relation to their practical needs and competences (Lie & Sorensen, 1996). This particular way of appropriation the facilities at home that seems highly motivated by their mixture of preferences, values, intentions and conventions makes them powerful actors at home.

KARINA AND EDWIN ARE FORCED TO AN ENERGY INEFFICIENT VENTILATION PRACTICE

Karina and Edwin find their house rather comfortable, but it has one big disadvantage: the windows cannot be left open unattended. This interferes strongly with their preference for 'always fresh air' at home. They rather prefer to leave windows slightly open during the day, but are hindered by their perceptions about the neighborhood and the location of their house:

> *"Look, we are not at home during the day, so we cannot leave the window open. I would not be at ease because we live on the ground floor. It is a place prone to burglary. We also have to close the windows for the insurance. But when we are at home, then the windows are open ajar all day long. "(Edwin)*

They have the intentions to leave intruders outside, to prevent burglary and comply with the requirements of their insurance. Their meanings of safety wring with their preferences for a comfortable indoor climate. They can however leave the ventilation vents always open, nevertheless, they provide insufficient fresh air.

These socio-technical dynamic setting influence their behavior and stimulated them to develop a ventilation program to realize their needs of always fresh air as best as possible. They interact actively with material elements at home. Every workday when they get up in the morning, first thing they do is open de windows to let in some fresh air and turn on the radiators in the living room. Afterwards they get dressed and have breakfast. Just before they leave for work, they close the windows and turn off the radiators. As Karina and Edwin return from work, it is cold and stuffy inside. The lack of fresh air is unhealthy according to them, which motivates them to open the windows. But the fresh air is also cold, which conflicts with their need for a comfortable warm room. Therefore, they turn on the radiators at the same time as they have their windows open and wear some extra clothes.

A good alternative for them would be to install thieve claws on the windows. That would be ideal, because then they can leave windows secured open during the day and close them when they are home and heat. The claws could thus paly a mediating role that actively contributes to the way how they want to shape a comfortable indoor climate. It could take over their some of their interactions with the windows that they have to perform in order to guarantee safety. The locks would become responsible for fresh air during the day and safety. It will result in 'fresh' house when they come home and therefore they can close the windows in the evening and only heat. Therefore, the claws would also contribute to energy saving behavior in relation to the indoor climate. Despite many motivated request their side; the housing corporation does not give permission to place the locks. Thus their ventilation behavior is not only linked to their immediate socio-technical home environment, but also depends on further social disstimuli like their housing company.

They know that their current behavior is not efficient from an energy point of view[32], but they find it also important to be comfortable warm. Thus, their behavior can be partly explained from their user logics, but they motivate that they are 'forced' by safety circumstances, windows and ventilation vents and unwilling Housing Corporation to perform certain interactions. Their environment gives them the freedom to develop a creative ventilation program in different way than probably were envisioned by engineers. They opted for better alternatives, but without result.
Therefore, their behavior can better be understood as a result from the socio-technical dynamics around their than from their user logic. They reason that if they could leave the windows open during the day, their behavior would be different and more energy efficient. They hope for a better solution, but for the time being their order actively their environment as best as possible to their own meaning of comfort at home.

SANNE AND THE SOCIO-TECHNICAL THERMOSTAT FOR OPTIMAL COMFORTABLE WARMTH

Sanne articulated that the main convention of a commune is taking each other into account and respect other views and preferences in shared areas. This also applies for the indoor climate.

> *"Eight different people, eight different preferences. It's a trade of give and take: everyone has to give a bit and will get something in return."(Sanne)*

Thus, living in a residential group entails for all members to do justice to needs and rights of other members and that personal freedom is restricted. She chooses deliberately for this social set up and knew that this was part of the deal. Furthermore, it brings also many advantages, and therefore she does not consider it as a big concern.
What is more problematic at home is to realize an optimal indoor climate that is comfortable for everyone.

> *"Someone prefers a temperature of 14 degrees, another likes 23[…] one walks around in only a T-shirt and open all the windows, and the other wears a thick sweater and turns on the heating."(Sanne)*

The normal approach to realize optimal comfort in common rooms is via monthly meetings. Via regular negotiations they attempt to find compromises for conflicting preferences, values, and strategies. Sanne talks about these negotiations in terms of 'home politics' and conflicting interests. Therefore, it seems quite an explicit and official way to realize common house rules for optimal comfort. According to Sanne, this approach is necessary, because the household members have no family bond in which disputes are settled more unconsciously and natural. In these meetings have group values like environmental consciousness high priority and they stimulate to develop energy efficient groups behavior. Each member can hand in concerns that need to be discussed groups wise. These will be debated one by one during the meetings and afterwards they vote democratically for the best solution. If the chosen solution has sufficient support, it will turn into a new 'house law'.
The commune has developed several house rules to organize a comfortable heating practice. For example, a common rule for the temperature is drawn up for the living room-kitchen: 18 degrees is the standard, and a thermometer serves as referee. If a member notices that the thermometer displays a temperature below 18 degrees, he or she should take action. One can close the window and/or open radiators until the room reaches a temperature of 18 degrees. If the thermometer shows that it is warmer than 18 degrees, someone should undertake opposite actions. To ensure that they do not waste energy they added the rule that if someone leaves the home as last, (s)he should turn of the radiators. Furthermore, they tuned the central heating unit to the outdoor temperature

[32] They made clear that in another material setting, their behavior would be different.

and set it so that it can only heat between 7:00h and 00:00h. So they realize together with their technical environment a constant temperature of 18 degrees which lead to optimal comfortable warmth.
The group shaped a thermostat at home in which users and the material are interwoven and interact continuously. The task of referee is delegated to the thermometer; the group members are responsible to interact actively with windows, doors and radiators in order to organize a temperature of 18 degrees. They take into account that they should not waste energy, so when nobody is at home, radiators can be closed. They trust each other that they stick to their tasks, because it is in everyone's interest to secure optimal comfort. Everyone is responsible for energy efficiency, but a part is also distributed to the settings of the central unit. Those ensure that no energy is spilled on heating on warm days and during the night. This socio-technical thermostat results in a stable comfortable and energy efficient indoor climate practice.
Their heating behavior to form a socio-technical thermostat can be explained from the dynamics of their socio-technical environment and their household logics. The socio-material environment seems to push on the house hold logics to develop optimal comfort rules and those rules affect how the socio-technical environment becomes ordered.

5.3.2 In conclusion

The previous sections presented and discussed the realization of a comfortable indoor climate at home. It showed variation and diversity among the six cases on negotiations and interactions with their socio-technical environment and highlighted several complexities of user-climatic interfaces interactions in practice. The main conclusion is that the realization of a comfortable indoor climate appears to be a socio-technical achievement in daily practices. The discussions made clear the logics of users alone are not adequate to understand the behavior of users towards their indoor climate. Further socio-technical causes provide also many logical motivations for users to realize their indoor climate as they do. The next section discusses further socio-technical causes at home.

5.4 BEHIND CLIMATE BEHAVIOR: USE LOGIC, HOUSEHOLD LOGIC AND TECHNICAL INFRASTRUCTURE

This section should answer the question: *Which user logic(s)lay behind the realization of a comfortable indoor climate at home?* Having presented and discussed six cases of how users actively realize in various ways warmth and fresh air with heating and ventilation interfaces at home, the initial goal was to explore how these practices can be understood from the logics of users. But the findings revealed that in daily life is much more at stake than only the user logics behind the realization of a comfortable indoor climate.
So far we have come to recognize the shaping of a comfortable indoor climate as a sociotechnical achievement at home. Due to the complexities that are part of daily life at home, it is difficult to explain climatic behavior only by the concept of user logic. This section identifies and discusses household logics and technical infrastructures to understand the dynamics behind the realization of a comfortable indoor climate. This section closes with an opening to make climatic behavior more sustainable

INDOOR CLIMATE BEHAVIOR IS MORE THAN ONLY USER LOGICS

Users interact (or not) with their climatic interfaces to realize warmth and fresh air, but the motivations they gave for their behavior with the heating and ventilation systems reached beyond their own preferences, values, intentions and conventions. For users it was normal to think also about the wishes and strategies of other household members, and how they talk, bicker and deal with each other for solutions, under which circumstances they (non)use, manipulate and/or struggle with heating and ventilation devices, their needs to open or close windows and reasons to wear more or less clothes, and other household chores that intervene the indoor climate behavior. This means that in the realization of a comfortable indoor climate at home is more at stake that only the interactions between user and climatic interfaces and their considerations behind these actions. Users have to negotiate and interact with their socio-technical environment to realize warmth and fresh air. Therefore a comfortable indoor climate can be understood as socio-technical achievement.

Understanding the realization of a comfortable indoor climate as a socio-technical achievement makes it difficult to explain indoor climate behavior only by the logics of the users. What other dynamics are at work in regular domestic live? In revisiting the question, household logics and technical infrastructures at home behind indoor climatic behavior are highlighted, and the resulting difficulties can be understood as logical reasons for users to motivate their behavior.

HOUSEHOLD LOGICS

A way to understand underlying dynamics behind a comfortable indoor climate is to situate the logic of the user behind this realization in the daily household practices in the regular home environment and consider the household logics. The increase of scale from user logics to household logics comes with complexities. Not only the number of household members (can) increase, but also the number of negotiations and (inter)actions mediated by the individual climatic interfaces increase. Also other relevant household chores and further material infrastructures are of concern. One of the complexities is the number of household members increase. At least in cases with a more-persons household, not one household member is a user, but more household members are at the same time users of heating and ventilation systems. Each household member has her own mixture of preferences, values, intentions and conventions for heating and ventilation. This means that more logics related to the interactions with indoor climatic interfaces should be taken into account. But in the same vein, there is not only a division of work to be delegated to household members and technologies, but also between individual household members. Another complexity is that the realization of a comprehensive comfortable indoor climate is a practice with several 'core activities'. 'Core activities' of warmth and fresh may positively or negatively interfere with each other. This means that the related interactions with heating as well as ventilation systems matter at the same time. Moreover, not only user- climatic interfaces interactions drive that drive the realization of the indoor climate practice, but also further household chores. Other household activities in domains of bathing, cooking, cleaning, laundry and sleeping, may cause negative or positive interfere with what is going on in the realization of the indoor climate. Such interfering household chores should be taken into account in household logics. This kind of complexities of household logic matter, because they influence the user logics in search for a comfortable indoor climate that is situated at home.

The higher complexity of household logics causes difficulties that influence the user logic behind the realization of a comfortable indoor climate. Especially tensions within the household logics have an impact on the negotiations and interactions behind indoor climate behavior of users. Various kinds of tensions cause difficulties. Some of the difficulties are that different user logics may wring with each other. For example household members' preferences for warmth can vary widely as at Sanne's home; partners can behave differently towards their heating practice like Brenda and Marieke; and Tineke's intentions to find out how thermostat works clashes with her husbands' idea not to tamper with the settings. Other difficulties like internal indoor climate activities can contrast each other. To heat an enclosed room leads to a warm room quickly and permanently, but lacks fresh air. That makes concentration more difficult, result in fatigue and health issues. Vice versa, a room with mostly fresh air is for most users too cold. Furthermore, different household practices can be rivalry. Such as while cooking heat releases and that contributes to warmth, but it also results in food smells that interfere with fresh air or cleaning activities that hinder comfortable warmth. These are just a few difficulties that may arise when a higher level of complexity of household logics is taken into account.

Nevertheless, for users the dynamics of the complexities of household logics are normal and part of their everyday household practice. They experience many difficulties in daily live at home and have or find their way to deal with them in practice. Users seek to (re)organize and combine their whole of household practices in an optimal way. When they negotiate a comfortable indoor climate and interact with heating and ventilation interfaces, they take the tensions and complexities of the whole household logics into account. They try to coordinate the tensions in a harmonious way. For users it is logical to search for a comfortable 'match' of their whole household organization in the home environment. Much of their climatic behavior is rooted in routines of negotiations and interactions of (un)aware happenings guided by the household logics.

TECHNICAL DEVICES AND MATERIAL INFRASTRUCTURES

The findings demonstrated that the technical devices and further material infrastructures at home influence the realization of a comfortable indoor climate. Also much of users' climatic behavior is embedded In patterns of (un)conscious action guided by the technical set up of the home environment. Certain technical features of heating and ventilation interfaces support or hinder the negotiations and interactions of users.

