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Assessing the climate change adaptation over four European cities

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In recent years, climate change has been widely recognized as a potential problem. The building industry is taking a variety of actions towards sustainable development and climate change mitigation, such as retrofitting buildings. More than mitigation, it is important to account for climate change adaptation and investigate the probable risks and limits for mitigation strategies. For example, one major challenge may become achieving low energy demand without compromising indoor thermal comfort during warm seasons. This work investigates the future energy performance and indoor thermal comfort of four European cities belonging to four different climate zones in Europe; Barcelona, Koln, Brussels, and Copenhagen. An ensemble of future climate scenarios is used, including thirteen climate scenarios considering five different general circulation models (GCM) and three representative concentration pathways (RCP 2.6, RCP 4.5 and RCP 8.5). Through simulating the energy performance of the representative buildings in each city and considering several climate scenarios, this paper provides a comprehensive picture about the energy performance and indoor thermal comfort of the buildings for near-term, medium-term, and long-term climate conditions.

1. Introduction

Global building energy consumption accounts for 40% of global carbon emissions[1]. In Europe, building energy consumption accounts for 30% of the national energy consumption [2]. To achieve reasonable energy use in the context of future climate change, it is essential to understand the potential impact of global warming on the thermal performance of buildings and take appropriate measures to prevent unnecessary energy waste by saving energy Design and operations management. The external climate is an important factor affecting the internal environment of a building, so the energy consumption of a building, especially the energy used for heating and cooling, is closely related to the outdoor climate. Under the influence of global warming, the outdoor climate is gradually changing. It is expected that the strength and frequency of extreme climate events, such as heat/cold-waves, will increase, which will affect the energy use of buildings and energy flows in urban energy systems considerably [3]. Due to advanced construction technologies, the service life of buildings is increasing, while they are mostly designed for the past or current climatic conditions.

After the PMV indicator was proposed, Fanger ([4]) and Tanabe ([5]) et.al. Verified the accuracy of PMV prediction through artificial climate laboratory experiments in different countries. The experimentally obtained neutral temperature is expressed as ET. Under the conditions of relative humidity of 50%, wind speed of not more than 0.2 m/s, and clothing thermal resistance of 0.6clo, the neutral temperature values obtained in each experiment were 25.6°C, 25.7°C and 25.3°C. The results show that if the indoor environmental parameters are strictly controlled and the personnel's dress and activities are strictly regulated, the human body's neutral temperature will not be affected by season and climate. Experiments conducted in the United States, Denmark, Japan, and China have all obtained neutral temperatures close to 26°C. Other articles related to thermal comfort research, the concept of thermal adaptability, have gradually become the mainstream view in thermal comfort and have been widely recognized. From the perspective of thermal adaptability, people and the environment together form an interactive system. People are not passive receivers of a given thermal environment but actively participate in the process of multiple feedback loops. The environmental conditions required when a person feels comfortable can change with changes in environmental parameters and the person's own state. Based on the summary and analysis of a large number of field survey data, de Dear et al.[6] Brager et al. ([7]) established a thermal adaptability model. They believed that there was a simple linear correlation between the indoor temperature and the monthly outdoor temperature, and 80% of the population were acceptable Temperature range. When formulating the operation strategy of the air conditioning system, the natural room temperature calculated by the building thermal environment simulation software can be compared with the comfortable temperature range determined by the thermal adaptation model. If the natural room temperature is within the comfortable temperature range, natural ventilation can be used to achieve the comfort requirements, otherwise, an air conditioning system is required.

2. Methodology

From 2009 to 2012, TABULA developed residential building types for 13 European countries. Every country's typology includes a classification scheme according to the building's size, age, and types. TABULA also provides a variety of air-conditioning systems to match the type of building. Each reference building has a typical energy consumption value and estimates the energy savings through different retrofit measures. The method mainly aims at the energy consumption of residential heating and living hot water. This means that cooling, air conditioning, lighting and electrical appliances are not considered[8].,

This work's climate data has been integrated using the RCA4 Regional Climate Model (RCM). More details about the synthesized weather data set can be found in [9][10].RCA4 is the fourth-generation RCM of the Rossby Center of the Swedish Institute of Meteorology and Hydrology, with a spatial resolution of 12.5 km and a temporal resolution of 15 minutes. RCM is dynamically downscaling the global climate model (GCM) to a temporal and spatial resolution suitable for energy simulation. The GCM considered in this work is (1) CNRM-CM5 . (2) ICHEC-EC-EARTH (3) IPSL-CM5A-MR . (4) MOHC-HadGEM2-ES: is the coupled Metropolitan Office Hadley Center (MOHC) (5) MPI-ESM-LR.

