Energy consumption and Comfort in Homes

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Abstract
Indoor environment in buildings affects human comfort; however, most literature is aimed at environmental conditions dealing with thermal, acoustical, visual, and air quality parameters. Since a majority of domestic energy consumption is related to water and spatial heating, most research on comfort has focused on its thermal dimension, which in its turn is heavily influenced by physiological aspects while socio-psycho-cultural aspects are often disregarded. Similarly, energy behaviour is researched with a focus on economics and engineering. The link between energy consumption and comfort tends to be bridged by the thermal parameter since: a) heating represents the majority of the consumption and b) people mainly report thermal elements as a theme in home comfort-making, such as clothing, bathing, place temperature, and ventilation. This paper is a literature study aimed at exploring further dimensions of comfort and energy consumption at homes in terms of their interactions with each other and as multidisciplinary subjects. It is suggested that comfort and energy behaviours are more complex than its technical-physiological parameters and that when studying both topics as multidimensional and interrelating concepts, missing links from other disciplines could be discovered, which can allow for more comfortable and healthy environments, and for more comprehensive strategies for better energy behaviours.

Keywords – comfort and energy practices, homes,

1. Introduction

Enjoying a ‘comfortable, good life’ at home is strongly linked to high energy consumption: the more comfortable one wants to be, the more energy one needs to consume [1]. Even with the implementation of energy efficient and sustainable measures, energy consumption in Western countries keeps rising while comfort and health seem to decrease [1, 2].

Current literature on comfort and energy demand is dominated by thermal comfort, and its techno-physiological attributes. This is mainly due to the fact that the link between energy consumption and comfort tends to be bridged by the thermal parameter since: a) heating represents the majority of the consumption and b) people mainly report thermal elements
as a theme in home comfort-making.

This literature review explores the current complexities of the concepts of comfort and energy consumption. First, the meaning of comfort is provided based on its multidisciplinary definitions, followed by the multiple dimensions of comfort at home. Subsequently, different multidisciplinary definitions of energy behaviours are presented. Finally, since comfort and energy demand are closely linked, but inappropriately researched, it is proposed that both concepts should be more holistically studied, which may allow to find out the missing or inaccessible information in both comfort and energy use, and thus, which may enable the creation of strategies to better influence energy demand reduction while increasing comfort and ultimately health.

2. Comfort: definitions and concepts

Comfort is a complex, multidisciplinary and multidimensional concept which is defined differently among disciplines. This section gives an overview of some definitions of the concept.

The Merriam Webster dictionary [3] provides two definitions of comfort: “a state or situation in which you are relaxed and do not have any physically unpleasant feelings caused by pain, heat, cold, etc.” and “a state or feeling of being less worried, upset, frightened, etc., during a time of trouble or emotional pain”.

In the indoor environmental quality (IEQ) literature, comfort is viewed from a physiological-technological perspective and described through the following lenses: visual (with aspects such as view, illuminance, reflection), thermal (air velocity, humidity, temperature), acoustic (control of unwanted noise, vibrations, reverberations), and air quality (smells, irritants, outdoor air, and ventilation) [4]. Each lens has specific standards for the indoor environment. Within the IEQ vision, the ASHRAE defines comfort as “a state of mind where a person expresses satisfaction with the thermal environment” [5], focusing on the thermal physiological aspect. Another definition of comfort is provided by Brager, de Dear [6] as: “the absence of discomfort”.

Therefore, there is a lack of a multidisciplinary definition, and currently, each discipline focuses on aspects of comfort which are relevant to the discipline itself. Other authors have proposed more holistic definitions including further dimensions; for example Slater [7] proposes “a pleasant state of physiological, psychological and physical harmony between a human being and its environment”. It has also been proposed that there are three elements of comfort that are certain amongst all the fields [8]; Comfort is

a. A construct of a subjectively-defined personal nature;
b. Affected by factors of a various nature (physical, physiological, psychological); and

c. A reaction to the environment.

Though redefining comfort with a single definition that fulfils the scope of all disciplines would not be effective, recognizing that comfort is a concept that is multidimensional would allow for better and more comprehensive research of comfort.

3. Multi-comfort

Domestic comfort provision is dictated by the IEQ perspective focused on physiology and technology. The fact that comfort is constructed by more than the physiological perspective has been acknowledged but not fully researched. This section shows an overview of further factors beyond the physio-technological ones, that compose comfort in homes.

3.1 Four Dimensions of Comfort


Perceptual comfort is the way in which a person can create mental representations of a home through their senses. It is further divided into six factors: the complexity of stimulation within the home, the composition that enables meaning-making of the place, the understanding of the place in such a way that it allows the occupant to carry behaviours, the comparison of the stimulation thereby enabling behaviours, the competence of the stimulation which allows for control, and the complications that the place can create in terms of difficulties of action. In addition, perceptual comfort also incorporates elements of the environment such as spaciousness, aesthetics, livableness, and friendliness of the place [9].