The analysis of the individual cases was especially focused on those instances in which the technical context wrings with comfort at home in a broad sense. If the technical set up interferes with users' meaning of comfort, it causes difficulties for the user logics of a comfortable indoor climate. For example the case of Emiel demonstrated that he wishes to behave differently, but he cannot. Especially the technical setup of his socio-technical context forces him into a non-user of his own heating facility and encourage him to develop an anti-program to let the warmth escape. Although he has technical competencies and capabilities, that is not enough to behave efficient in regard to energy. Another example was presented in the case of Brenda and Marieke. They cannot appropriate their ventilation system into a meaningful device that contributes to their personal wellbeing. Although the system purifies their air environment, it calls their attention because it produces noise and unpleasant smells of their neighbors' practices. The device evokes resistance by the ladies and triggers them to perform creative hacks against its functioning. While that it is at odds with their household logics to mistreat something and they know it would be better not to do so because of ventilation optimal comfort of all and energy waste, the system results into too much discomfort they cannot ignore. Here, the inconveniences of the technology stimulate inefficient energy behavior. One more example was provided in the case of Tineke. She and her husband cannot domesticate the programmable thermostat. The responsibility of the schedule and preferable temperature of comfortable warmth is entirely delegated to the thermostat. However, the heating routine that it provides is a total mismatch with their daily household practice. The structure of the program is too complex for them: the device hinders them to change it settings. The material layout of the thermostat is inoperable too them, and turns them into non-users and ensured that they lost autonomy over comfortable warmth. Technology did not only take over control over their heating, but also lay hold to former corresponding awareness of energy savings of Tineke. These examples demonstrated that the technical setup causes difficulties for users' meanings of comfort at home. These technical difficulties interfere with their user logics of the realization of a comfortable indoor climate.

These examples demonstrated that the technical devices and material infrastructures at home matter for indoor climatic behavior. The technical factors take an active role in the realization of a comfortable indoor climate. Latour (1992) and Verbeek (2005) would argue that the technologies are not neutral but influence the common negotiations and interactions of users at home and mediate their daily behavior. The way how the particular technologies guide the users in these cases resulted in waste of energy or creates inefficient energy habits and routines. This means that the heating and ventilation devices and further material infrastructures are co-responsible for the way how indoor climate behavior develops and for what results.

Household and technical difficulties as comprehensive explanation for behavior

The household logics as well as technical infrastructures at home cause many underlying reasons for indoor climatic behavior of users. Many of the difficulties caused by household logics of technical infrastructures are lead to comprehensible reasons for users why they realize their indoor climatic as they do. Their reasoning may interfere and impact positively or negatively with energy efficient climatic behavior. It shows that at home is much more at stake than only energy savings. In many cases are users willing to save energy, but it is impossible or discouraged by the technical set up of home. Or other things are more important at home than saving energy, especially their comfort in a broad sense is important. Many of the difficulties of the household logics and/or technical set up are good reasons for users to behave in a certain way. However, such kind of behavior may be difficult for researchers to foresee in research. It is likely that such user behavior is seen by researchers as just energy inefficient and therefore called incompetent behavior. While users can be quite capable, but focus on much more than only energy and have logical motives due to their household logics or technical infrastructures to behave as they do at home.

Openings to make indoor climate behavior more sustainable

This section closes with a final comment. The recognition that the realization of a comfortable indoor climate is a social-technical achievement offers possibilities for more sustainable practices. The negotiations over fresh air and warmth and interactions with heating and ventilation systems are being shaped and driven by social structures of user and household logics and also by material stimuli and constraints that are integral parts of the home environment. They make that specific forms indoor climate behavior become embedded in patterns and routines of everyday life at home. It appears that the routines and patterns become deeper rooted in daily life, the longer users live together with the same household member(s) and/or in the house.

However, if something changes in the socio-technical context of users, their meaning and realization of a comfortable indoor climate are open for discussion. This was said latterly by some users. Other users told more indirect about past situations in which the socio-technical circumstances were different and they had other habits and routines. Or users foresee that their will behave differently when they think about the future. This implies that changes in the socio-technical environment are openings for change.

That is consistent with the claim of Jelsma (2005) claimed that user logic is in motion. He suggests that changes offer opportunities for energy efficient injections into everyday practices. I suspect that the chance of success of achieving energy efficient practices most likely will succeed when there are changes in the socio-technical context and that impact will be little in homes with firm socio-technical bonds. Perfect moments to stimulate energy efficiency could be a migration, a reconstruction of renovation, the introduction of new technology, removing obsolete technologies, a break up between partners, a new relationship, family planning, a baby etc. Such kind of changes make that users have to reconsider their everyday practices again. Therefore are changes in the socio-technical context promising moments to stimulate energy efficiency.

5.5 CONCLUSIONS

This chapter addressed the shaping of a comfortable indoor climate at home from the perspective of users. The main conclusion is that the shaping of a comfortable indoor climate at home appears as a socio-technical achievement. As expected the diverse six cases showed a variety of what actually happens in 'natural habitats' of potential users of climatic interfaces that are under study at ECS research practice. This made it difficult to identify a shared construction of a comfortable indoor climate by users and a common way to organize the indoor climate.

How is "comfort" regarding the indoor climate constructed by users at home?

The meaning that users give to a comfortable indoor climate of users was gradually examined from broad to narrow. This allowed to discuss shared dimensions of housing selection, feeling at home and indoor climate conditions as warmth and fresh air that matter for users, but are outside the scope of researchers. For users it is normal to consider the indoor climate as a dynamic interplay of indoor climatic conditions like warmth and fresh air. Users have rather different ideas about indoor climate conditions and describe them in different ways than is normal for researchers to do. Users do not submit to a definition of indoor climate that is predefined in research practice, but actively make sense of the indoor climate from their own home context. Therefore, users' meanings matter as well as their socio-technical environment matter and should be taken into account in ECS research. Furthermore, for users the meaning of a comfortable indoor climate reaches far beyond only the indoor climate. Also aspects like status and appearance of their house, outside view, neighborhood, daylight, but also their interpretations of autonomy, safety, health, coziness and being together and many other elements at play a role. Users give meaning to a comfortable indoor climate they focus on their feelings and experiences in relation to other people and circumstances at home. Especially if they were able to choose their own house and feel at home contributes to their wellbeing at home. For users normal to consider their indoor climate is a characteristic of the socio-technical environment.

How do users realize a comfortable indoor climate in at home?

After the discussion of the users' meaning of a comfortable indoor climate followed how they realize it daily practice. It highlighted negotiations between household members and interactions with heating and ventilation systems. This allowed discussing the complexities of technologies in use in daily practice.

Which user logic(s)lay behind the realization of a comfortable indoor climate at home?

The initial goal was to identify (elements of) user logics that help to understand their indoor climate behavior. But the cases showed that the realization of a comfortable indoor climate is more than the interactions between user and climatic interfaces and their logics behind these actions. At home, the realization of a comfortable indoor climate can best be understood as a socio-technical achievement. The complexities that users come across in daily life and are part of their socio-technical home environment make it difficult to understand their indoor climate behavior only from user logics. But it allowed to isolate household logics and technical infrastructures and identify important dimensions that cause difficulties that interfere with the core activities of a comfortable indoor climate at home. The difficulties that users have to deal with in practice provide many comprehensible reasons for their indoor climate behavior. Furthermore, their meanings and realizations of a comfortable indoor climate become gradually taken for granted by the stronger the bond with their socio-technical become. But if something in their socio-technical environment changes, this offers opportunities to stimulate more sustainable indoor climate practices.

At this point, the users are pretty much in constant engagement in the practical challenge of negotiations and interactions with their socio-technical arrangement of home and in the realization what for them are comfortable indoor climatic conditions. It is a dynamic process of trading, juggling and manipulation, whether wishes, clothes, activities, windows, health, autonomy, or building related systems. For users it seems normal to adapt their strategies to the circumstances at hand.
Essential is that a comfortable home in a broad sense, requires a socio-technical context that offers adequate opportunities for adjustment and adaptions: a home in which users can make themselves comfortable. This way of thinking makes sense because heterogeneous users are able to fit in various conditions in the kind of reactions and behavior they embrace.
With this perspective it is possible and perhaps realistic to see climatic interfaces tools by which users want achieve a comfortable indoor climate experience. It is challenging to specify the relation between individual climatic devices, the meaning and the experiences they bring about for users. Users can make themselves comfortable (in combination) with other means too like doors, windows and clothes. So far became clear that the realization of a comfortable indoor climate stretches beyond the appropriation and use of individual climatic interfaces. But technological aspects of heating and ventilation systems have a co-responsibility for the way behavior develops and for what result.

6 COMPARISON

This chapter provides a comparison and analyses some of the complexities behind deviation between calculated energy efficiency of indoor climate systems and actual energy consumption in housing.
In chapter four was analyzed how user representations and comfort constructions are combined into a coherent research process with underlying design logic on which the researchers agree. In chapter five was analyzed how users give meaning to and realize a comfortable indoor climate. Their behavior was not only being shaped and driven by use logic, but also depends on household logic and the material context that are integral part of the practice at home. These findings will be compared in an aggregate way.
The goal is to identify underlying dynamics for differences between calculated energy use in research and actual consumption at home by comparing design logic and use logic for inconsistencies. In section 6.1are three aspects of design logics of the research process and underlying logics of the daily practice put side by side for a comparison to see to what extent they are different. The differences are useful to deduce clues for deviation of actual energy consumption from calculated energy use, and provide openings for change to stimulate energy efficiency. Section **Error! Reference source not found.** discusses openings for design logics to incorporate use logics in a better way aiming at research that supports users well-being better in the in the home environment, in responsible of scares resources.

6.1 COMPARISON BETWEEN ECS RESEARCH AND DAILY PRACTICE AT HOME

This part provides an aggregate comparison between elements from ECS research logics and reality of use logics at home. Three aspects of design logic and use logic will be compared for discrepancies. Firstly, the normalized definitions of comfort and standardized user representation that are inscribed due to standards into the research process on indoor climate systems will be examined in contrast to the diversity and variety of daily practices at home. Secondly, the representations or 'mental models' of the smart and incompetent user that are reproduced in ECS research area are compared with users' actual climatic behavior at home. Thirdly, the different understandings of a comfortable indoor climate of ECS researchers at work and users at home are compared.

6.1.1 STANDARDS VS DIVERSITY

Standards are logical means for researchers to bring in users and their comfort needs into technical ECS research. But do standards give a correct picture of users and their comfort needs?
A first point of comparison is made between the normalized way of thinking in relation to the diversity at home. The second point of comparison is the underlying assumptions of standards in relation to real users at home.

STANDARDIZED USER AND NORMALIZED DEFINITION OF COMFORT VS DIVERSE USERS AND COMFORT NEEDS

The findings in chapter four showed that standards embody a 'standardized user' and represent normalized definitions of comfort. These conceptually molded constructions are idealized ideas about how a large and heterogeneous group of users are supposed to behave and their whimsical needs for comfort. The standardized user and normalized definition of comfort serve as 'neutral' theoretical guidelines for researchers to define users in interactions with indoor climate systems. The application of standards helps to focus on measuring and testing the efficient operation of indoor climate systems. The application of standards is designed to make certain knowledge about users and their comfort needs more 'normal' than others. The researchers use standards mostly because they work in an area with no to little knowledge about users and their comfort needs. Thus standards serve as a practical solution for information in a situation in which concrete details about real users are hardly available. At the same time, standards make it normal for ECS research to think about users as technical factors. With help of standards ECS research conforms to statistics, rules and formulas about users and comfort. This way of thinking about users and comfort is very dominant in technical research setting.

However, the normalized way of anticipating users in ECS research does not match with the diversity and variety that was observed in users' actual everyday life at home. The six cases demonstrated that users come in many different shapes and sizes and each story about behavior and comfort needs was unique. This means that the abstract formulized consistent, uniform and average user with universal comfort needs as present in ECS research does not exist within the six cases starring actual users. The differences reach much further than just variation between demographic factors and only diverse preferences for a certain temperature: much more is outside the scope of the researchers. The six cases showed that users have different experiences, insights, knowledge and skills, behavior and actions, needs and desires. But also the choices and flexibility at homes vary greatly among users: for example, the findings showed great diversity in how users organize their household, deal with circumstances at home and adapt to the home environment. These kinds of differences are all relevant. Because of the heterogeneity among the cases, each user has a dissimilar position in relation to their indoor climate systems at home. The findings showed that the standardized expectations of ECS researcher deviate greatly from the diversity and variety of what actually happens at home.