GCM is forced by three representative enrichment pathways (RCP) RCP 4.5 and RCP 8.5. RCP is the greenhouse gas concentration trajectory adopted by IPCC "Fifth Assessment Report" (AR5) [11].

There are many standards for evaluating indoor thermal comfort that has been developed concerning PMV indicators to guide the design and control of the indoor thermal environment. For example, ASHRAE standard 55-20040 gives recommended values for indoor working temperature under office conditions (sitting, physical work, metabolic rate 1.2met) and indoor wind speeds not exceeding 0.2m/s [12]. In this study, Baruch Givoni [13]adapted the humidity map from ASHRAE, which is a bioclimatic map of the building.

3. Result and Discussion

This section investigates the building's heating/cooling demand and indoor temperature and their variations during 2011–2100. It should be mentioned that results are based on adopting an ensemble approach, considering the combination of 13 future climate scenarios (five GCMs and three RCPs). This approach is adopted in this work since the main intention is to generate a general picture about the plausible future conditions by considering all the (available) climate scenarios at once. Surely climate uncertainties are important and affect the assessment results as previously shown by the authors [14], but they are not discussed in this work, by looking at the distribution of average temperature and relative humidity on the psychometric chart to analyze the possible indoor thermal comfort situation in the future.

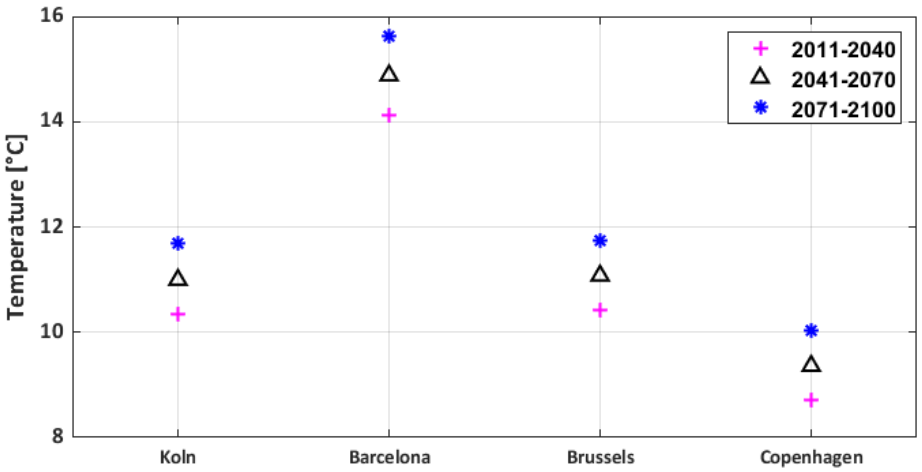

Figure 1 Average outdoor temperature in 4 cities for three 30-year periods considering 13 future climate scenarios

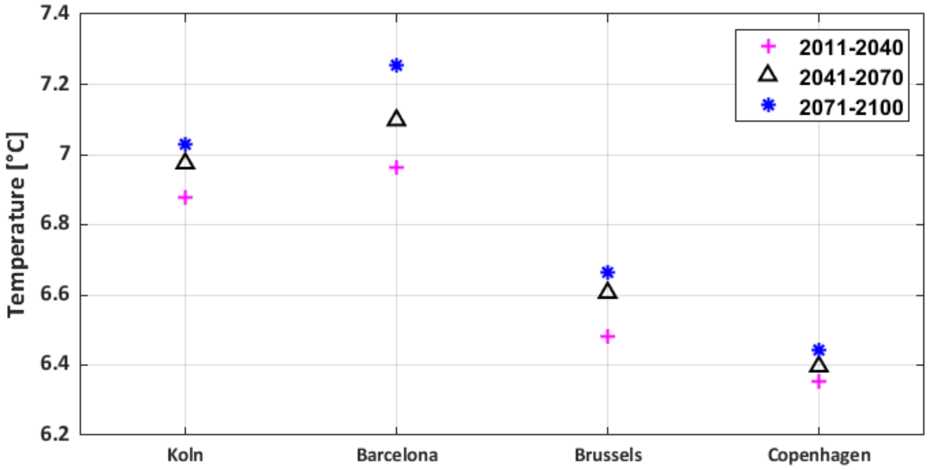

Figure 2 Standard deviation outdoor temperature in 4 cities for three 30-year periods considering 13 future climate scenarios

Figure 1 shows the average outdoor temperature for the target cities. The temperature differences between 2011-2040 (P1) and 2041-2070 (P2) are ranged between 1 °C to 2 °C, and 2°C to 3°C between 2041-2070 (P2) and 2071-2100 (P3). Figure 2 shows the standard deviation, which varied much more between each period. For example, the large variation of the standard deviation between P1 and P3 for cities like Koln and Barcelona is a cooling-dominated city or both heating and cooling-dominated cities. For Copenhagen, the standard deviation changes less between P1 P2 and P3 than the other three cities.

