MAPPING RESIDENTIAL THERMAL COMFORT GAP AT VERY HIGH RESOLUTION SPATIAL SCALE: IMPLICATIONS FOR ENERGY POLICY DESIGN

João Pedro Gouveia, CENSE – Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal, email: jplg@fct.unl.pt

Pedro Palma, CENSE – Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal, email: p.palma@campus.fct.unl.pt

Júlia Seixas, CENSE – Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal, email: mjs@fct.unl.pt

Sofia Simões, CENSE – Center for Environmental and Sustainability Research, Department of Science and Environmental Engineering, Faculty of Science and Technology, Universidade NOVA de Lisboa, Caparica, Portugal, email: sgcs@fct.unl.pt

Overview

With the purpose of meeting the set targets for 2020, the EU has steered its policy towards the reduction of building's energy consumption, which nowadays represents 40% of the EU total energy consumption, mainly through energy efficiency (EE) improvement, as stated in the EU Directive 2010/31. Nevertheless, residential sector cannot disregard the thermal comfort, which relates to people's health, welfare and ability to function. The effect of changes to buildings' structure, materials used or installations, should always take into account the maintenance of the thermal comfort quality of the building (Peeters et al., 2008).

Excess seasonal deaths are associated with thermal efficiency of housing and inability to maintain the adequate thermal comfort indoor temperatures. In Europe, due to poor building construction, low household income and the rise in energy costs, between 50 and 125 million people are not able to have thermal comfort in their households (WHO, 2012). Chronic exposure to low ambient temperatures results in an adverse impact to the physiological condition of humans (Healy and Clinch, 2002).

In this work we use Portugal as case study due to its location in Southern Europe, targeted as one of the most likely climate impacted regions. According to Santos e Miranda (2006), a generalized increase of monthly cooling energy demand and a reduction of monthly heating energy demand, as well as a reduction of the heating season and a consequent extension of the cooling season is likely for Portugal.

The achievement of thermal comfort is a relevant issue to be addressed, as about 28% of the population are enable to keep their house warm during the winter, the highest percentage among the EU15 and the second highest in all European Union (WHO, 2012). During the summer, an estimated 40% of the general population cannot keep their house cool (WHO, 2012), as most residential buildings rely on natural ventilation for cooling (Barbosa and Santos, 2015). The aim of the study is to determine heating and cooling energy needs and assess the energy gap on thermal comfort at households, both in heating and cooling seasons. The approach was applied throughout the 5 climatic zones of Portugal, ranging from the coldest, with more than 1800 heating degrees-day per year and a summer outside temperature between 20º and 22ºC and the warmest zone, with less than 1300 heating degrees-day/year and an outside summer temperature above 22ºC. All the 3092 civil parishes and approximately 3.8 million dwellings, occupied and of usual residence, were considered, while capturing specific details of construction, climate, average households areas for each region to support local dedicated energy policies and instruments.

Methods

A buildings typology approach supported on a set of key building's characteristics (e.g. area, walls, bearing structure) was used. A total of 11 different building typologies were established for each region of the country. The distinct building characteristics of each region were taken into account in the typologies. The number of dwellings was estimated from data regarding the building stock and subsequently assigned to the different housing typologies. Energy needs for space heating and cooling were calculated according to the most recent Residential Buildings Energy Performance Regulation (REH) using a steady state method resulting from the related European Directive and build upon work previously carried out by Lopes (2010).

Heating/cooling energy demand derived from this method, indicates the value of energy needs for a household, considering the hypothesis of a permanent heated/ cooled area during the heating/cooling season. These needs are theoretical since in residential buildings, the actual cooled and heated area represents only a small fraction of a household and the devices that supply this demand are switched-on only part of the time. As mentioned by

Asimakopoulos et al. (2012), the partial coverage of the energy needs due to social and economic reasons is difficult to predict (i.e. evolution of poverty).
The results were benchmarked to the real energy consumption estimated for heating and cooling equipment ownership data and energy use statistics. Several sensitivity analysis scenarios based on adjustments concerning the typologies average cooled/heated areas and the operating hours related to different occupancy schedules were tested in order to analyse a more realistic approach to the theoretical energy needs. Results were mapped using the QGIS software for visualization and spatial analysis.

Results

Our analysis for the all country parishes show that the average gap between the real energy consumption and heating and cooling energy needs, is respectively 92,6 and 97,5%, taking the indoor temperature set by legislation. This means that the average energy consumption is only 7,4 and 2,5%, for heating and cooling respectively, of what it is theoretically demanded, in order to heat or cool, for 24 hours a day, 100% of the area of a Portuguese civil parish.
It is possible to observe that 87% of all civil parishes have a heating gap higher than 90%, whilst for cooling, 99% have a gap bigger than 90% (Figure 1). The low percentage of central heating and cooling equipment ownership and the considerable number of aged buildings (about 20% of dwellings are dated from before 1960) without insulation and with materials with high thermal conductivity, are also important factors that explain these gaps.
In order to bridge this thermal comfort gap, the national consumption for heating and cooling, would be approximately 11 and 26 times (respectively) bigger than the consumption in 2013 This analysis red flags the problem for public policies, both for addressing the current fuel poverty levels across the country as also to understand how this issue could be tackled in a sustainable environmental way.
Under the sensitivity analysis scenarios, where the shares of households’ area heated/cooled and the operating hours equipment were changed according to the climatic zone, the results show, that for distinct reductions from 25% to 50% in household heated areas and in hours of climatization equipment use, the average heating gap is reduced to 31%, and the cooling gap 86%. Nevertheless, despite this strong reduction, according to this scenario, to have thermal comfort all over the country, the heating and cooling energy consumption should be 1,12 and 4,86 times bigger than the 2013 consumption. Regionally, several civil parishes in the north of Portugal have the most significant heating gaps, whilst high cooling gaps can be observed across all region of the country.

Conclusions

Lack of thermal comfort is a real concern to a considerable part of the European population and it is an issue that should be quickly and seriously addressed, as it constitutes a risk for population’s health and proper living. Policies and strategies related to building rehabilitation and building construction are paramount to be considered, instead of the current trends on social tariff support being given by governments.
The outcomes of this analysis are key to support energy efficiency policies at central and local level, allowing effectiveness on energy consumption reduction while guarantying acceptable thermal comfort levels, with a special focus on vulnerable population.

References

Asimakopoulos DA, Santamouris M, Farrou I, Laskari M, Saliari M, Zanis G, et al. Modelling the energy demand projection of the building sector in Greece in the 21st century. Energy and Buildings 2012 2012;49:488e98.

Barbosa, R.; Vicente, R., Santos, R. (2015). Climate change and thermal comfort in Southern Europe housing: A case study from Lisbon. Building and Environment 92, 440-451

Healy, J.D., Clinch, J.P. (2002). Fuel poverty, thermal comfort and occupancy: results of a national household-survey in Ireland, Applied Energy 73, 329-343

Lopes, T.M.P. (2010). Potencial de Poupança de Energia na Climatização de Edifícios Habitacionais, MSC, Univerisdade Nova de Lisboa, Departamento de Ciências e Engenharia do Ambiente.

Peeters, L., Dear, R., Hensen, J., D’haeseleer, W. (2009). Thermal comfort in residential buildings: Comfort values and scales for building energy simulationn. Applied Energy 86, 772–780

Santos FD, Miranda P, editors. Climate change in Portugal: scenarios, impacts, and adaptation Measures e SIAM II project; 2006. Gradiva. Portugal. (In Portuguese).

World Health Organization. (2012). Environmental Health Inequalities in Europe.