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Climate change and thermal comfort in Southern Europe housing: A case study from Lisbon

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ABSTRACT

The world has been experiencing a significant increase in daily average temperatures per decade and climate change scenarios are projecting high probability of more frequent heat waves. In vulnerable regions, like Southern Europe, where most of the residential buildings still rely on natural ventilation for cooling, impact on thermal comfort can be significant in terms of health, well-being and also energy consumption. The question is particularly important for the existing building stock, which was not designed considering the projected future climate conditions and is prone to be subjected to interventions with the purpose of improving thermal performance. The study presents a vulnerability framework and methodology for the assessment of thermal comfort in existing dwellings in the context of climate change. Results relating to a 1960s typical building case study in Lisbon, Portugal, suggest that specific dwelling characteristics, such as orientation, and occupancy profiles are relevant when assessing vulnerability, suggesting significant differences, of up to 91% in discomfort hours on an annual basis. Furthermore, increased insulation seems to be effective in decreasing discomfort, as the best results (48% in discomfort hours decrease) stem from a context of external insulation for a heatwave situation. The methodology can be useful for assessing vulnerability in existing dwellings and its specific conditions. It can also contribute to understanding the effect of energy retrofitting measures in future climate conditions, assisting energy efficiency policies and decision-making regarding retrofit interventions.

1. Introduction

As the world experiences a progressive increase in temperature, climate change is recognized as a global key challenge for the 21st century. According to the Intergovernmental Panel for Climate Change (IPCC), an increase in the global mean surface temperature is expected to range from 0.3°C–0.7 °C to 2.6°C–4.8 °C until 2100 in relation to a 1986–2005 baseline [1]. Moreover, results from modeling studies indicate a 5 to 10 factor increased probability in the occurrence of more frequent and severe heatwaves in a 40-year timeframe [2]. Heatwaves are considered to be life-threatening events and are an object of concern regarding adaptation [3]. During the 2003 European heatwave, still seen as a reference due to its intensity, duration and geographical extension fields [4], countries like France, England and Portugal registered an increased number of deaths related to abnormal high temperatures inside dwellings [5].

Cities are at the forefront of this challenge. It is estimated that, for a developed nation, about 25%–40% of energy-related anthropogenic emissions of carbon dioxide can be attributed to buildings [6]. Acknowledging this fact, energy efficiency of buildings has been promoted as an important mitigation factor in the political and technical European agenda. With a focus on the concern about the rational use of energy and associated reduction of emissions, legal measures and regulations were adopted in order to establish minimum levels of thermal performance for both new and existing buildings.

However, whether due to slowly changing climatic conditions or more frequent, sudden extreme events, existing buildings (and their occupants) will most likely have to cope with conditions for which they were not initially designed, thus compromising their ability as "climate moderators" [7]. These views combined suggest there is a need to balance mitigation and adaptation to a changing climate. In Europe, the vast majority of residential buildings still

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remain naturally ventilated [6], therefore proving relevant the discussion in literature about the factors motivating the increasing uptake of home air conditioning devices [8]. A core argument is that, in response to future expectations of change in temperature, the installation of such devices is likely to increase, which would lead to a greater energy demand from buildings [9]. This line of thinking is important to the extent that studies point out high levels of fuel poverty occurring already in Europe, predominantly in Eastern and Southern European countries [10] and that the most vulnerable households may not afford the increasingly high fuel costs in summer, leading to interesting discussions around the concept of summer fuel poverty in those countries [11].