Interactive comfort deals with the elements of the dwelling that allow the occupant to carry out or not social interactions in the place. Thus, this takes into account allowing for a range of privacy and interaction, without reaching the extremes of crowding or isolation.

Facilitative comfort deals with being able to perform wanted or needed activities (i.e. chores/hobbies). This relates to the potential of the home to be modulated in accordance to the occupants’ needs.

Personalization comfort is what allows transforming a house into a home: when an emotional bond between place and person has been formed. The house that becomes a home is one that reflects the occupant’s personality.
3.2 Domestic Multi-Comfort

Further research into the different dimensions of comfort was carried out by Burris [10], who conducted studies in the UK on how household occupants achieve comfort in their homes. She proposed that comfort is multi-dimensional and that each of the dimensions is interconnected with and influenced by each other. Three main comfort dimensions are proposed: Meaning of Comfort at Home, Home Environment, and Comfort Experience (Figure 1, adapted from Burris [10]).

Meaning of comfort at home is made of freedom of action (ease of activities that are enjoyable or necessary in the home), control of the environment (such as environmental parameters, visitors), and security (fundamental human need; feeling safe within one’s surroundings).

Home environment comfort comprises several dimensions: aesthetics, spatial dimension, order, ambiance and environmental conditions.

Creating an aesthetic space can be achieved by the occupant personalizing the space from the large scale (renovation projects) to small scale (decoration, displaying belongings). Personalizing the surroundings allows the occupants to bond with the place, thus, making it a home.

Spatial dimension deals with having enough space for the occupant to carry out wanted activities. It is linked with the adaptability of the space: possibility of occupants to move furniture to create a desired space. Being able to adapt a space also means multi-functionality of the space: the capability of hosting different activities within the same room, by only adapting the elements within it.

Order of the home means the way in which furniture and belongings are arranged, which creates in its turn tidiness comfort. Furthermore, having convenient places to store elements is another factor that creates order comfort.

The ambiance comfort of the home deals with the feeling or impression that the place elicits to the occupant. Ambience comfort is created by two elements: stimulus and sensation. Stimulus are the elements that create the atmosphere, while sensation are the feelings elicited via the stimuli. A multisensorial experience with pleasant stimuli can create comfort, such as having an open fire while drinking a hot beverage.

Comfort through environmental conditions deals with the indoor environment of the home, and this relates to the physiological perceptions of the indoor environment: temperature, sounds, light and visual quality.
Figure 1: Comfort dimensions and sub-dimensions: Meaning of Comfort at Home, Home Environment, and Comfort Experience
**Comfort experience** is divided into four subcategories: physical comfort, psychological wellbeing, activities, and social interactions. This type of comfort relates to the occupant being active and reactive with the space, rather than receiving stimuli from it.

Physical comfort refers to the occupant being comfortable in terms of their body (i.e. posture). It deals with the adaptive responses of the occupant to the thermal environment. Physical comfort is related with adaptive responses throughout the seasons, such as enjoying incoming sunlight in the summer.

Psychological wellbeing includes factors attributed to the occupant’s state of mind, especially, in terms of having a space that allows for relaxation, stress-free, and with privacy when needed.

Two types of activities which are comfort-making are identified by Burris [10]. Rewarding activities: activities that are intrinsically motivated and thus challenge and let the person learn from them, such as playing an instrument or exercising and routine activities, such as watching TV or cooking.

Social interactions that create comfort are characterized by the ability of occupants to invite guests over. This is also dependent on the space itself, which can allow if such activities can even take place. Other interactions that create comfort are those that enable technologies (computer games, internet, smart phones). Such technologies allow the person to achieve comfort through interacting with other people, whether they are away or in the same space. Finally, interactive freedom is when the place allows the occupant to choose privacy or social interaction within communal spaces.

### 4. Energy behaviour and comfort: definitions and concepts

From many studies it can be deduced that the development of sustainable, efficient technologies is not enough to reduce energy consumption. This is partly due to consumer behaviour, which often has a greater impact on energy demand than the efficiency of technologies used [11].

Similar to comfort, different fields describe energy behaviour according to their relevant scope. Five main perspectives of energy behaviour were identified in literature: sociology, economics, engineering, psychology, and education. The engineering-economics approach seems to dominate the literature. It is suggested that due to this dominance, much is missed in terms of what social sciences can offer to the subject [12].

In this section, theories of energy behaviour are described by discipline. These approaches present their views on the reasons why householders exhibit particular forms of energy behaviour.
4.1 Sociology

The sociological theory states that energy use is invisible: there is a switch and energy is used until it runs out from the supply systems, without the user being aware of the consumption. Energy systems are complex in terms of their infrastructure, control options, comfort and social norms. Many of such factors lie beyond the control of home occupants: they are passive receivers of energy [13]. Shove [14] proposes a ‘co-evolutionary’ approach to understand comfort and energy consumption as a whole: both social and technical dimensions play a role for comfort making, and so, three relationships have to be explored: the one between technologies and social practices, between technologies and social norms (meanings behinds practices), and the relationship between social norms and social practices. By understanding these three relationships, Shove claims that social norms can be influenced to stimulate a reduction in energy demand and sustainable lifestyles.