ASSUMPTIONS ABOUT PASSIVE USERS AND ISOLATED INDOOR CLIMATE CONDITIONS

Furthermore, the technical way of thinking about users that is promoted by standards bring about certain assumptions that also underlie ECS research; these expectations show mismatches with findings about real users at home. Two of such assumptions are compared with reality. One assumption of using standards is that users, their behavior and comfort needs exist independent of the indoor climate systems. The standardized user and normalized definitions of comfort promote to express users' behavior and their comfort needs as functions of indoor climate. In this way, researchers consider users as constraints or construct them as passive recipient of indoor climate stimuli. However the findings about users showed that users do matter, they are powerful actors in real life. Users are not passive, but give actively meaning to comfort and make themselves comfortable in their home environment. Another assumption stimulated by standards is that a comfortable indoor climate can be fine-tuned and reproduced. The resettable parameters of the standardized user and normalized comfort definitions allow researchers to experiment in a laboratory and manipulate and monitor indoor climate conditions in order to gather data about technical performance of indoor climate systems. But the stories of the users showed that their home environment is extremely important.

The indoor climate becomes meaningful in relation to, and appears as a characteristic of their own socio-technical context. This means that the meaning of users and their realization of the indoor climate depends on the context and cannot be copied into another environment. Thus, investigating the systems independent of users and their environment to repeat and control the climatic situation is at odds with what happens in the real world. These two assumptions present in the ESC research domain about how user behave at home derived from standards, are incorrect according to the results of the study about real users in daily life.

6.1.2 SMART AND INCOMPETENT USER REPRESENTATIONS VS REAL USERS AT HOME

The findings showed that real users are not present in ECS research, but that users are nevertheless present. Besides the standardize user that is derived from standards are more users present in forms of personal anecdotes of researchers and family members, complaints of users, systematic biases towards technology, and (gender-) stereotypes of ECS researchers. These result in 'mental models' of the smart user and the incompetent user in design logics of the research process. To what extent do these user representations correspond with reality?

The first point of comparison is the representation of the smart user with a real case, and then follows a comparison between the incompetent user and actual cases.

REPRESENTATION OF THE SMART USER VS REALITY AT HOME

The findings of the ECS research practice demonstrated that the representation of the 'smart user' is based on personal expert experience of researchers in the home situation via the 'I-methodology'. Each researcher has strong picture in mind of how users should behave smart with indoor climate systems at home. A typical smart user has technical knowledge and skills, an investigative attitude and aims for innovation and energy savings. Smart users are in control and motivated by increasing comfort and energy and financial savings. Researchers justify the smart user on the basis of its contribution to achieve research goals. Smart behavior leads to logical and rational interactions with indoor climate systems. Moreover, they believe that a smart user interacts investigative and intelligent with the systems. This will lead to potential innovations that benefit the (energy) efficiency of the systems.

The case of Emiel serves as a good example to compare with the smart user. Emiel is a PhD student Civil Engineering. He has technical understandings and values efficient working of technologies in general. He has an investigative attitude towards the world around him, opts for improvement and wants to be in control. These characteristics match with those of the representation of the smart user, and researchers would probably agree that Emiel is a smart user.

But despite the smart characteristics, Emiel is not able to behave smart in at home. His socio-technical environment is arranged in such way that it works too perfect: it becomes excessively warm in his home on top of the building. The roof insulation, the setup of the central heating system of his flat and the condition that warm air goes upwards, result in a situation in which his own heating behavior depends on the heating practices of his neighbors. A temperature of 30 degrees is easily achieved in his room and he really needs to do his best to get rid of the warmth by using doors and windows. From an ECS research point of view, Emiel's behavior cannot be described as smart. In line with a technical perspective of interaction with indoor climate systems, his behavior would be described as illogical, irrational and does not support energy efficiency. Emiel's behavior at home is difficult to anticipate and hinders accurate predictions. Good chance that he will be considered as an incompetent user by researchers.

In the case of Emiel his actual behavior at home cannot be explained from his user logic, in reality counts much more to understand his interactions with indoor climate systems. Despite his smart user characteristics, it is his socio-technical environment that forces him to specific behavior and turn Emiel into a non-user of the heating device at home. It is the context that provides comprehensive reasons to explain why Emiel does not behave smart at home. Apparently, just technical understanding of users does not necessarily result in smart behavior with indoor climate systems at home. The case of Emiel proves that the user representation of the smart user is thus not (always) accurate to reflect reality.

Representation of incompetent user vs reality at home

The findings of the ECS research showed that the representation of the 'incompetent user' is based on two methods and always linked to a form of technical incompetence. Researchers combine their personal observations of their family members with official complain of users. These family members behave inappropriate with indoor climate systems to their opinion and they tacitly assume that complaining users are not able to handle the technical situation in a good way. These personal ideas about real lay users bring about the representation of the incompetent user, and it stands for the majority of lay-users of indoor climate systems. The core of the incompetent user is that he or she lacks technical insight, skills and capabilities. This user is incapable to behave competent with indoor climate systems. Researchers are skeptical about this kind of user. They characterize the incompetent user as impulsive, clumsy and stupid, easily frustrated, barely interested in technological development and having difficulties or not willing to adapt their behavior to new efficient technologies. It is difficult for to deal with the incompetent user in technical research, because researchers consider incompetent behavior as illogical and irrational. Researchers believe that incompetent behavior complicates the technical performance of indoor climate systems and interferes with making precise prediction about energy use at home.

But to what extent does this representation of the incompetent user match with lay users in daily life? Already at this point it becomes problematic, because none of the users from the five remaining cases fits precisely the description of an incompetent user. The beliefs of ECS researchers about the characteristics of an incompetent user do not accurately reflect reality.

The case of Tineke might be the best example to relate to the incompetent user, because she would likely consider herself as a kind of incompetent user of her programmable thermostat. Besides many other characteristic like being open-minded, flexible and willing to change, she also described herself as insecure, uncritical, and doubt if she has the appropriate knowledge. The researchers would probably isolate the last characteristics and label her as an incompetent user too. The stabile heating pattern that is facilitated by the thermostat does not match their flexible daily household schedule. She would like to adjust the settings of the programmable thermostat, but she is not able to accomplish that. Tineke, who could use some help and encouragement, is held back by her husband, who is afraid to mess up the settings. In addition, the operation of the device is too complex according to Tineke, which complicates to appropriate the device. The home situation turns her into an 'excluded' user because she cannot access the thermostat. Without any reference to the situation at home this behavior can be easily labeled as incompetent behavior. It does probably not seem rational and is difficult to foresee for researchers. However, her 'incompetent' behavior only be explained partly form her own characteristics and user logics. She would like to behave different, but her socio-technical environment provides understandable reasons why the situation does not change in this home. Presenting Tineke as an incompetent user would result in a one-sided picture that does not accurately reflect on the actualities at home.

Another example that might at first sight look like incompetent behavior is the case of Karina and Edwin. However, they have comprehensible reasons to develop an energy inefficient ventilation program. They would like to ventilate for fresh air during the day, when they are at work. However due to safety issues in their neighborhood they cannot leave their windows open unattended. Moreover, their housing company does not allow them to place thieves' claws; otherwise they could leave the windows secured open. Without ventilation possibilities during the day, they find that their living room is cold and stuffy at the end of the day. Therefore, they heat and open windows during the evening. This behavior may look incompetent, but it cannot be explained from their own user logics, nor do they have incompetent user characteristics. They would rather like to behave differently, but their socio-technical environment contributes to energy wasting behavior. Also in this case the representation of incompetent use fails to reveal what actual is at stake.

Also in the remaining cases happen things at home that may be considered as 'incompetent' behavior. All users explain their realization of a comfortable indoor climate from their home context. In normal life is much more at stake that only the energy efficient side of their heating and ventilation behavior. For the other cases I invite the reader to read chapter 5.

The home context comes with further socio-technical complexes that influence climatic behavior. Especially the household logics and technical and further material infrastructures at home are discussed as concept that provide underlying reasons for indoor climate behavior of users. These concepts show that at home are other priorities than only energy efficiency. The cases make clear that at home, behavior reaches far beyond the technical considerations of smart and incompetent user-technology interactions.

To conclude, the 'mental models' of researchers form about users are not sufficient to explain users climatic behavior. The mental models do not only represent users self in a limited way, but also ignore other dynamics at home like use setting, household logics, material infrastructure and other circumstances of the socio-technical context that influence climatic behavior of users. .

6.1.3 UNDERSTANDING OF COMFORTABLE INDOOR CLIMATE: IN RESEARCH AND AT HOME

This section compares differences between understandings of a comfortable indoor climate in research logic and at logics of users at home. It highlights the differences between the concept as a technological notion and well-being at home; the narrow and broad meaning; the different vocabularies for the indoor climate in research and at home and finally it zooms in to two indoor climate conditions.

THE CONCEPT OF A COMFORTABLE INDOOR CLIMATE: CLIMATIC TECHNOLOGY VS WELL-BEING AT HOME

ECS researchers understand 'a comfortable indoor climate' as an *object* bound concept. Researchers interpret (human) comfort experience as something that can be regulated with indoor climate systems, such as heating and ventilation systems. Because they belief that climatic systems are in service to control indoor climate conditions. Their focus is on how well the systems can provide indoor climate conditions and investigate if those can be improved, rather than the well-being of future users. Thus, in the ECS research area the concept of 'a comfortable indoor climate' is related to climatic interfaces.

But users think rather different about the concept of a comfortable indoor climate. They relate it to their own well-being at home. Users give meaning to the indoor climate in relation to domestic circumstances and socio-technical home environment. Their own comprehensive feelings and experiences of satisfaction, calmness, relaxation, and contentment are leading to determine the indoor situation as comfortable or not. Thus, users consider a comfortable indoor climate as *subject* bound concept.

The meaning of a comfortable indoor climate: strict in research vs broad at home

In the ECS research area, a comfortable indoor climate has a narrow and abstract meaning. Researchers understand a comfortable indoor climate as a technical achievement. For practical reasons researchers translate a comfortable indoor climate, with help of standard, into a function of technology. That allows studying the built-in comfort function of indoor climate systems in ECS research area. Thermal comfort standards allow reducing a comfortable indoor climate to 'thermal comfort'. Thermal comfort specifies thermal conditions that determine human satisfaction with the environment. The researchers told that temperature is the most important thermal condition. Furthermore, thermal conditions are also a little bit of air circulation, humidity and air composition.
These four conditions have to be coordinated by climatic systems and that should lead to a comfortable thermal experience of the environment. Researchers approach the coordination and four conditions of comfort as a technical problem that requires quantification. Comfort equations are offered by the standards. Researchers use the abstract formulas and numbers as definitions for the thermal comfort function of indoor climate systems. Thus, thermal comfort equations are applied to define a comfortable indoor climate in research setting.

The strict meaning that researchers give to a comfortable indoor climate deviates from how users give meaning to a comfortable indoor climate.
Users meaning of a comfortable indoor climate is rather broad and reach beyond only comfortable indoor climate conditions. Users understand a comfortable indoor climate as a state of being that they have or want to reach in relation to their socio-technical environment. Thus they consider a comfortable indoor climate as a socio-technical achievement. Comfort ideas about housing, living atmosphere and indoor climate itself influences their meaning of a comfortable indoor climate. Three conditions are essential to determine an indoor climate as comfortable. A first conditions is that users want to make a deliberate choice for a house so that they can accept the indoor climate as a consequence of their choice. In their choice they take into account factors like: status and appearance of their house, outside view, neighborhood and daylight. But they also think of the doors, windows, building related systems, arrangement of the house. For users, is it normal to consider these factors in their decision, this leads to indirectly to the expectation of a certain indoor climate as a characteristic of their house.
A second essential condition is that they have to 'feel at home'. This means that users want to experience privacy as being free from interference from others outside their home, freedom to do what one likes to do, maintain good relationship with other people at home and that the organization of the home mirrors their personality. This set of dynamic 'feeling at home' dimension have a strong impact on how they think about the indoor climate. The socio-technical environment has to offer possibilities to maintain a 'feeling at home'. A third condition is that their environment has to be comfortable warm and have fresh air. Such conditions are relevant for users to determine the indoor climate as comfortable (or not). This means that a comfortable indoor climate at home is not about four climatic conditions, or technology, nor only about interactions user-climatic interfaces, but many more social-technical (f)actors matter. For users a comfortable indoor climate has a wide meaning at home.