The study of these issues is therefore significant not only from a perspective of human well-being but also from an energy savings and efficiency point of view. Several studies suggest that there are potential significant impacts to be expected in terms of discomfort as a result of climate change and extreme events, differing according to the geographical location, building type and function [12] as well as constructive characteristics [13]. For this reason, thermal comfort and adaptation studies are being conducted on a common ground, with an underlying discussion regarding the adequacy of thermal comfort standards in assessing indoor conditions in the future [14] and which kind of climate projections to use [15]. The review highlights the fact that Northern Europe and United Kingdom in particular, have been the most active in research on impacts and adaptation to a changing climate in buildings, either from monitoring and/or modeling [16], but studies focusing on Southern Europe are scarce in comparison. In that context, a study worth of note related to Portugal, is Aguiar et al. [17], devoted to thermal loads of a typical single-family house and an apartment. Results indicate that a reduction in heating requirements is expected, but it would not compensate entirely for the increase in air conditioning demand in summer, which suggests a considerable impact on the thermal performance of buildings. The study was part of a broader research regarding scenarios, impacts and adaptation in Portugal [18], concerned with impacts on the energy sector and assisting the preparation of the National Adaptation Plan. National Adaptation Plans are generally considered the backbone of regulation and strategies regarding adaptation, although approaches for implementing and evaluating the proposed strategies seem to be lacking [19]. This gap is acknowledged by Gangolells et al. [20] while exploring the impacts of the Spanish stock of buildings to climate and summer overheating. It argues for the role of regulatory instruments, until now focusing strongly on mitigation, as well as the very constitution of the existing building stock, concerning age and physical quality. In fact, Southern Europe is characterized by a stable and aging building stock of significant proportions, mainly built prior to the implementation of thermal regulations [6], which has been already been identified as a major challenge regarding sustainable development [21]. In existing buildings, adequate thermal performance is mainly promoted through retrofitting actions, prone to increase thermal insulation and air-tightness, and several authors have already suggested that a heating-reduction driven policy and decision-making regarding measures such as insulation, can have unexpected effects if considered in a climate change context [22,13,20]. These studies also stress the fact that most literature dedicated to adaptation regarding thermal comfort is technically focused and driven to understand adaptation measures to be applied to buildings [12,23,24]. In comparison to building design, attention given to the role of occupants and their behavior while operating naturally ventilated building controls in reviewed studies across Europe, is limited [25,26].

This paper contributes to this body of work briefly presented above, by focusing on the influence of insulation measures in building envelopes, particularly in residential buildings and at the scale of dwellings, where occupant behavior and ventilation strategies can be determinant in avoiding indoor discomfort. Consequently, an examination of prevailing thermal comfort standards and their usefulness in assessing comfort in a changing climate context, is also a key aspect of this study.

Additionally, this study conceptualizes the problem as a vulnerability issue. Vulnerability represents a well-researched and mature approach to understand a system's response to change, despite the variety of definitions and approaches found in literature [27]. The IPCC definition, as “the propensity or predisposition to be adversely affected” [28] consider it to be a function of the magnitude and character of the climate variation and change, its exposure, sensitivity and adaptive capacity. While recognizing the generic nature of this definition, vulnerability here is approached from a biophysical perspective [29] and the dwelling, as a unit of accommodation, is seen as a system, encompassing the physical environment, the occupants and the rules and institutions regulating how occupants interact with building controls in order to achieve comfortable conditions [30]. The above-cited definition presupposes exposure as related with “the presence of people (…) infrastructure or economic social or cultural assets in places that could be adversely affected” [28]. Furthermore, sensitivity is defined as “the degree to which a system (…) is affected (…) by climate variability or change” [28] and adaptive capacity is considered to be “the ability of systems, (…) to adjust to potential damage (…) to respond to consequences”[28]. From this viewpoint, adaptive capacity is not a direct component of vulnerability, as generally interpreted [31]. Instead, it is operationalized as a property of the system, capable of offsetting or reducing vulnerability, through the implementation of adaptation strategies.

A methodology is proposed to assess relative effectiveness of changes in thermal comfort vulnerability and is illustrated and developed through its application on two dwellings in Lisbon (Portugal).

2. Methodology

The main objective of this study is to develop a methodology to assess thermal comfort vulnerability in residential buildings for Portugal, taking into consideration potential changes, namely those regarding levels of insulation and occupancy. This section presents the materials and methods used and elaborate on the particularities of the case study used to develop the methodology.

2.1. Case study

With a recorded increase in average temperature of 0,5 °C per decade, Southern Europe is considered to be more vulnerable to climate change than Northern Europe [18]. As an example of dense Mediterranean cities with a significant heat island effect [32], Lisbon has mild winters and hot and dry summers with high levels of solar radiation. According to the monthly climate data for Lisbon, the hottest month is August, with an average temperature of 23.5 °C. The highest absolute temperature ever registered was 42 °C, during the 2003 heatwave [4]. During the last decade, heatwaves were recorded in at least half the years, occasionally more than once a year, and lead to significant losses in terms of human lives and well-being [33].

Most of Lisbon buildings constructed after 1950 used reinforced concrete [34] at a time when specific building codes and thermal regulation were still lacking - the first Portuguese thermal regulation only came in place in 1990 (DL. 40/90 of February 6th). With the gradual neglect of vernacular architecture features and insufficient knowledge about new construction techniques, buildings