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Energy efficient office buildings with passive cooling – Results and experiences from a research and demonstration programme

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Abstract

To gain access to information on energy use in office buildings, the German Federal Ministry for Economy launched an intensive research and demonstration programme in 1995. In advance of the 2002 EU energy performance directive a limited primary energy coefficient of about 100 kW h m^{-2} a^{-1} as a goal for the complete building services technology was postulated (HVAC + lighting) for all demonstration buildings to be supported. A further condition was that active cooling be avoided. Techniques such as natural or mechanical night ventilation or heat removal by slab cooling with vertical ground pipes as well as earth-to-air heat exchangers in the ventilation system were applied. An accompanying research was established to keep track of the results and the lessons learned from about 22 demonstration buildings realized and monitored until the end of 2005. As one outcome this paper summarises the energy performance of a selection of characteristic buildings together with an overview on the summer thermal comfort situations achieved. The research program will proceed during the next five years. