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AN ALTERNATIVE DESIGN APPROACH FOR CURRENT ENERGY-EFFICIENT HOUSING CONCEPTS: CONCEPTUAL FRAMEWORK ENABLING A DYNAMIC WAY OF LIVING THROUGHOUT THE SEASONS

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INTRODUCTION

The search for sustainable and quality housing renovation leads to a strong focus on energy-efficiency where the implementation of housing concepts, such as passive houses, has become common practice. The imposed measures focus mostly on optimizing the building envelope and introducing extra systems to lower operational energy consumption. It is therefore an object-centred design approach. However, not all effects are beneficial, since the material consumption and renovation costs of energy-efficient buildings are rapidly increasing. Besides, highly insulated, energy-efficient environments, where the resident is considered passive, can still have higher energy consumptions due to the influence of user practices[11].

These problems, arising from an object-centred design approach, indicate a need for an alternative solution that considers the environmental impact from buildings (supply) *and* residents (demand) [2, 24]. Finding consistency between supply and demand is seen as a fundamental component to promote more efficient use of all resources (materials, energy and costs) in the built environment, also referred to as *resource*-efficiency [23]. European policy on resource efficiency for buildings aims to provide designers with usable information on decision-making and promote improved design to bring resource efficiency gains [5]. Therefore, the overall research shifts away from an object-centred energy-efficient supply to a user-centred design approach which promotes more sufficient energy demand by dealing with an active resident.

This paper provides theoretical insights on challenges of the current object-centred approach in energy-efficient buildings by investigating user interaction between the resident and environment. In addition, the paper explores alternative design criteria for an innovative user-centred design approach. This results in a conceptual framework which considers the interactive relationship between resident and environment (building and climate) and proposes a more dynamic way of living throughout the seasons for residents to lower the actual energy demand.

METHOD

First, by means of a literature study, the interactive relationship between resident, building and climate is explored through literature on “dynamic architecture” which clarifies the complex interaction between the residents and environment. Secondly, the paper investigates the current lack of user interaction in energy-efficient housing concepts by means of studies on occupant behaviour and comfort, resulting in three design challenges within an object-centred design approach. Thirdly, as a response to these design challenges, alternative design criteria that promote more effective user interaction are derived from literature on user-centred design methodology.

RESULTS & DISCUSSION

User interaction: A static built environment responding to a dynamic resident and seasonal changes

Due to the influence of user practices on the energy demand, exploring interaction between resident and environment is needed. Within the field of "dynamic architecture", the interactive relationship between resident, building and climate serves as the foundation for designing efficient buildings. This interaction is described as the environment acting on, responding to and interacting with the resident and vice versa [17]. The building can be seen as an intrinsically static, solid element with a potential ability to adapt, move and rotate, otherwise referred to as adaptable, transformable and flexible architecture. Although there are many interpretations for "dynamic architecture", the overall aim of the building is responding to change, more specifically, seasonal changes and residents [8].
The latter is seen as, active, moving and energetic, also defined by the Oxford dictionary as *dynamic,* due to diversified comfort and spatial preferences[3]. The dynamic resident interacts with his environment by occupying, utilizing (heating, cooling, ventilation) and experiencing the indoor living environment in different ways. These user interactions vary daily but recur every season and can be considered as a pattern, the living pattern of the resident. The living pattern, characterized by carrying out activities (e.g. cooking, sleeping, bathing) and actions (e.g. opening windows, changing thermostat), influences the energy demand. Similarly, the outdoor climate is a non-static element as it is characterized by varying climatic conditions throughout the seasonal changes [9]. The underlying dynamic parameters of the outdoor climate (position of sun, sun radiation, temperature, wind and humidity) are directly and indirectly (comfort of resident) influencing the energy demand. Consequently, dynamic residents and seasonal changes can highly affect the steady-state of the built environment. The intrinsically static building needs to respond to these changing elements with a more user-centred design approach in order to promote an efficient living pattern and sufficient energy demand.
To further develop such an alternative approach, a conceptual framework is derived from literature which serves as a red dread throughout the overall research. The framework builds upon the three key parameters which influence the actual energy demand: resident, building and climate. It presents the current design challenges of object-centred energy-efficient building which cause a lack of efficient user interaction. As a response to these challenges, the framework also suggest three design criteria based on a user-centred design methodology which deal with dynamic residents and seasonal changes. To clarify the application of the suggested design criteria, design support is added to the framework and presented as examples throughout the paper.