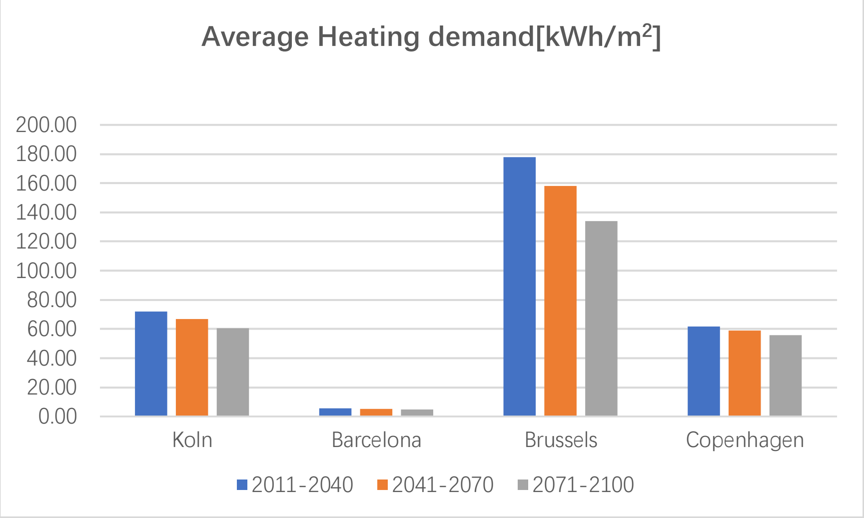

Figure 3 Average annual heating demand in 4 European cities

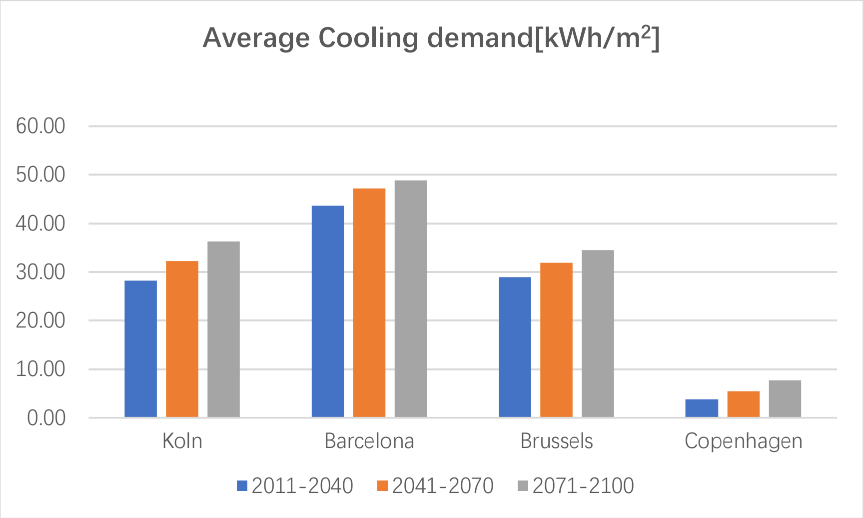

Figure 4 Average annual cooling demand in 4 European cities

Figure 3shows the impact of climate change on the heating demand between each period. It is obvious that the heating demand decreasing and cooling demand (Figure 4) increasing across each period. The relative change in heating for Copenhagen between each period is relatively less than in other cities. Brussel shows a very sensitive change in heating demand corresponding to climate change. As for cooling demand, Koln shows a large increase of 14% between P1 and P2, followed by 12% between P2 and P3.