To conclude, the meaning of a comfortable indoor climate differs in the logics of researcher and users. Researchers think about comfort in strict and abstract terms: they link thermal comfort conditions to the indoor climate systems regardless users and environment. However, for users reaches comfort far beyond thermal comfort only, they link it to their own home environment, so that comfort appears as a socio-technical achievement in which all household members, further technology, situation at home and the context itself matter.

VOCABULARY OF A COMFORTABLE INDOOR CLIMATE: RESEARCHER AND USERS

Researchers and users use different descriptions to phrase the 'indoor climate'. According to the researchers, the indoor climate is determined by four indoor climatic conditions of temperature, air circulation, humidity and air composition. Researchers take the indoor climate as a taken for granted concept. For users, it more complex and took more effort to determine what the indoor climate is. Users mention several climatic phenomena like warmth, fresh air, draft, smell etc. These phenomena are in their terms indoor climate conditions and form together the indoor climate.

Their descriptions of the conditions that form the indoor climate differ, but also when the indoor climate is 'comfortable'. Researchers focus on quantification, they need numbers for the individual climatic conditions and a formula to fine-tune the four conditions with each other. Comfort is a matter of solving the comfort equation. For users become indoor climate conditions meaningful in relation to their home environment. They describe how they experience and organize conditions at home by linking them to their socio-technical context. For example, 'humidity' is associated with the bathroom and appears after a shower, humidity is explained as damp, and appears as a layer of moist on the mirror and windows. Ventilation is required to get rid of the humidity and avoid the formation of mold, and therefore they open windows or doors etc. This is just one condition, but all the indoor climate conditions together form the 'total phenomenon' of the indoor climate for users. The whole of the indoor climate does at home not appear as a sum, but as a dynamic interplay. Within this dynamic interplay of the indoor climate arise tensions throughout the day. For example, different user logics, different conditions can be contradictory or household tasks can interfere with the indoor climate. A comfortable indoor climate is for users not only a matter of fine-tuning climatic conditions but also coordinate tension within the interplay. Thus researchers count and calculate, whereas users describe and gather the indoor climate as comfortable.

DIFFERENT VOCABULARIES FOR TWO INDOOR CLIMATE CONDITIONS

The first indoor climate condition is in researchers' vocabulary 'temperature', and in users terms 'warmth'. The researchers use temperature as a comparative objective to measure the 'hot' or 'cold' that a heating systems should provide. For users is 'warmth' much more than temperature and technology. Although users have no common description for warmth, shared dimensions of warmth could be identified. Users think about the practice of heating and focus on the result: warmth. First of all, their heating practice includes more sources that contribute to warmth than only heating devices: it also includes for example sunlight, the stove, the oven and candles. Secondly, their particular doings at certain moments guide what they consider as comfortable warmth. For example, different activities like vacuum cleaning, computer activities for work or chill on the couch watching TV matters. Their comfortable warmth preferences vary if they are physical active, need to concentrate or relax. Thirdly, in some cases depends their comfortable warmth depend on the practices of their neighbors. The effect of heating sources, activities, dependence of neighbors heating practices on comfortable warmth vary and have to be coordinated throughout the day at

home. Finally, for all users are clothes and blankets means to fine tune their personal preferences comfort with the warmth in the environment.
Thus when users think about their heating practices at home to define comfortable warmth, heating systems are just one of the means to achieve comfortable warmth, and warmth is more than only temperature. It is thus difficult to catch ‘warmth’ in the number of a ‘temperature’ and give heating systems a central place in the practice of heating.

The second indoor climate condition has to do with air. Researchers consider the mix of composition, circulation and humidity of air. They quantify air with numbers to know what ventilation systems should technically produce. Users describe comfortable air as: new, natural, cold, healthy, and oxygen-rich. Users think about the practice of ventilation and focus on the result: fresh air. For users it is important that fresh air comes from the outside and flows through their house. They prefer to use vents, windows or doors to let fresh air in. That is because the observable openings ensure them that it is actually fresh air. The lack of fresh air is a strong motivation to ventilate, because it causes problems for health, concentration and mood. The most important difference of the descriptions of air between researcher and users is that users call it natural and that they have to see (to ensure) that the air comes from the outside.
The differences between the description for air have an impact on ventilation. For researchers is ventilation: the organization of the composition, circulation and humidity of air, whereas ventilation for users means the organization of fresh air. According to researchers ventilation can be organized with ventilation systems, but users reject this literally. To users’ opinion, ventilation system cannot provide the ‘fresh air’ as they describe it. Users understand that ventilation units can clean or filter the indoor air, but that is artificial air to them. The main problem of users with ventilation systems is that they have no guarantee that the air comes from the outside, they want to be able to see that.
In addition, in the case of collective ventilation systems, users do not notice the benefit of ventilation systems above windows or doors. Moreover, they notice mainly the negative influences of the collective ventilation when practices of their neighbors interfere with their own fresh air conditions at home. For example when the can smell food, smoke and toilet visits of their neighbors, they find this extremely uncomfortable and may open windows. Users are no big fans of ventilation systems, but it probably would help if users can observe that the facilitated air of ventilation systems comes from the outside.

To conclude, this comparison shows that a comfortable indoor climate means much more to users than heating systems that can control temperature and ventilation systems that regulate the composition, circulation and humidity of air. The inconsistencies between research area and the home domains are presently outside the scope of ECS research. The perspective of real users relevant to take into account in research on indoor climate systems because they help to understand why users deviate from the standardized, smart and incompetent user representation.

6.2 CHANGING DESIGN LOGIC TOWARDS INCLUSION OF USE LOGIC

The comparison gave an aggregate evaluation of some aspects of design logics and use logics. By comparing the actual practice with research process several discrepancies with relevance to underlying dynamics to anticipated (energy) behavior and actual (energy) behavior in reality arose.

On top of these discrepancies lays one major difference between the research logic and logic of the daily practice. The underlying logic of the research process is that a comfortable indoor climate is seen as a technical achievement of indoor climate systems. But in daily practice at home a comfortable indoor climate appeared as a socio-technical achievement in context. in the underlying logic of the daily practice not only the logic of users shape and drive their climatic behavior, but also household logics, material infrastructure and further circumstances of socio-technical home context influence the daily practice. Thinking about the indoor climate as a socio-technical achievement would help to improve design logic of the research process to support energy savings in daily practices in a more effective way.

SHAPING A COMFORTABLE INDOOR CLIMATE AS SOCIO-TECHNICAL ACHIEVEMENT

The key point is that 'the home' is the place where users are in 'control' of shaping their comfortable indoor climate. For users a comfortable indoor climate comes about in a home environment that offers possibilities for adjustment and adaptation. In other words, users make themselves comfortable in their socio-technical environment. From the perspective of users a comfortable indoor climate should not be defines as a function heating or climate systems, but it should be viewed as a socio-technical achievement at home. Accordingly, conditions count as comfortable when users are offered varied, flexible and socially as well as technically viable means of avoiding discomfort. This way of thinking helps to understand that users adapt their strategies to the circumstances at hand, not only in terms of thermal comfort, but in all sorts of behavior they adopt in a broad sense at home.

In the underlying logics of daily practice, users are pretty much in a constant engagement in the practical challenge of giving meaning, negotiations and interactions in the shaping of a comfortable indoor climate. The socio-technical achievement of a comfortable indoor climate can be understood as a creative process of trading, juggling and manipulation, whatever other household members, clothes, health, activities, autonomy, household chores, and material infrastructures at home. This means that in the underlying logics at home heating and ventilation systems have not a central place at home; they are just like various other people and materials part on the home environment.

With this perspective it is possible and perhaps more realistic to see heating and ventilation systems in research process as means that can support users in their organization of a comfortable indoor climate experience. Be aware of the socio-technical factors and other materials in the home context. It would be good to recognize that a comfortable indoor climate stretches far beyond the appropriation and interaction with individual climatic interfaces. It is challenging to specify the relation between individual climatic devices, the meaning and the experiences they bring about for users. Users can make themselves comfortable (in combination) with other means too like doors, windows and clothes. The indoor climate systems should at least offer the users a degree of autonomy and possibilities for adjustment and adaptation. So that they can assemble their indoor climate as they want and let the users decide themselves what is good. Because otherwise, if users are not content, they will find other ways to organize comfort. Moreover, it would be good to consider how the systems support the substances of a comfortable indoor climate. Users do not solely consider the temperature and the quality of air, but they need comfortable warmth and fresh air.

STANDARD DO NOT REFLECT THE DIVERSITY IN REAL LIFE

This means for design logics that the standardized user and normalized definition of comfort and underlying assumptions are far from perfect as research tools to anticipate real users and comfort in daily life. Just because users, behavior and comfort needs are stamped with formulas and numbers does not, by itself, indicate that the standards fit for any particular case. In actuality, neither users, their behavior, nor needs are homogeneous categories. The single entities of the standardized user and normalized comfort definitions as set of disparate characteristics, to serve the functionality of technology, do not merge into tight configuration to accommodate the real world. The reality of the relationship between users, their behavior and preferences concerning indoor climate systems at home cannot be captured in standards. Thus expectations about future users derived from standards will deviate positively or negatively with what actually happens in the real world of users.

Regardless of the great mismatch between expectations and reality, the research logic behind the application of standards highlights especially its usefulness. ECS researchers gave several motivations for the use of standards. Standards are not only valuable as an easy available means, theoretical guideline and variety control for users and comfort needs. But standards also appreciated because they help to make research activities itself and the distribution of research tasks more efficient, errors during research decrease, and research methods, procedures and results can be compared with each other. In addition, the ECS research group is a participant in a broader network of actors in the built environment. Within this network, standards are widely accepted and serve as professional reference. Standards function as solution to coordination problems and help to maximize compatibility with the other actors, ensure interoperability and interchangeability of technologies within the built environment. These motivations focus especially on how helpful the standardized user and normalized definitions of comfort are for ECS research, despite the downside that a link with real life practices misses.

Despite their strong plea for standards as practical means, this does not make that the standardized user and normalized definitions of comfort that are embedded in ECS research are correct. Their argumentation is no guarantee that the chosen standard will meet expectations about all users' behavior and needs or even that standards are the best available option.

The research logics determine how the standardized user and normalized definitions of comfort become inscribed in the research process in such way so that users and comfort become 'functional'. Translating the functionality of standards has an advantage. It makes clear that standards are no objective properties of research, and that the standardized user and normalized definitions of comfort are only one of the more possible constructed ensembles.

According to Jelsma (2005), design logics are a- deterministic in that it depends on the logics of the members of the research team. If the ideas of researchers change or the research team itself by adding others, the design logics on standards may change, and thus inscribed values of users and comfort. Realizing that standards do not match the real life of users may very well be a signal for success. Standards should not be examined so much from the practical benefits for research, but rather form the viewpoint whether they help to achieve the bigger goal to save energy in actual practice. The researchers should take the responsibility to consider standards as correct tool to bring in users into research, reflect on the agency of users and the context of use of indoor climate systems, specify good standards or other alternatives enforce compliance and use the methods correctly.

USER REPRESENTATION OF SMART AND INCOMPETENT USE DO NOT REFLECT ACCURATELY THE REALITY AT HOME

Neither the user representations of the smart and incompetent users provide images that correspond with the underlying logic of the daily practice. By isolating smart and incompetent characteristics and behavior in relation to indoor climate systems, researcher produces stereotypes that are representative for a large group of users. For example, the majority of lay people can be considered as a homogeny group. But as the comparison made clear, both the smart and incompetent user representations are far from perfect. They give an oversimplified, exaggeration and generalization picture of reality. They fail to convey the real needs and desires, negotiations and interactions of users' side and leave no room to take into consideration the complexities and priorities due to the socio-technical home environment. The user representations as such are mainly used as justification for research conduct. The smart user is mobilized to support the assumption of intelligent user-technology interactions in research setting, and the incompetent user as an argument to keep lay people at distance.

The big problem is that users do not speak for themselves, but are rather spoken for, interpreted and reviewed by the researchers. Both the smart and incompetent user representations are developed by researchers. The researchers use their own experience and their interpretations of experiences of family members and complaining users to generate a model of smart and incompetent users. These models are not only created by the researchers, but also judged by the researchers self as (in)appropriate in combination with indoor climate systems.