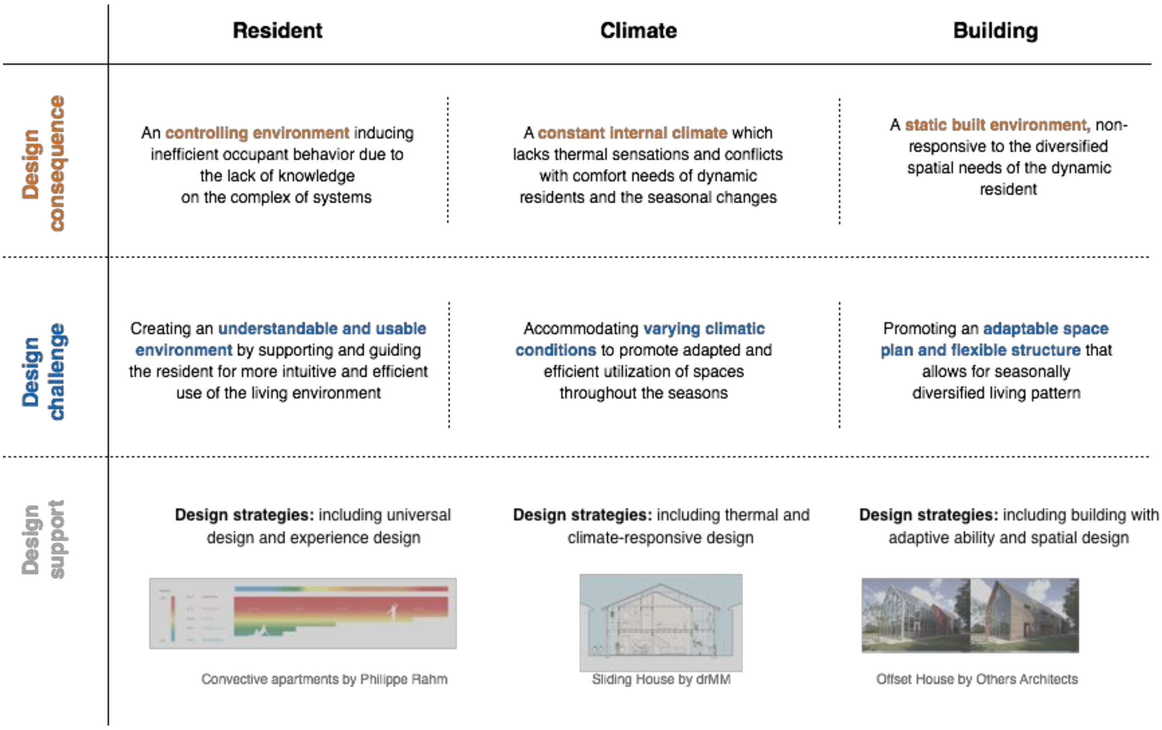

Figure 1 Conceptual framework enabling a dynamic way of living throughout the seasonal changes

The conceptual framework aims for enabling varying indoor climatic conditions for more adapted use of spaces, adaptation to diversified occupation of spaces throughout the seasons and support and guidance of the dynamic resident for more experience and user satisfaction. Therefore, the intrinsic concept of the framework within the context of the research is defined as enabling a dynamic way of living throughout the seasonal changes. In the next three paragraphs, the paper elaborates on these design challenges, criteria and support.

1. From an actively controlled environment to an intuitive, user-friendly environment

The first, often recurring energy-efficient measure is implementation of active systems for heating, ventilation and cooling (HVAC). Currently, critical questions about actively controlled environments are raised by researchers as well as architects, for instance "What is more important: efficient technologies or efficient user practices?" [10]. Through the standardization of comfort norms in combination with the excessive use of fully automated HVAC systems, the need of the resident for personalized conditions and the possibility to feel in control of the environment is neglected.[3]. The mechanization of the built environment is generating a controlled, complex environment for the non-passive resident and unfolds as a first indication of lack of user interaction.
Currently residents are often implicitly seen as passive recipients of their environment. However, residents intend to change and interact with the indoor conditions in a dynamic manner to assure optimal comfort [6]. Field studies on occupant behaviour show that residents are more satisfied and tolerant in a living environment when experiencing control and having more options towards changing the internal conditions[18]. However, the complexity of the operation of active systems often overpasses