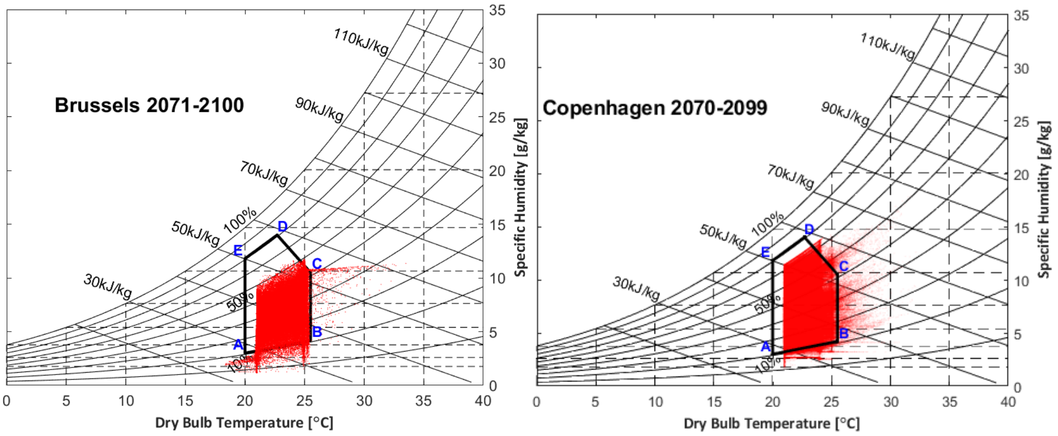

Figure 5 Indoor distribution (left Brussels) and outdoor distribution (right Copenhagen)

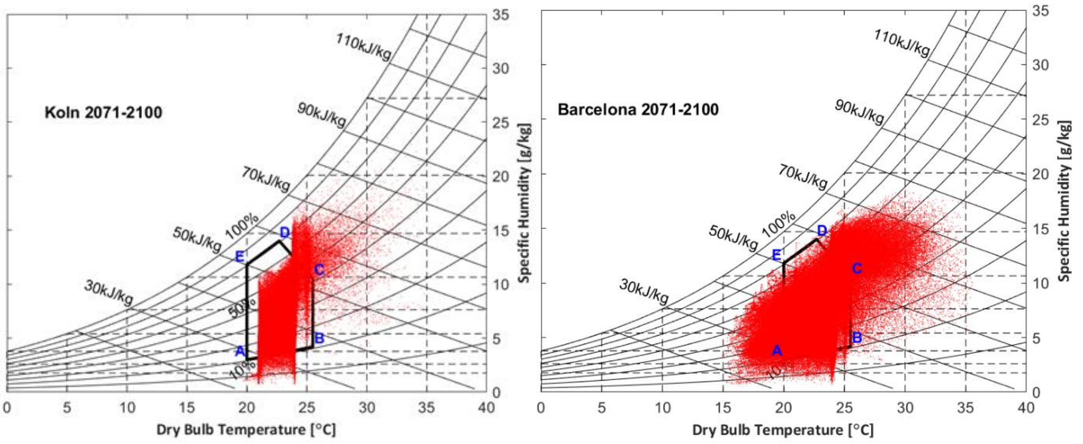

Figure 6 Indoor distribution P3 (left Koln) and indoor distribution P3 (right Barcelona)

Figure 5 shows the indoor thermal condition for Brussels and Copenhagen indoor thermal conditions.. The ABCDE zone is the thermal comfort zone. Brussels and Copenhagen generally show the best thermal comfort (over 98% of comfort hours that calculated the point inside the thermal comfort zone) compared to other cities. Figure 6 shows the indoor condition variation for Koln and Barcelona for P3. Results show overheating frequently occurs in the future for Barcelona compare with Koln. The overheating hour is up to 15% compared to Koln 3.5%. Results indicated that climate change in the cooling-dominated city (Barcelona) is relatively vulnerable, corresponding to climate change.

4. Conclusion

In this work, the impact of climate change on the energy of Cologne, Barcelona, Brussels and Copenhagen was analyzed with sample buildings as representative residential areas. Consider the three RCP (RCP2.6, RCP4.5 and RCP8.5.) With the determined future climate scenario, the heating demand decreases. For example, the heating demand between 2071-2100 decreased by 17%-23% compared to 2011. However, despite the changes in the RCPs, the demand for cooling in the colder regions of Northern Europe has not increased significantly. For the Nordic countries, such as Copenhagen, were mainly dominated by heating in winter, there are minimal overheating hours in summer (0.7%), and thermal comfort does not change much in the three periods. For Koln, which has both cooling in summer and heating in winter. Approximately 3.5% of the overheating time. For Barcelona, which is dominated by summer cooling. The overheating in summer has obvious manifestations in P3. The overheating hours is about 15%. In order to achieve a comfortable indoor environment, the existing cooling requirements can no longer be met, and indoor comfort may be achieved in the future. This will put much pressure on the electric cooling system.

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