What is problematic that ECS actors give themselves via the 'I methodology' a dual role to themselves: that of researcher and of expert users. This dual role allows them to project unconsciously their own behavior and interests on the future user and ignore other needs and behavior. They translate their beliefs and thought into 'facts' that can be used in research practice. The dual role makes it difficult for researchers to recognize that their foreseen smart and incompetent relation to the indoor climate systems are different from the way that real users perceive the relation form their own socio-technical context.

The user representations suffer from at least three flaws. They are the result from the experiences of those that are active in the investigation of indoor climate systems. The researchers suffer from bias and their images of typical users are skewed in relation to indoor climate systems. Furthermore, the ECS research area is dominated by men; they can easily plot their own masculine bias rooted in the dominant design logic on the user images. And perhaps more troubling, the user representations seem to suffer from a systematic bias rooted in the dominant research logic. Since the researcher participate in technical research area, they are biased to seeing the world of indoor climate systems from a technical point of view.

Furthermore, the user representations that researcher mentally form about users are not sufficient to explain climatic behavior. At home is much more at stake than good or bad interaction with indoor climate systems. Users do not only explain their behavior from their own logics, but also household logic and the material culture and other circumstances in the use setting influence their behavior.

Understanding how user representation are constructed, their role and shortages, may give an opening for injecting ‘real’ user into ECS research in a better way. Are there better alternatives? What is the role of ECS actors in the research area and what are their responsibilities to protect the users and energy savings? Would it not be better, to let real lay users participate in research as so-called ‘experts’ about their everyday user-climatic interfaces interactions in daily life at home?

7 Conclusions, discussions and recommendations

The purpose of this explorative research was to analyze with a socio-technical perspective shaping an indoor climate. The thesis presented here aimed to find out about dynamics behind the difference between calculated energy use in research and actual energy consumption at home by comparing how users shape a comfortable indoor climate at home with how users anticipate users, their behavior and comfort in research on indoor climate systems. Two separate studies were undertaken, with the means of qualitative empirical methods. The first study on ECS research investigated the comfort construction, user representation and underlying design logic of the research process in regard to comfort and users. The second study on daily practices at home assessed users meaning and realization of a comfortable indoor climate at home and underlying logics of this daily practice. The results of the two studies were presented and analyzed in chapter 4 and 5. The previous chapters were the separate findings compared for inconsistencies. From these inconsistencies can clues for deviation between actual energy consumption and calculated energy use be deduced.

The format of this chapter is as follow: Section 7.1 provides the main conclusions; Section 7.2 gives some general reflection on this thesis; Section 7.3 provides a theoretical discussion and recommendation for further STS research and finally Section 7.4 offers a practical discussion and recommendation for ECS research.

7.1 Conclusions

Overall, the aim of this research was to investigate the research area and daily practices at home to give an answer to the main research question:

What underlying dynamics can be identified for the difference between calculated energy use and actual consumption by comparing (a) how actual users shape a comfortable indoor climate at home and (b) how researchers anticipate users, their behavior and comfort in research on indoor climate systems?

The main mismatch that can be identified is that in the design logics on research on indoor climate practices 'a comfortable indoor climate' is considered as a *technical achievement*, whereas in the underlying logic of daily practice at home 'a comfortable indoor climate' appears as *a socio-technical achievement.* This main mismatch results in inconsistencies between research practice and daily practices at home. These are summarized below.

A first inconsistency between research and daily practice is that researchers focus solely on technology, but in daily practice users and their socio-material environment matters. ECS research is driven by a technical viewpoint, researcher investigate the functionality of indoor climate systems and judge the systems explicit on energy efficient grounds. Users, their behavior and comfort needs are considered as function of technology. The systems are studied under controlled conditions, independent of the use setting. But at home, users are in control of shaping a comfortable indoor climate. Users are pretty much in a constant engagement in the practical challenge of giving meaning, negotiations and interactions in the shaping of a comfortable indoor climate. But their climatic behavior cannot be explained only by their own logics, also household logics, the material infrastructure and further circumstances of the home context matter. The indoor climate becomes meaning full in relation to and appears as a characteristic of their own socio-technical context. Thus taking users as a function and investigate systems independent of users and their environment to repeat and control the climatic situation is at odds with what happens in the real world.

A second inconsistency between research and daily practice is that researchers rely on standardization, but users are in control at home and the different indoor climate practices are varied and diverse. Researchers make use of standards to incorporate 'standardized users' and normalized definitions of thermal comfort needs in research. These conceptually molded constructions are idealized ideas about how a large and heterogeneous group of users are supposed to behave and their whimsical needs for comfort. Standards construct users as passive recipients of indoor climate stimuli and encouraged the idea that the indoor climate conditions can be manipulated to gather data about the performance of indoor climate systems. The standardized expectations deviate greatly from the diversity and variety of the actual practice at home and that at home the user is pretty much in control. The six cases showed that users, their behavior and comfort needs come in many different shapes and sizes. Users have different experiences, insights, knowledge and skills, behavior, actions, needs and desires. Choices and flexibility at homes vary greatly and these differences are all relevant. But these aspects of daily life are not reflected in standards. Standards are not a good way to represent users and comfort and users, their behavior and comfort needs easily deviate from the expectations derived from standards.

A third inconsistency between research and daily practice is that researchers work with representations of smart and incompetent user in mind, but at home it is not so much about good or bad use with indoor climate technologies. The representations that researchers have in mind highlight user behavior that is good or bad in energy efficient interaction with indoor climate systems. A typical smart user has technical knowledge and skills, an investigative attitude and aims for innovation and energy savings. Smart users are in control and motivated by increasing comfort and energy and financial savings. This case proved via the case of Emiel that the representation of the smart user in actual practice does not result necessarily in smart behavior with indoor climate systems at home. Despite his smart characteristics, his socio-technical environment forces him into energy inefficient behavior. Incompetent users lack all the characteristics mentioned above and generally behave energy inefficient. Users that may seem to behave incompetent and wasting energy, have in reality usually good reasons why they behave as they do. These reasons usually do not stem from their own skills, intentions or values, but are rather caused by their socio-technical environment. Especially the household logics and technical and further material infrastructures at home are discussed as concept that provide underlying reasons for indoor climate behavior of users. This means that in daily practice it is not so much about good or bad use of indoor climate systems, but that there is much more at stake. Furthermore, comfort at home gets higher priority than energy efficiency. To conclude, the 'mental models' of researchers form about users are not sufficient to explain users climatic behavior. The mental models do not only represent users self in a limited way, but also ignore other dynamics at home like use setting, household logics, material infrastructure, comfort priorities and other circumstances of the socio-technical context that influence climatic behavior of users.

A fourth inconsistency between research and daily practice is the different understanding of a comfortable indoor climate in research and at home. At least four underlying differences could be identified in their understandings of a comfortable indoor climate. The first difference is that in the

research setting is ‘a comfortable indoor climate’ related to climatic interfaces, while at home users related it to their own well-being. For users a comfortable indoor climate becomes meaningful in relation to their socio-technical home environment. Second difference is about a narrow definition in research and a broad definition in practice. In research, a comfortable indoor climate has a strict and narrow meaning. Four thermal comfort conditions (temperature, air circulation, humidity and air composition) and the coordination of these conditions are considered as a function of technology. This technical meaning of an indoor climate deviates greatly from how users give meaning to a comfortable indoor climate. Their meaning of comfortable indoor climate is rather broad and reaches far beyond indoor climate conditions. For example, several dimension about housing, living atmosphere and indoor climate influence their meaning. A third difference lies in the different vocabularies of a comfortable indoor climate. According to the researchers, the indoor climate is determined by four indoor climatic conditions of temperature, air circulation, humidity and air composition. For users the indoor climate is a total phenomenon of several climatic phenomena like warmth, fresh air, draft, smell etc. They also differ in what qualifies as ‘comfort’. Researchers focus on quantification and see comfort as a matter of solving the comfort equation. For users become indoor climate conditions meaningful in relation to their home environment: users describe how they experience and organize conditions at home by linking them to their socio-technical context. The whole of the indoor climate does at home not appear as a sum, but as a dynamic interplay. Finally, researchers and users have different vocabularies for climatic conditions. Two examples are provided her. The first indoor climate condition is in researchers’ vocabulary ‘temperature’, and in users terms ‘warmth’. The researchers use temperature as a comparative objective to measure the ‘hot’ or ‘cold’ that a heating systems should provide. For users is ‘warmth’ much more than temperature and technology. Although users have no common description for warmth, shared dimensions of warmth could be identified. The second indoor climate condition has to do with air. Researchers consider the mix of composition, circulation and humidity of air. They quantify air with numbers to know what ventilation systems should technically produce. Users describe comfortable air as: new, natural, cold, healthy, and oxygen-rich. Users think about the practice of ventilation and focus on the result: fresh air. For users it is important that fresh air comes from the outside and flows through their house. They prefer to use vents, windows or doors to let fresh air in. That is because the observable openings ensure them that it is actually fresh air. To conclude, the big difference is that users understand a comfortable indoor climate as much more than heating systems that can control temperature and ventilations systems that regulate the composition, circulation and humidity of air.
Much of what is important for a comfortable indoor climate at home is currently left outside the technical scope of research.

7.2 General discussion of this research

This study has several limitations, mostly due to its explorative character and time frames of this thesis. Several decisions had to be taken. The first limitation is related to the scope of research. Overall, there are too many ECS researchers, users, and indoor climate systems, and other aspects related to indoor climate at home to include them all in my research. For example, indoor climatic technologies were limited to ventilation and heating systems and indoor climate practices were narrowed down to ventilation and heating practices. This means that other technologies and practices that are related to i.e. cooling and warm tap water were outside the scope of this research. Nevertheless, such choices had to be made to define the boarders of this research. For future research, result can be improved or complemented, if more resources are at disposal to do additional

research or to change focus on other aspects of the indoor climate. Most likely, this will result in a more complete and detailed accounts of what kind of dimensions are important for shaping a comfortable indoor climate.
For what was in the scope of this research, a second important limitation was the size of the samples. Small sizes of samples were used, of only four researchers and six cases of users at home. This makes it difficult to consider the samples representative for the population. As a result only tendencies and no generally transferable conclusions can be deduced from the specific findings. However, for this explorative research the samples provided sufficient information to create evidence and presumptions for use in future research.
A final limitation of this thesis is its constraint on generalization. The findings are general conclusions that are only informed assertions about reality. Nevertheless, it was possible to point out real mismatches between research and daily practices, despite that they were based on only six cases. The empirical research allowed recognizing patterns in both ECS research and daily life at homes. That enabled to describe relationship between categories, display the inner workings and to define the how's and why's of phenomena that are important for this research. Given the complexity and diversity of individual cases, the results of the two studies can only be compared on the level of patterns. Nevertheless, this offers an opening to check the quality of incorporated anticipated use in ECS research and to discover inconsistencies between anticipated use and reality. As such, this explorative thesis offers initial assumptions and a base for further research and decision-making.

7.3 Theoretical discussion and recommendations for STS research

This exploratory research offers several theoretical contributions. As mentioned in the introduction, research on the subject of building related innovation and its dual purpose of saving energy and improving comfort is scarce. Although there has been some research on the development of energy technologies for housing and how engineers try to fulfill the dual promise (Ganzevles, 2007), but in this research the actual homes of users was outside of scope; or attempts to bridge the gap between technology and behavior with the aim to develop a methodology for designing products that help users to behave more efficient (Jelsma, 1999, 2005, 2006a; Jelsma & Knot, 2002) but the focus was improving energy of one technology and not so much about its place in the use environment; and studies on the comfort that resources intensive technologies provide at home (Hand & Shove, 2007; Shove, 2003; Shove, Chappels, Lutzenhiser, & Hackett, 2009). Little empirical research has been done on the actual fulfillment of the dual promise of energy efficiency and comfort situated in the home context. So the data of this research and the corresponding conclusions represent a contribution into this field.

