Journal of Building Engineering 5 (2016) 86–95

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: www.elsevier.com/locate/jobe

Impacts of external insulation and reduced internal heat loads upon energy demand of offices in the context of climate change in Vienna, Austria

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ARTICLE INFO

Article history:
Received 8 July 2015
Received in revised form
8 November 2015
Accepted 16 November 2015
Available online 19 November 2015

Keywords:
Climate change
Building simulation
Office buildings
Energy input for district heating and cooling system
Cooling demand
Heating demand
External insulation
Internal heat loads

ABSTRACT

As a consequence of global climate change, a vicious circle of raising outdoor temperatures and consequently increasing CO_2 emissions associated with raising energy demands for cooling during hot summers is anticipated for office buildings in general.

This paper investigates possible mitigation and adaptation strategies by applying regionally downscaled weather data from future climate scenarios in dynamic thermal simulation of four sample office buildings in Vienna, Austria.

The effects of the appliance of external insulation and reduced levels of internal heat loads upon overall net energy demand and final energy demand under future climatic conditions are shown: By trend, external thermal insulation slows down nocturnal cooling processes in summer. It is this fact which frequently arises the question whether thermal insulation might prove counterproductive under climate change premises. However, it is shown here that winter savings due to external insulation will continue to outweigh summer constraints even in the future.

Different levels of energy efficiency in IT equipment and artificial lighting influence net cooling demand in the sample buildings to a more significant extent than does the influence of a changing climate. Still, it has to be kept in mind that the reduction of internal loads in turn increases heating demand during cold periods as they compensate for heat losses then. Thus, reasonable combinations of improvements in internal heat loads and external insulation of the building envelope have to be developed.. The novelty of the approach presented here lies in that it simultaneously takes effects of external insulation and reduction of internal heat loads as well as their respective counter effects into account.

1. Introduction

In a previous study [1] the authors simulated 9 sample buildings with different constructions (and hence different thermal properties and performances) in thermal simulation under the appliance of future climate data sets taking predicted climate change into account. These generally yielded increasing cooling energy demands while heating demands were diminished in all buildings.

It could be shown that buildings dating from different epochs and thus displaying distinctively different constructions react in different ways to climate change.

Office workers strongly rely on comfortable conditions in order to be able to perform complex tasks, especially in uniform indoor environments where occupants are not allowed or not able to use personal ("adaptive") comfort systems. Thus, their productivity is directly and negatively influenced by increased indoor temperatures [2–4]. Seppänen et al. [5] analyzed literature relating work performance to temperature and found a general decrement in working performance when temperatures exceeded those associated with thermal neutrality. It thus comes without big surprise that a swift increase in office spaces equipped with mechanical cooling has been observed on European level since 1990 [6].

Abbreviations: COP, Coefficient of Performance; EER, Energy Efficiency Ratio

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http://dx.doi.org/10.1016/j.jobe.2015.11.005
2352-7102/

Table 1
Climate data set description.

Climate data set denomination	Description	
Temporal resolution	howa 61	Semi synthetic data set [21] of weather observations for the period of 1961 to 1980
	howa 80	Semi synthetic data set of weather observations for the period of 1980 to 2009
	howa 2025	Semi synthetic Scenario for the period of 2025
	howa 2050	Semi synthetic Scenario for the period of 2050

New overall concepts for efficient buildings such as low energy, nearly zero, passive and even plus energy houses have emerged during the last decade [7]. Though these concepts focused on new constructions, the strategies and measures applied in them have diffused to and been applied in major refurbishment schemes as well. Whatever the concept, sound external insulation plays a significant role in all of them. Its basic function is to minimize heat exchange between two adjoining temperature zones. This property not only enables insulation to keep interior spaces warm in winter but also to prevent them from overheating in hot seasons. However, as desirous as this might be during daytime temperature highs, by trend it also slows down nocturnal cooling processes in summer. It is this fact especially which frequently arises the question whether thermal insulation might not prove counterproductive under climate change premises

Harnessing low night time temperatures requires elaborated ventilations strategies and may even demand the appliance of mechanical ventilation and activated thermal mass.