4.2 Economics

The economic theory postulates that energy is a commodity and occupants are rationally-driven buyers whose decisions directly respond to energy prices: the higher the prices, the lower the demand. Nevertheless, studies have shown that such classical economics definition seldom applies to real behaviour. It has been shown that gas consumers in colder winters will use more gas even when they know gas prices rise [15], or that potential energy savings have no influence in occupants’ decisions to apply efficient technologies at home [13]. Therefore, thermal comfort might have a stronger impact than costs do. Behaviour economics is a new branch which tries to analyze consumption from financial and social perspectives, for example to explain the rebound effect [13].

4.3 Engineering

The engineering view focuses on developing and installing innovative, sustainable, energy-efficient measures, which should provide an acceptable range of comfort while saving energy and thus being cheaper. These are developed based on physical and physiological calculations and models and installed with the assumption that consumers will use the technologies as they are designed [10].

4.4 Psychology

This view proposes that energy behaviour is the result of the response mechanism of the occupant to a perceived stimulus. Most theories on behaviour follow the ABC model: the occupant Attitudes towards energy consumption influence their Behaviour, which eventually influence their consumption Choices. It is also suggested that the more the occupant can
make a link between an energy consuming device and the degree of consumption, the more the person is conscious of their energy demand [16].

4.5 Education

The education theory proposes that energy consumption is a skill that is learned through experience. Users are people with different learning capabilities and different motives for learning. The theory suggests that people learn energy management skills through feedbacks, such as their bills, their energy system, comfort preferences, etc., and so their consumption is based on what they perceive as the ‘right’ or ‘wrong’ action in terms of savings, social responsibility, etc. [13, 17].

5. Discussion

Residential energy consumption and ‘comfort-making’ by occupants are two complex topics that should perhaps not only rely on models, since this seems to create a set of ‘blind spots’ in the understanding of the topics. As seen in this review, in order to provide better comfort to occupants while influencing their behaviour into a more sustainable one, the notions of comfort and energy consumption need to be approached not only from a technical point of view, but from a comprehensive one, including more input from behavioural sciences.

As Shove [14] proposes, there is a need to understand comfort as a dynamic concept, which results from the interaction of daily routines, building technologies, and several other factors. By considering comfort as a multidimensional concept, a gap opens up in the understanding of energy consumption, as comfort dimensions –beyond the physiological ones– may have an important contribution in energy behaviours. As spatial heating is the main part of energy consumption in residences, thermal comfort becomes an important actor for energy demand reduction measures. Literature is heavily influenced with a technical perspective of thermal comfort, which complements the engineering view of ‘comfort’ standards of buildings. These standards do not necessarily translate into ‘comfort’ as perceived by home residents [18].

Similarly, energy use needs to be considered from a holistic approach, which shall allow for a more sophisticated understanding of it, and thus for strategizing for reduction of energy use, rather than relying on oversimplified models based on technical aspects, which keep offering sustainable, efficient, or conservation solutions to occupants, without ultimately reducing energy consumption [12].

This approach to energy use should be characterized not only by taking a more social view, but also by acknowledging the limitations of current
theories, while trying to understand people and their actions rather than seeing them as automated objects.

The focus of this literature review was energy consumption and comfort. However, health is just as important to consider and will be incorporated in a next study. There is a need to understand the relationship between energy consumption and health, and between health and comfort [2]. Discomfort has an effect on health, and vice versa. And health includes the dimension time. Exposure to a certain situation can result directly in discomfort, while health effects can take a while to manifest.

6. Conclusion

Comfort and energy consumption are closely linked in residences. Many fields of study have tried to improve people’s comfort, and to reduce energy use. Unfortunately, it seems that the topics have not been studied well enough in terms of their interrelationship, and in terms of the dimensions that they are both made of.

Comfort is more than feeling thermal, acoustic, visual, and air quality satisfaction. Comfort is a multidimensional construct, which is influenced by what the environment offers and enables, and by what the occupant does within the environment. Therefore, comfort should be studied in more ways than through physiological standards, for example by adding psychosocial and environmental components.

Energy behaviour has been tried to be explained by different disciplines in an unarticulated manner: engineering, education, sociology, economics, and psychology. Often with an emphasis on the technical and economical aspects, which focus on providing sustainable and efficient measures to people, while keeping physiologically ‘acceptable’ comfort standards. Such an approach seems to neglect certain links, since energy consumption often keeps rising in spite of such measures.

Although health has not been considered in this literature review, it is an important aspect and needs to be considered as well. The biggest challenge of today lies in the accomplishment of a sustainable and low-energy built environment and at the same time a healthy and comfortable built environment. To accomplish this ‘consumers’ and ‘users’ should start being treated as humans which can be listened to, observed, and that can provide valuable insights, rather than as passive objects that receive technologies and that need to be corrected.

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