the knowledge of the resident, which is only inducing disconnection between the resident and the built environment [13]. Consequently, when the dynamic resident is not interacting properly or is dissatisfied with the systems, it is inherently linked to actions (e.g. opening windows for ventilation, heating with additional devices) which are conflicting with the operating systems (e.g. automatic thermostat). The lack of proper user interaction and efficient occupant behaviour are two of the underlying causes of the performance gap, leading to higher actual energy demands [20, 25].
Thus, taking control over the indoor environment, or controlling the resident, is not inducing effective user interaction or promoting efficient use (e.g. space heating) of the building. Therefore, a first design challenge is derived: an actively controlled environment, can induce a lack of user interaction and lead to inefficient occupant behaviour and higher actual energy demand due to lack of knowledge about the operation of the complex systems.
Consequently, there is a clear need for a living environment that is more understandable and usable for residents to promote effective user interaction and consequently, more (energy)-efficient use of the indoor living environment [22]. User-centred design improves the quality of user interaction, not by forcing residents' behaviour, but guiding and supporting them [1]. Underlying strategies, such as Universal Design (UD), enable more intuitive, easy-to-use environments that allow for more experience, more sustainability, more interaction through an alternative design process and the implementation of design principles [15, 14]. For instance, by designing an environment in such a way that inefficient occupant behaviour becomes more difficult and sustainable behaviour is made easier [26]. Therefore, as a response to the previous design challenge, a first design criterion for the framework is proposed: creating a living environment that is understandable and usable for a more intuitive and efficient use of the indoor living environment by supporting and guiding the dynamic resident.

2. From an insulated, constant internal climate to varying climatic conditions

A second important measure within the object-centred design approach are the large amounts of insulation, rapidly filling our buildings and isolating the resident, from the outdoor climate [21]. Besides the implementation of active systems, highly insulated buildings can induce higher comfort temperatures (e.g. keeping a constant 22°C within the *whole* building volume throughout the year) [16]. Therefore, the efficiency of optimizing the building envelope turns into an increase of the actual energy demand due to change in occupant behaviour (e.g. higher comfort needs) [11].
Consequently, the benefits of implementing high amounts of insulation are argued by researchers and practicing architects by pointing out that it is leading to the disappearance of the appreciation of thermal variations and sensation for the resident [4, 16]. Furthermore, in comfort studies it is often questioned if it is necessary to keep such a constant indoor climate, as it can lead towards designing our buildings with anticipation of constant and high comfort conditions[3].
Sociological studies on occupant behaviour show variations in heating consumption depending on residents' activities and behaviour and the diversified thermal requirements of these activities [12]. In addition, comfort experiences of residents can vary widely because they have personalized preferences throughout the year regardless of the often anticipated constant indoor climate[12]. Therefore, a conflict arises between insulating buildings and isolated residents who are in need of varying thermal conditions. Thus, leading to a second design challenge: a constant internal climate with lack of thermal sensations is in conflict with seasonal changes and the comfort needs of a dynamic resident which can lead to higher energy demand than needed.
As a response, it is argued that varying indoor climatic conditions answer better to the seasonally diversified comfort needs of residents as it is a source of sensory and pleasure [3]. Although, people are

quite sensitive to subtle changes in the thermal conditions of the environment, it is also shown that people have a wide range of thermal conditions they can adapt to [16]. Within the field of physiology and psychology, some research aims for varying indoor climatic conditions to induce dynamic human experiences and recognition of activities with different thermal requirements [6]. Additionally, in practice, designers argue that a principle of energy-conscious architecture lies not only within taking advantage of the energy of the dynamic climate, but also from the energy produced by residents who acclimatize the indoor environment in different ways throughout the year [4, 7]. Therefore, as a response to the second design challenge, a new design criterion is derived that responds to the isolation of the resident from dynamic (outdoor) climate by aiming for: accommodating varying climatic conditions for the living environment that promote an adapted and efficient utilization of the living environment throughout seasonal changes

For instance, the Swiss architect Philippe Rahm experiments with varying indoor climatic conditions in his "Convective apartments" where he uses the phenomenon of stratification to divide the indoor living environment in different thermal zones.

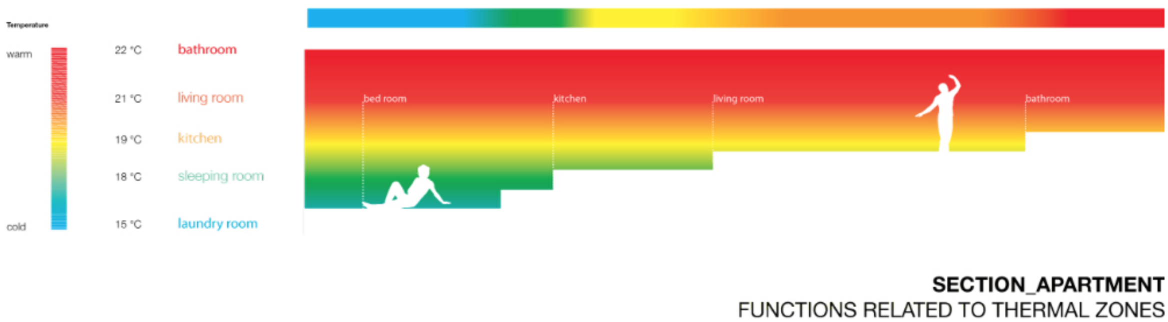

Figure 2 Convective apartments by Philippe Rahm (2010), derived from philipperahm.com on 19/12/15

3. From a static built environment to an adaptable and flexible living environment

The third challenge within an object-centred design approach relates to the static built environment. The resident is often forced to adapt to the buildings' design rather than the building responding to the dynamic living pattern of residents (e.g. different occupation rates of spaces throughout the seasons), only inducing the lack of proper user interaction. Studies on occupancy prediction and occupant behaviour show the high influence of the occupation pattern on energy demand[20]. For instance, the amount of energy wasted during non-occupied hours can be higher than during occupied hours due to buildings' design and static features that are not responding to the daily varying occupancy rates of spaces[7].