This study had a socio technical perspective and relied on the reasoning of Elisabeth Shove that at home the social meaning and realization of the practice (of shaping a comfortable indoor climate) requires energy and that energy intensive (heating and ventilation) technologies are part of this practice. The STS perspective of this thesis learned that there is a gap between research and practice. At home the shaping of a comfortable indoor climate appears as a socio-technical achievement: users make themselves comfortable, their interactions with heating and ventilation systems are part of the practice and situated in the socio-technical home environment. Thus, at home a comfortable indoor climate is not a technical achievement of technology as considered by researchers. At home the focus is contrast to research not on one technology, but the technology is part of the socio-technical context. Thus, saving energy cannot be achieved by one system only, the practice should be made more energy efficient. At home it is not so much as in research about if users use the system good or bad, but more about how good or bad the systems fit to the situation at home. Furthermore at home is much more at stake than what only users want. Also household logic, the material culture and context influence climatic behavior. These findings imply that neither the social side, nor the environment should be ignored in research on the actual fulfillment of dual purpose. Research should be aware of social aspects and other materials in the home environment. Accept that users have autonomy or search for ways so that they assemble their indoor climate as they want it. Let users decide what is good at home; otherwise users at home will find another (probably unexpected) way. Maybe technical engineering should accept that energy efficiency of technology cannot be predicted or controlled fully, and should be made less important. These are fresh insights for technical research, so the STS perspective of this thesis can be useful to and enrich energy research done with a technical viewpoint.

There is a mismatch in this thesis between the theory and empirical results of the research practice. Whereas the theoretic part was more about the scripting theory of Akrich (1992) and how engineers inscribe their visions about future users and behavior into the material lay out of a design, the findings were analyzed in light of the theory about user representations (Akrich, 1995). The reason for this was that during this study became clear that not all researchers were involved in ‘design’-development, but mainly in ‘research’-development. The researchers interviewed did not create indoor climate systems, but investigate already produced products. Thus they did not objectify their ideas into the technology. This made it impossible to identify ‘scripts’ about users and comfort in indoor climate systems that were inscribed by researchers. Nevertheless, researchers do envision users, their behavior and comfort needs in research area. Therefore the analysis focused on the generation, articulation and role of user representations in ECS research. The methods, user representations and function of user representation are nevertheless inscribed in the research process of ECS research.

Only one of the four methods observed among ECS researchers was previous expressed by Akrich. She formulated the ‘I-methodology’ (1995). The method of ‘standardization’ was already described in work of Jelsma (2005). The other two methods may be added to her record of user representation techniques. Need to note that ‘referring to family members’ was observed by Patrick Feng (2005), but he did not formulated it as a method yet in his work. ‘Using complaints’ seems to be a remarkable method in ECS research.

Another concept that caused some trouble was ‘design logic’ of Jaap Jelsma. Jelsma follows Akrich in the sense that he considers the design stage of a technology as a process of scripting, where designers inscribe their ideas into the design of a technology. *Design logic* is the consistent whole of ideas, views, values and intentions in the design stage of technology that guides the process of inscription and principles of a local design practice (Jelsma, 2005). Since researchers interviewed were not involved in design-development but research-development also the concept of design logic was less adequate for this thesis. However, a process of scripting takes also place in the research development but in a different way than in design development. Also researchers work with a coherent plan with underlying logics in the research practice on which the research team agrees. Researcher inscribe (and reproduce) the consistent whole of their core principles into the research process in order to deliver ‘functional’ research products. Their logics about how research should be done becomes objectified and mirrored in research content, methods, tools, and strategies. Research can be accorded as a measure of agency, depending upon how it is arranged; it permits and presents certain courses of actions. But this way of scripting differs from what happens in design/development, therefore I would to suggest to develop a concept in the line of design logic, that is better applicable for a research process.

Another reflection is on the concept of use logic of Jaap Jelsma. He uses this figure to illustrate how script terminology connects design with use networks:

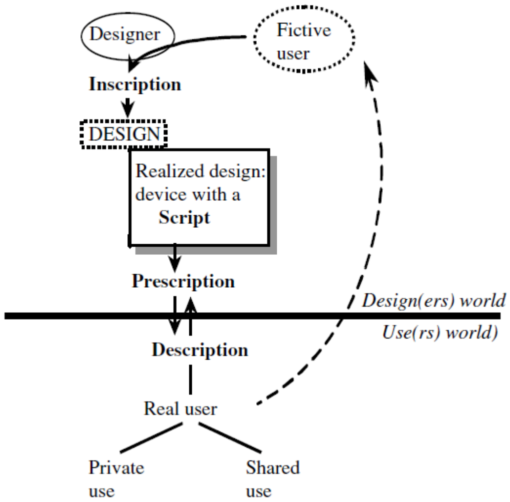

Figure 2: world of designers and users connected via script terminology (Jelsma, 2006a, p. 224)

This figure shows actually the actions – prescriptions- of one designer and - descriptions- of one user. This image suggests that in the world of design, more designers agree onto the same design logic of a process of inscriptions of a local development practice. This was also found in this thesis. However, this image suggests also that in the world of use, more users have similar use logic. However, this was not found in this thesis. This thesis showed that each case can be considered as one single unique 'use world', and that thus more 'use worlds' exist. The cases showed a great variety and diversity among the use logics of users in the different cases. Thus, users in different use-practices do not necessarily agree to the same use logic. Moreover, this image suggests that there is one user in the 'use world', and thus that there exist one use logics in the use setting. In this research this holds for just one case, in the five other cases were more users at home. In the cases with more users, most users have their own use logic. Thus, in one use setting can be more users that do not necessarily agree to the same use logic. Nevertheless, it was possible to find shared dimension of use logics among the six cases. To conclude, this image gives a simplified picture of the use setting in practice. Further research that builds upon this concept of use logic, should consider a variety of use worlds and, a diversity of users. It would be good not to see use logics as something general of all users, but I rather recommend thinking of shared dimension of use logic among different users.

A final reflection is also on the concept of use logic. When use logic of users in interactions with a technology is studied in the use setting, the concept of use logic is too limited to explain behavior of users. This thesis studied climatic behavior of users in their socio-technical home environment and demonstrated that it was difficult to explain their 'doings' only by use logics. In the home environment are more socio-technical factors that cause understandable reasons for their behavior. This thesis identified that climatic behavior of users could not only be explained by use logics, but that also household logics, material culture and further circumstances at the home context matter.

This should be taken into account and maybe can in other use settings further underlying dynamics be identified.

7.4 Practical discussion and recommendation for ECS research

How to respond to the conclusion that there exists a mismatch between research understanding of 'shaping a comfortable indoor climate' as a technical achievement of technology, while in users domestic world the indoor climate practice turns out to be a socio-technical achievement that depends on the home context? What needs to change so that the design logic of ECS research process can better incorporate the shared dimensions of use logics of the meaning and realization of a comfortable indoor climate?

The main recommendation for ECS research is *to adapt a socio-technical perspective* on research on climatic technologies with a dual energy and comfort purpose. A social-technical perspective makes it possible to do justice to the challenges of users in daily practice. The current technical approach takes comfort as a function of technology and implies saving energy as a matter of abstract calculation. This allows to studying energy and comfort performance of climatic technologies via measuring, manipulating and simulating. But there is another side of the coin which is not yet taken into account: the social use side of technologies. This means that much is outside the scope of present research. For example: this thesis showed that the indoor climate practice at home is a 'total phenomenon'. The indoor climate is a complex whole which includes (more than one)user and climatic technologies and the further socio-technical home environment. Users have their own logics for making sense of and realize a comfortable indoor climate. But if their climatic behavior deviates from what is expected in research does not makes them necessarily 'incompetent'. Some users not just behave 'incompetent' but often other reasons matter in practice. The specific material culture of the home environment and household logics at stake provided understandable reasons to why users deviate from 'smart' to 'incompetent' behavior. Such reasons are logical in domestic practice. If such aspects of the daily domestic practice are not taken into account, then search results calculated at the technical side may continue to be nullified at the social side of indoor climate systems. Therefore, the both sides should no longer be treated separately at TNO, but a socio-technical approach is desirable for research process on energy and comfort.

ECS research should integrate both sides by a socio-technical approach and understand the shaping of technology as a socio-technical achievement. This begins by taking the use side of indoor climate systems serious: users and their context matter. To realize more energy efficient indoor climate practices, (energy efficient) behavior should be understood as the outcome of user-indoor climatic technology interactions that are situated within the dynamics of the socio-technical home context. The realization of a comfortable indoor climate should be understood as a socio-technical achievement. Furthermore, the focus should be to make this socio-technical achievement at home more energy efficient. By recognizing the realization of a comfortable indoor climate as a socio-technical achievement at home offers new ways to look at the challenge to save energy.

A second recommendation is to invest in *research methods* that are based on solid empirical knowledge about daily life concerns at home and variety and diversity of users that interact with indoor climate systems. They should rather develop methods and facilities that allow studying users in interactions with indoor climate systems in their everyday environment, than (re)create artificial surroundings to test indoor climate systems in isolated space. In order to extent the scope of laboratory-based research in the hope of resolving or at least accommodating observed

discrepancies between predicted and actual energy savings are here some recommendation provided.
ECS could rethink their methods for user representation. The present methods I-methodology, standardization, referring to family members and using complaints are merely implicit. It would be relevant to think about more explicit techniques via which potential users are consulted directly as sources. This means to think about user involvement, reconsider standards and give up the 'I-methodology. This is of course not easy in a pure technical environment. Users do not have to be involved directly, but users could be consulted via surveys, use tests in domestic setting, feedback on experience, user panels, etc. This may go better with help of multi-disciplinary research teams, in which engineers and behavioral scientists of TNO work together on the same goal instead of in separated research units. Another suggestion is to include field workers into research that go beyond the borders of laboratory. They should especially dig into the unknown 'incompetent' side of users. Their investigations of users at home will support better (pro)active ways to anticipate 'unexpected' behavior.

A third recommendation is that the focus in research should be that *new indoor climate systems* should be able at recruit users and easily be integrated in household routines of users in daily live at home. Here follow three suggestions arise from the present study. First, indoor climate systems should be attractive, especially for those users who display so-called 'incompetent' behavior. The examination of incompetent behavior can reveal underlying causes. Often, there are very comprehensible reasons behind their behavior. Such insights can help to develop to ideas to break through wasteful routines. Second, users want that indoor climate systems allow flexibility and offer possibilities for adjustments. This means that indoor climate systems should not be fully automated, but that users have a certain degree of freedom. This will meet the diversity and variety of users. In addition, when users think that they are in control, this will contribute to their responsibility and awareness to save energy. Third, users do not want to be forced or disciplined by indoor climate systems in ways that interfere with their needs for privacy and freedom to make their own choices. It would be better to invite or challenge them into energy efficient interactions with technology and reward them for their energy savings. These are just three suggestions, but more or better may be found when ECS research adopts a socio-technical approach

A fourth recommendation is *to search for new ways to collaborate with partners* in the built environment and with new partners beyond the built environment to change energy behavior or users. A socio-technical perspective allows identifying moments in the practices of users when they have to reconsider their climatic behavior. The moments when users have to reconsider their behavior are excellent opportunities to introduce new ideas, information, concepts and technologies into their lives in order to change their energy consumption. These critical moments for change are those moments when something changes in the socio-material relationship of their daily practice, for example a relocation, renovation, new relationship, a divorce, family planning, grown up children that leave the house etc. It would be a good idea to collaborate with authorities that are involved or related to such a change in users' life, in order to change users' energy behavior. For example, parents that go with their baby for consultation at a newborn health clinic, get already information about parenting, health, food etc. This information provision can be extended easily with suggestions for heating and fresh air needs for the baby. Parents will take these into consideration and may change their energy behavior. For all such critical moment may be identified new ways of collaborating with partners in other to change energy behavior of users.

While these suggestions and recommendation may not be particularly welcomed by some ECS researchers, some sort of change along these lines seems necessary. If the goal is to realize indoor climate systems that are not only are energy efficient in laboratory, but also save energy without reducing comfort in real life of users at home, use logics should become embedded explicitly and adequately in design logics ECS research process. Then, the outcomes of energy efficient research stand a better chance to match with energy consumption in real life when research is more informed by users' needs, negotiations and interactions at home.

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ANNEX A: GENERIC INTERVIEW SCHEDULE FOR ECS RESEARCHERS

Note: this interview guide is fairly generic and should be adapted to the current researcher as needed.

<u>Introductie, uitleg onderzoek, algemene profielschets</u>

Wat is je functie?
Wat is je specialisatie?
Met welke klimaatsystemen heb je gewerkt?
Wat zijn je werkzaamheden?

<u>Binnenklimaat</u>

Wat betekent 'binnenklimaat' volgens jou?
Welke factoren spelen een rol bij 'binnenklimaat' volgens jou? Waarom/voorbeeld?

Wat is voor jouw werk belangrijk in relatie tot het binnenklimaat?
Hoe wordt binnenklimaat in onderzoek geformuleerd? Waarom/voorbeeld?
Welke binnenklimaat-factoren spelen een belangrijke rol tijdens werkzaamheden?

