Mapping Residential Thermal Comfort Gap at Very High Resolution Spatial Scale: Implications for Energy Policy Design

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OVERVIEW

With the purpose of meeting the set targets for 2020, the European Union (EU) has steered its policy towards the reduction of building's energy consumption, which currently represents 40% of the EU total energy consumption. Nevertheless, the residential sector cannot disregard the thermal comfort, which is interconnected with people's health, welfare and ability to function. The effect of changes to buildings' structure, materials used or appliances, should always take into account the maintenance of the indoor thermal comfort (Peeters et al., 2008). In EU, due to poor building construction, low household income and the rise in energy costs, between 50 and 125 million people are not able to ensure 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).

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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 (Santos and Miranda, 2006). The achievement of thermal comfort is a relevant issue to be addressed, as about 24% of the population are unable to keep their house warm during the winter, the highest 5th highest percentage among the EU28 (Eurostat, 2017). During the summer, an estimated 36% of the general population cannot keep their house cool (Eurostat, 2017), ranking second in all EU28 countries, as most residential buildings rely on natural ventilation for cooling (Barbosa et al, 2015). Simoes et al. (2016) analysed 29 Portuguese municipalities and estimated that 22% and 29% of the inhabitants are potentially fuel poor, regarding the heating and cooling needs of their homes.

The aim of this study is to determine heating and cooling energy needs and assess the energy performance gap on thermal comfort of households, as in Wilde (2014) and Callì (2016), both in heating and cooling seasons. The approach was applied throughout the five 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 near 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 the definition of local dedicated energy efficiency policies and instruments. Current average country consumption for heating is 1.51GJ/capita and for cooling is 0.35 GJ/capita in the residential sector (INE and DGEG, 2011 and DGEG, 2017).

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 specific building characteristics of each region were taken into account in the typologies. The number of dwellings was estimated from building stock data (INE, 2011) and subsequently assigned to the different housing typologies. Energy needs for space heating and cooling were calculated according to the most recent legislation - Residential Buildings Energy Performance Regulation (REH) using a steady state method (Palma, 2017), and building upon previous work by Simoes et al. (2016) and 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 (DGEG, 2016). Two sensitivity analysis scenarios (Conservative and Strict) based on regional 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 than the theoretical energy needs. Results were mapped using the QGIS software for visualization and detailed spatial analysis.

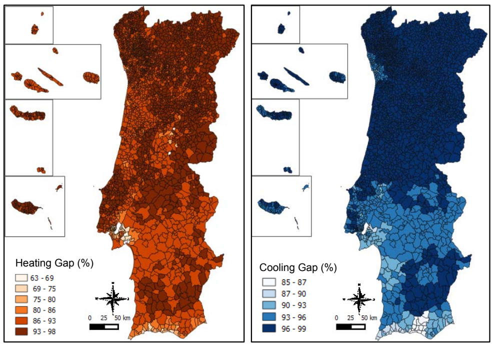

Figure 1 - Heating and Cooling gaps for the Reference scenario

RESULTS

Our study for the all civil parishes shows that the average gap between the real energy consumption and heating and cooling energy needs, is respectively 92.5% and 97.1%, considering the indoor temperature set by the legislation. This means that the average energy consumption of a Portuguese civil parish is only 7.6 and 2.9%, for heating and cooling respectively, of what it is theoretically demand in a reference scenario, assuming that the whole dwellings' area is heated and cooled for 24 hours a day.

About 87% of all civil parishes have a heating gap higher than 90%, whilst 99% have a cooling gap bigger than 90% (Fig. 1). The parameters set in the reference scenario for the estimation of the energy needs are the main reason for such considerable gaps. The low percentage of central heating and cooling equipment ownership and the considerable number of aged buildings (about 20% of dwellings were built before 1960) without insulation and with materials with high thermal conductivity, are also important factors that explain these gaps. For cooling, the gaps are even higher due to the low rates of ownership of any kind of cooling device. In order to bridge this thermal comfort gap, the national consumption for heating and cooling, would be approximately 12 and 26 times (respectively) higher than the 2013 consumption. This analysis red flags the problem for public policies, both for addressing the current fuel poverty levels across the country and 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 of equipment were changed within the different climatic zones, the results show, that for different reductions in household heated areas and different hours of equipment use, the average civil parish' heating gap is reduced to 52%, and the cooling gap to 76% in the Conservative scenario. In the Strict scenario, the average civil parish' heating and cooling gaps are 11 and 23%. About 24% of all civil parishes still have a heating gap, while approximately 75% have a cooling gap.

CONCLUSIONS

The results obtained from the scenarios indicate that the civil parishes' gaps that are annulled, might be explained by climatization patterns set purposely by the consumers. Heating and cooling only a fraction of the dwelling's area, and for a selected period of the day, does not necessarily jeopardize the state of thermal comfort (Magalhães and Leal, 2014), which can be assumed for this case. As for civil parishes that still have a gap in the Strict scenario, this difference between energy needs and consumption is of such magnitude, that it might highlight energy poverty levels of the population and a systemic problem of thermal discomfort. As demonstrated in this work, lack of thermal comfort is still a real concern to a considerable part of the Portuguese 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, instead of the current trends on creating social energy tariff support as done by the government. The outcomes of this analysis are key to support EE policies at central and local level, allowing effectiveness on energy consumption reduction, while guarantying acceptable thermal comfort levels.

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Interviews continued

ARILD NYSTAD, PAST PRESIDENT AND PAST VICE PRESIDENT FOR CONFERENCES

I have been connected to this organization as a member since 1984 when we established the Norwegian chapter. I have served as VP Conferences for 7 years, president elect and President in 2001. During my years as a VP Conferences I enjoyed working closely together with David Williams to re-shape the conference planning for the international conferences. We worked out a new conference manual and went from a three months planning horizon to a three years with the result of safeguarding the IAEE economy.

For me the value of IAEE has three features:

Firstly the networking part: I always enjoy meeting people from academy, industry and oil producing countries. This aspect of IAEE becomes quite addictive as we are all part of the same family and we enjoy spending time together. This networking part has value for my work and gives stimuli to new ideas.

Secondly the global energy aspects that gives the opportunity to learn more about energy policies, environmental aspects and new research. I work within oil and gas sector, and listening to discussions and paper presentations during IAEE conferences contribute to my understanding of the O&G markets and the environmental aspects, which gain more and more focus.

Thirdly the international aspect of IAEE has great value. I have been to conferences in many countries and I enjoy learning other cultures. As an example of international projects, we have recently established an advisory group within IAEE, collaborating with Mexicans in an advisory capacity for the new Energy Museum in Mexico (MUNET) related to energy and educational expertise from the IAEE's council members.

Finally we should make priority to bring the young generation actively into our organization. The young professionals have a great potential to contribute for the understanding of the new challenges and bringing new ideas to IAEE.

(Interviews concluded on page 55)