Keeping this in mind the present paper undertakes a general assessment of external insulation's capacity to reduce annual energy demand – while keeping indoor temperatures within comfort limits – in office buildings from different building epochs. Herein both heating and cooling requirements under future climatic conditions are investigated and an overall picture is established in order to demonstrate whether and how much thermal insulation will make sense even in the light of rising outdoor temperatures.

While external insulation represents an approach to keep heat flux from the hot outside into the building low, another strategy would be to avoid heat generation inside the building itself such as arises from IT equipment and artificial lighting. Offices generally display high levels of internal heat loads due to high rates of occupancy and significant density of technical equipment and lighting, both resulting in internal heat production.

By the selection of energy efficient devices reduction of internal heat loads has become increasingly feasible during the last years. At the same time, however, the overall appliance of IT and communications tool has continuously increased as well, hence offsetting any efficiency gains.

For instance, Menezes et al. [8] found that newer computers require less energy in 'low power' modes than older computers, while the demand for computers with increased processing power has resulted in higher demands when the computers are active.

On the other hand side, laptop computers consume only a fraction of the energy of desktop computers, presenting a big opportunity for energy savings in office buildings. Bray [9] predicts that the recent proliferation of laptop computers will have a huge impact on the overall energy consumption of office buildings. Technological developments such as the evolution of thin client computers and tablets are likely to drive power demand further down. The authors call to attention that this technology reduces power demand and resultant heat gains locally by shifting these to centralised processors with higher efficiencies.

Roberson et al. [10] showed that even the most energy efficient computers can save energy if they are properly power managed. Consumption is thus not only determined by the equipment's efficiency but also by the way it is actually used.

Prognoses for further developments are discordant, but tend to the estimation of a slight flattening of the trend curve of energy demand and related heat production. More efficient IT-equipment and lighting thus represents a means of reducing cooling loads and demands.

This paper therefore investigates the interplay of different levels of energy efficiency in these equipments and the influence of the investigated building's envelope's quality. It thereby demonstrates to which extent such efficiency and the associated reduction in internal heat production may reduce cooling demand in offices. Furthermore, it counterchecks to which extent energy savings in cooling demand due to reduction of internal heat generation may be outweighed by increased winter heating. Finally, it also investigates the influence of the second component in this interplay – namely: the investigated building's envelope's quality – by applying additional layers of (external) insulation.

2. Methodology

The description provided hereafter of the applied framework conditions is a brief résumé of a detailed description given by in [1].

2.1. Climate data sets

The WMO[1] – standard period 1961-1990 and the last available observational thirty years 1980-2009 were used for two climate data sets depicting past observations (1961–1980, 1981–2009). For future conditions under climate change, two periods not too far in the future, 2011-2040 for the near future and 2036–2065 for mid-century were taken into account (based on regional climate models (RCMs)[2] of the Max Planck Institute in Hamburg, Germany, which have been developed on behalf of the German environment agency (UBA) and are therefore denominated RCM REMO_UBA [11]). Table 1 sums up the applied climate data sets.

The following graph shows during how many hours of the year temperatures of all the applied climate data sets of "howa" range above a specific temperature value. Some relations can be derived from this graphic representation:

For low winter temperatures,"howa 80" ranges slightly above "howa 61". While the difference is more distinct for medium temperatures up to approximately 20 °C, the data sets tend to converge again for elevated summer temperatures (Fig. 1).

2.2. Sample buildings' constructions

Sample buildings' constructions were to be specifically depicted in the simulation model: thermal properties of load bearing structure, room layout and façade design substantially differ for varying building epochs, at the same time these parameters

[1] World Meteorological Organization.

[2] Dynamical downscaling uses RCM driven by boundary conditions from a GCM to derive smaller-scale information. RCMs generally have a domain area of 106–107 km^2 and a resolution of 20–60 km.