Welke hulpmiddelen gebruik je voor het binnenklimaat tijdens je werk? (onderzoeken, bronnen, tools, databases...) Waarom/voorbeeld?

<u>Comfort</u>

Wat betekent voor jou 'comfort' in relatie tot het binnenklimaat? Voorbeeld?
Wanneer is een 'binnenklimaat' comfortabel volgens jou?
Welke factoren spelen daarbij een rol? Waarom/voorbeeld?

Wat betekent 'comfort' in je werk? Met welke factoren houdt je tijdens onderzoek rekening?
Hoe formuleer je comfort in onderzoek? Waarom/voorbeeld?

Van welke hulpmiddelen maak je tijdens je werk gebruik? (gebruikers, bronnen, tools, etc)? Waarom/voorbeeld?

<u>Gebruikers</u>

Wanneer denk je dat gebruikers het binnenklimaat ervaren als comfortabel?
Wat ervaren ze als (on)comfortabel volgens jou? Waarom/voorbeeld?
Welke factoren spelen daarbij volgens jou een rol?
Welke eisen stellen gebruikers aan binnenklimaat systemen volgens jou?

Wat wil je weten van gebruikers? Welke informatie over gebruikers is noodzakelijk voor onderzoek? (wensen, voorkeuren, gedrag, kennis)
Met welke aspecten van gebruikers houdt je tijdens onderzoek rekening? Waarom/voorbeeld?
Hoe vertaal je dat naar onderzoek? Waarom/voorbeeld?

Hoe kom je aan de informatie over gebruikers? Welke hulpmiddelen (echte gebruikers, onderzoeken, bronnen) Waarom/voorbeeld?

Worden er gebruikers betrokken in het onderzoek naar comfort / binnenklimaat / comfortabel binnenklimaat? Waarom?
Zou je gebruikers (meer) willen betrekken in het onderzoek? Waarom?

<u>Overig</u>

Haal je buiten je werk ergens inspiratie vandaan voor je werk? (Mening, klachten, situatie thuis, vrienden, familie, buren?

Wie/wat zijn er naast gebruikers belangrijk voor comfort/ binnenklimaat/ comfortabel binnen klimaat? Met welke instanties, wetten, producenten, opdrachtgevers etc moet je rekening houden? Voorbeeld/waarom?
Wat is voor hen belangrijk in relatie tot comfort/ binnenklimaat / comfortabel binnenklimaat? Waar moet het aan voldoen volgens hen? Voorbeeld/waarom?

<u>Onderzoek binnenklimaat systemen</u>

Hoe onderzoeken jullie de systemen? Waar letten jullie op? Wat zijn voorwaardes?
Hoe testen jullie de apparaten in relatie tot binnenklimaat?
Hoe testen jullie de apparaten op de eisen van gebruikers?
Hoe testen jullie de apparaten op comfort?

<u>Afsluiting</u>

Hoe kan het volgens jou dat werkelijk energieverbruik bij mensen thuis afwijkt van onderzoek?
Wil je nog iets anders toevoegen, opmerken?

ANNEX B: OVERVIEW DATA COLLECTION OF ECS RESEARCH PRACTICE

OVERVIEW OF INTERVIEWS WITH ECS RESEARCHERS

Name	duration	date	reference	reference in thesis
Edo Wissink	61 min.	5 december 2012	E. Wissink, personal communication, 5 December 2012	*E.Wissink*
Piet Jacobs	108 min.	7 december 2012	P. Jacobs, personal communication, 7 January 2012	*P.Jacobs*
Roel Brand	65 min.	12 december 2012	R. Brand, personal communication, 12 December 2012	*R.Brands*
Jan Ewoud Scholten	65 min.	12 december 2012	J.E. Scholten, personal communication, 12 December 2012	*J.E.Scholten*

Table 3: references for the interviews with ECS researchers

OVERVIEW OF FURTHER DATA COLLECTION: REPRESENTATIVE CONTENT FOR ECS RESEARCH

Type of source	references
books	Fanger, P. O. (1970). *Thermal Comfort*. New York: McGraw-Hill
	Van Tol, A. (Ed.). (1986). *Jellema Bouwkunde 7b, voor opleiding en praktijk*. Delft: Waltman.
dissertation	Guerra Santing, O. (2010). Actual energy consumption in dwellings: The effect of energy performance regulations and occupant behaviour. TUDelft, Delft.
list	TNO. Parameters van invloed op ervaren comfort.
magazine articles	Jacobs, P. (2008). *Praktijkvoorbeeld van balansventilatie met WTW*. Imtech K&S.
	Jacobs, P. (2012). *Ventilatie in nieuwbouwwoningen met balansventilatie.* TVVL Magazine.
	Spiekman, M. (2010). Bedieningsgemak: luxe of noodzaak? TVVL magazine, 39.
PowerPoint Presentation	Itard, L. (2012). Werkelijk energiegebruik en gebruikersgedrag. Delft: TUDelft.
	TNO. (2011). Huidige markt: inzicht in elektra- en gas verbruik.
TNO research reports	Bax, F. T., & Vries, G. d. (2002). Eindrapport Zomertemperatuur en comfort in woningen, praktijk onderzoek in 5 typen eengezinswoningen van verschillende bouwjaren: Novem.
	Van den Brink, L. H., Attema, A. R., Kort, J., & Spiekman, M. E. (2010). Ontwikkelen van meetmeethode: waarom we de verwarming (niet) lager zetten: TNO.
websites	www.ecbcsa53.org
	www.huisvolenergie.nl
	www.ventilatieforum.nl

Table 4: overview of representative data and references

ANNEX C: GENERIC INTERVIEW SCHEDULE FOR ‘USER’-RESPONDENTS

Note: this interview guide is fairly generic and should be adapted to the current ‘user’-respondent as needed.

Introductie, uitleg onderzoek, profiel schets respondent

Leeftijd?
Hoogste opleiding?
Huidige baan?
Samenstelling huishouding, onderlinge relatie?
Is er in de afgelopen jaren iets veranderd?

Woning algemeen

Koop of huurwoning?
Hoelang woon je hier al?
Kun je een beschrijving geven van de indeling van je huis?
In welke ruimtes breng je de meeste tijd door?
Kunnen we straks even rondje door het huis maken, vind je het goed als ik een plattegrond schets?

Dagindeling

Hoe ziet voor jou een normale dagindeling van een door de weekse dag eruit?
Kun je een beschrijving geven?
Wat is belangrijk voor je? Waarom?

Comfortabel wonen algemeen

Wat vind je comfortabel aan deze woning? Waarom?
Heb je klachten of irritaties over deze woning? Waarom?
Hoe zorg je voor een aangename leef/woonsituatie? Voorbeeld, waarom?
Welke factoren spelen voor jou een rol in een prettige leefsituatie in huis? Waarom?
Verschilt het per kamer? Andere factoren of voorkeuren?
Wordt je wel eens belemmerd in het creeren van een prettige situatie? Door huisgenoten, apparaten, iets anders...?
Kun je een voorbeeld van storende factoren, en hoe je dat oplost?

Binnenklimaat - comfort

Waar denk je aan bij het begrip 'binnenklimaat'?
Welke factoren spelen een rol?
Wanneer vind jij het binnenklimaat in je woning als aangenaam?
Wat vind je onprettig? Voorbeeld/waarom?

uitleg binnenklimaat

schiet er nog iets te binnen?

Verwarmen - comfort

Wat vind je een prettige temperatuur?
Wat is van invloed? Verschillende voorkeuren per kamer? Voorbeeld/waarom?
Hoe organiseer je een aangename temperatuur?
Welke systemen heb je in deze woning om te verwarmen?
Maak je gebruik je vanandere dingen om het aangenaam warm te krijgen/maken? Zoals...?
Zijn er belemmerende factoren om een aangename temperatuur te creeren?

Wat doe je er aan?
Hebben jullie verschillende voorkeuren, meningsverschillen over temperatuur?
Hoe los(sen) je/jullie dat op? Wie onderneemt actie, afspraken, ruzie, alternatieven?

<u>Ventileren –comfort</u>

Ventileer je in huis? Welke ruimten?
Waarom ventileer je? Waarom?
Misschien verschillende voorkeur per vertrek?
Wat vind je prettig qua ventilatie?
Hoe ventileer je? Hoe pak je het aan? mbh van wat: ventilatiesysteem, ventilatieroosters, ramen, ventilator...)
Zijn er belemmerende factoren om te ventileren zoals jij wilt?
Hebben jullie verschillende voorkeuren, meningsverschillen over ventileren?
Hoe los(sen) je/jullie dat op? Wie onderneemt actie, afspraken, ruzie, alternatieven?

<u>Afsluiting</u>

Ben ik nog iets vergeten wat volgens jou misschien de moeite waard is?
Heb je zelf nog opmerkingen, aanvullingen voor mijn onderzoek?

ANNEX D: OVERVIEW DATA COLLECTION OF DAILY PRACTICES AT HOME

OVERVIEW OF INTERVIEWS WITH 'USER'-RESPONDENTS

Name(s)	duration	date	reference	reference in thesis
Brenda & Marieke	77 min.	18 December 2012	Brenda, personal communication, 18 December 2012	*Brenda*
			Marieke, personal communication, 18 December 2012	*Marieke*
Emiel	52 min.	27 January 2013	Emiel, personal communication, 27 January 2013	*Emiel*
Karina & Edwin	50 min.	13 December 2012	Karina, personal communication, 13 December 2012	*Karina*
			Edwin, personal communication, 13 December 2012	*Edwin*
Sanne	78 min.	11 December 2012	Sanne, personal communication, 11 December 2012	*Sanne*
Tamar	55 min.	6 February 2013	Tamar, personal communication, 6 February 2013	*Tamar*
Tineke	55 min.	12 December 2012	Tineke, personal communication, 12 December 2012	*Tineke*

Table 5: references for the interviews with 'user'-respondents

OVERVIEW OF FURTHER DATA COLLECTION OF MATERIALS CONDITIONS AT HOMES OF RESPONDENTS

Name	type of data	reference
Brenda & Marieke	photo of the house	Personal communication, 20 december 2012
	sketch of the floor plan of the house	Personal communication, 20 december 2012
Emiel	photo of the house	Personal communication, 27 January 2013
	sketch of the floor plan of the house	Personal communication, 28 January 2013
Karina & Edwin	photo of the house	Personal communication, 13 December 2013
	sketch of the floor plan of the house	Personal communication, 14 December 2013
	additional information via email	Personal communication, 12 January 2013
Sanne	photo of the house	Personal communication, 12 January 2013
	photo of the notebook	Personal communication, 11 December 2012
	photo of thermometer	Personal communication, 11 December 2012
	sketches of the floors plans of the house	Personal communication, 14 December 2012
Tamar	photo of the house	edited photo, original retrieved from http://goo.gl/maps/HTYr3, at 7 February 2013
	sketch of the floor plan of the house	Personal communication, 7 February 2013
Tineke	photo of the house	edited photo, original retrieved from http://goo.gl/8Yy6vu , at 6 March 2014
	additional photos daily situations	Personal communication, 12 December 2012
	sketches of the floors plans of the house	Personal communication, 14 December 2012
	additional information via email	Personal communication, 11 January 2013

Table 6: references of empirical data about material conditions at homes of respondents

ANNEX E: EMIEL

SOCIO-TECHNICAL CHARACTERISTICS

personal details	name	Emiel
	age	29 year
	gender	male
	education	MSc. (Civil Engingeering)
	occupation	PhD (Civil Engineering)
housing details	type of house	apartment flat
		situated on 14th floor
	year built	1970
	occupation	owner
	house	since 2009
social details	household type	one person household
	household size	1
technical details	heating	block heating, no thermostat
		radiators with thermostatic valves
	ventilation	central block ventilation, vent in bathroom, always on trickle vents in balcony doors
	other	balcony doors
		windows
		inside doors