Not anticipating and responding to the diversified spatial needs of residents can cause a weak link in energy-efficient building. Although, most occupancy studies focus on non-residential buildings, considering the dynamic resident and its daily *and* seasonally changing spatial preferences in dwellings is needed due to the influence on the actual energy demand. Therefore, the buildings' design must cope with dynamic and constantly moving residents by allowing for adjustments within the buildings' space plan or structure to fit the diversified spatial needs of residents [17]. Consequently, a third design challenge can be derived: a static built environment cannot efficiently respond to the diversified spatial needs of the resident throughout the day and seasons.

As indicated in the first paragraph on user interaction, literature on dynamic architecture (flexible, adaptable, transformable architecture), expresses the need for buildings that adapt to the dynamic resident rather than the resident, having to adapt to the (static) built environment [19]. A crucial principle of user-centred design, contrary to object-centred design, is starting the design process from the spatial preferences and personal comfort needs of a dynamic user by means of providing adaptive environmental conditions to enhance the user interaction [27]. More specifically, a flexible, adaptable mode of living promotes a living environment that can change when circumstances (e.g. seasonal varying climatic conditions) require it [17]. Therefore, a third design criterion is suggested: providing an adaptable space plan and flexible structure to promote seasonally diversified occupation of spaces, leading to more effective user interaction and dynamic use of the living environment.

For instance, the McCoy House Project (Figure 3) discussed in "Sun, wind and light" by DeKay and Brown (2014), where movable walls ensure different seasonal occupation possibilities for residents (e.g. from a closed building in winter to an open building in summer)

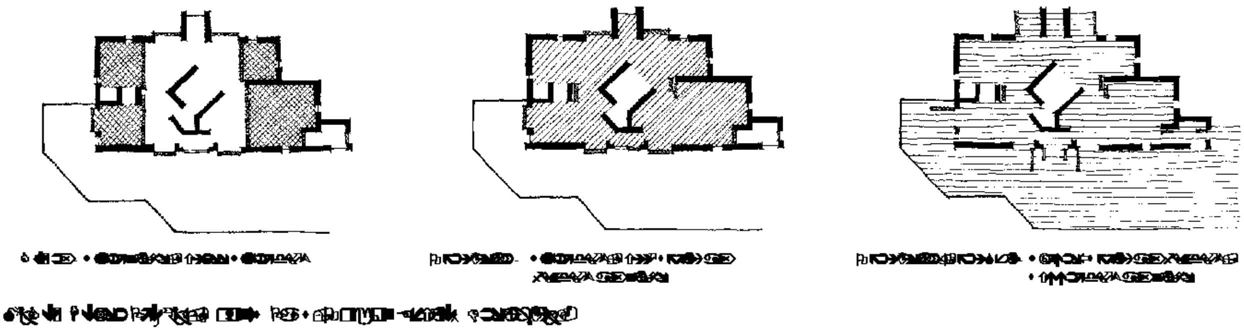

Figure 3 The McCoy House Project, derived from DeKay and Brown (2014)

CONCLUSION

Enabling a more dynamic way of living throughout the seasons for the resident for more (energy)-efficient use of the living environment

The applied object-centred design approach that focusses more on the development of an energy-efficient supply than promoting a sufficient demand for the resident induces new design challenges: a controlling, constant and static living and built environment for a dynamic resident and varying seasons. The lack of user interaction, inducing inefficient occupant behaviour, within energy-efficient housing concepts can lead towards higher actual energy demands when the building is in use. As a response, a user-centred design approach, by means of three design criteria, is suggested for further development of an alternative energy-efficient housing concept. The approach considers the seasonally varying comfort needs and spatial preferences of the dynamic resident to create more effective user interaction which is defined as a dynamic way of living throughout the seasons. The results are presented in a conceptual framework by means of design challenges and suggested criteria and aims for more (energy)-efficient use of the living environment. However, the research will further investigate if, when implemented, a dynamic way of living throughout the seasons can decrease the actual energy demand. Moreover, if the design approach limits the need for large quantities of additional materials (e.g. insulation) and expensive systems for more resource-efficient renovations.

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