Table 7: Overview socio-technical environment

Photo 1: front of house

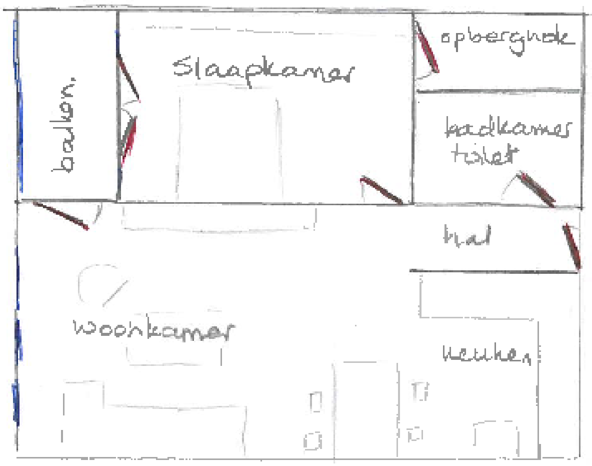

Figure 2: floor plan

ANNEX F: BRENDA & MARIEKE

SOCIO-TECHNICAL CHARACTERISTICS

personal details	name	Brenda & Marieke
	age	29 year & 27 years
	gender	female & female
	education	BSc. (Art & Technology) & MSc. (Special Education Studies)
	occupation	traffic manager & pedagogue
housing details	type of house	appartment flat
		situated on 3th floor
	year built	1970
	occupation house	owners
		since 2010
social details	household type	two persons household, partners since 2 years
	household size	2
technical details	heating	central heating with thermostat
		radiators
	ventilation	central block ventilation, vents in toilet & kitchen, always on
	other	balcony door
		windows
		inside doors

Table 8: Overview socio-technical environment of Brenda and Marieke

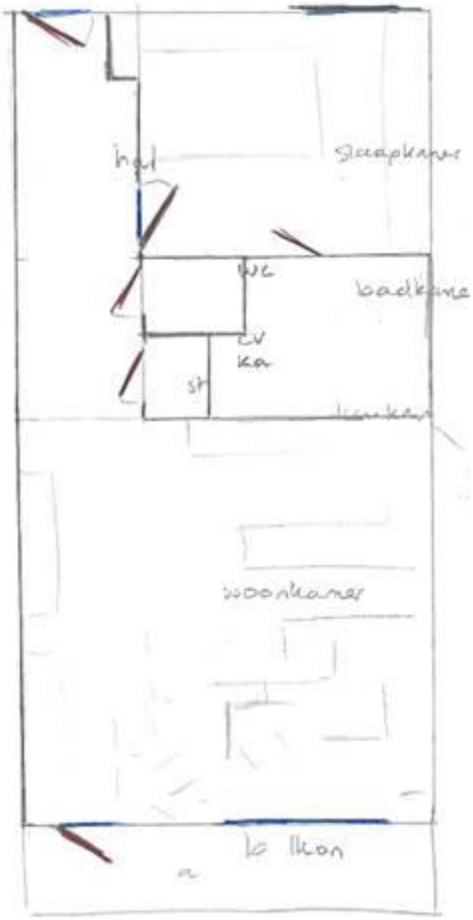

Photo 2: front house

Figure 3: floor plan

ANNEX G: TINEKE

SOCIO-TECHNICAL CHARACTERISTICS

personal details	name	Tineke
	age	57 year
	gender	female
	education	education for nurse
	occupation	nurse
housing details	type of house	semi-detached
	year built	1986
	occupation house	owners
		since 1986
social details	household type	two persons household, married for 32 years, 3 outhome children
	household size	2
technical details	heating	central heating with programmable thermostat
		radiators
	ventilation	mechanical ventilation, vents in toilet, bathroom and kitchen; always on
		trickle vents in some windows
	other	windows
		inside doors

Table 9: Overview socio-technical environment of Tineke

Photo 3: front house

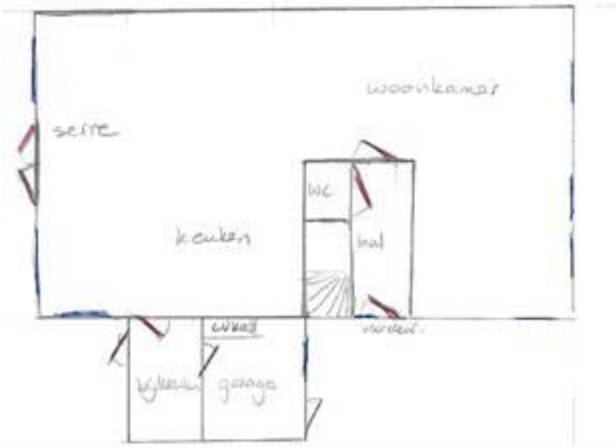

Figure 4: floor plan ground floor

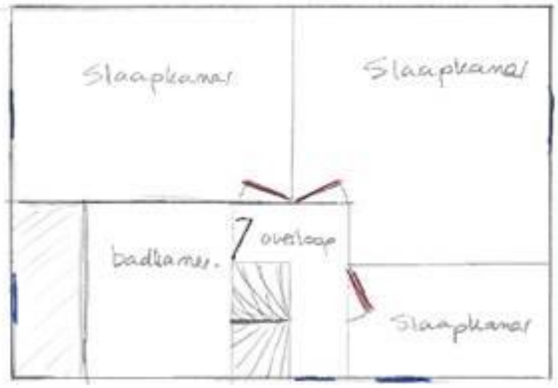

Figure 5: floor plan 1st floor

ANNEX H: TAMAR

SOCIO-TECHNICAL CHARACTERISTICS

personal details	name	Tamar
	age	27 years
	gender	female
	education	BSc. (Human Resources)
	occupation	employee housing corporation, student
housing details	type of house	terraced house
	year built	1970
	occupation house	tenant
		since 2010
social details	household type	family, partners and two young children
	household size	4
technical details	heating	central heating with thermostat
		radiators
	ventilation	mechanical ventilation, vents in toilet, bathroom and kitchen; 3 levels
		trickle vents in opening windows
	other	windows
		inside doors

Table 10: Overview socio-technical environment of Tamar

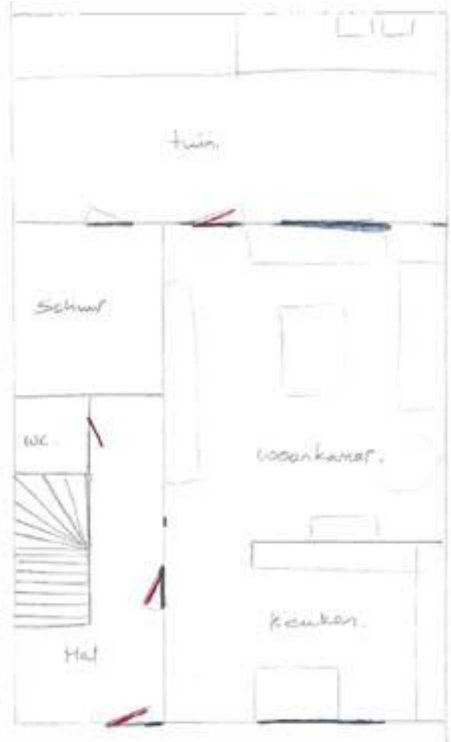

Photo 4: front house

Figure 6: floor plan

Annex I: Karina & Edwin

Socio-technical characteristics

personal details	name	Karina & Edwin
	age	28 year & 28 years
	gender	female & male
	education	BSc. (Social Legal Services) & MSc. (Communication Studies)
	occupation	enforcer & marketing employee
housing details	type of house	appartment flat
		situated on ground level
	year built	1975
	occupation house	tenants
		since 2010
social details	household type	two persons household, partners since 9 years
	household size	2
technical details	heating	block heating
		radiators with thermostatic valves
	ventilation	mechanical ventilation, vents in toilet & kitchen, 3 degrees
		trickle vents in opening windows
	other	balcony door
		windows
		inside doors

Table 11: overview socio-technical environment of Karina and Edwin

Photo 5: front house

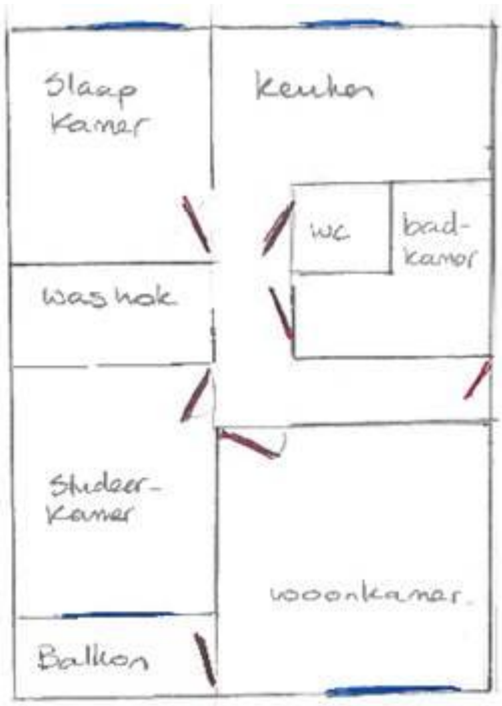

Figure 7: floor plan

Annex J: Sanne

Socio-technical characteristics

personal details	name	Sanne
	age	28 year
	gender	female
	education	BSc. (Art acedemy)
	occupation	graphic designer
housing details	type of house	canal house
	year built	1981
	occupation	tenant
	house	since 2011
social details	household type	eight persons household, commune / co-op living
	household size	8
		4 males, 4 females; 28 - 56 years
technical details	heating	central heating without thermostat
		radiators
	ventilation	central ventilation, vents in toilets, bathrooms and kitchen; 3 degrees
	other	balcony door
		windows
		inside doors

Table 12: Overview socio-technical environment of Sanne

Photo 6: front house

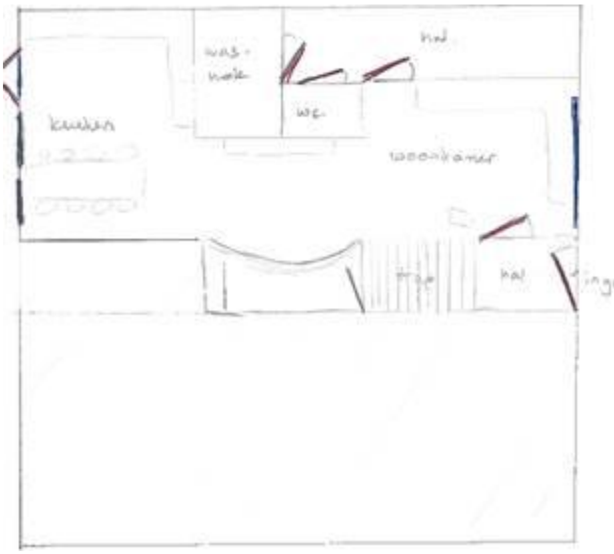

Figure 8: floor plan ground floor

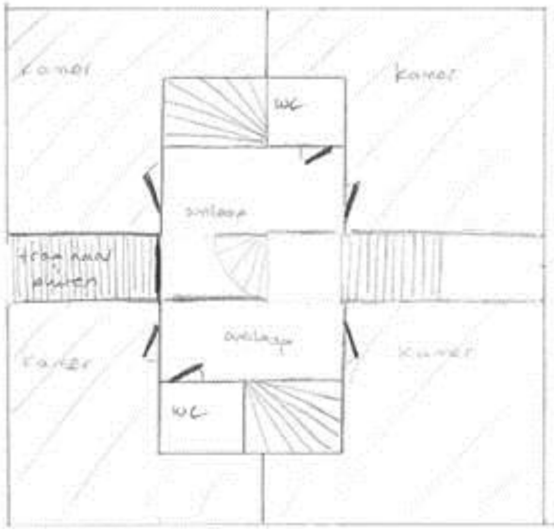

Figure 9: floor plan 1st floor

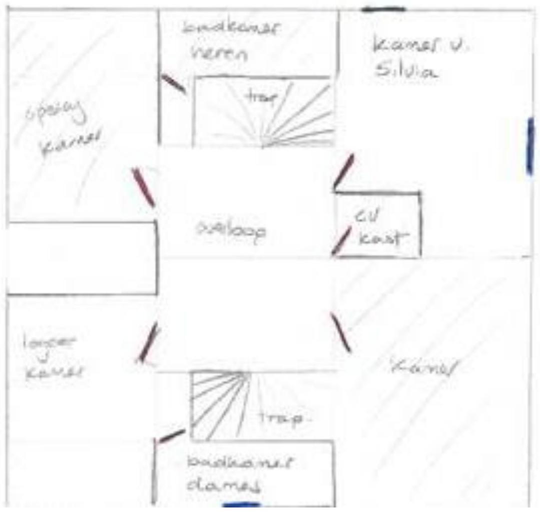

Figure 10: floor plan 2nd floor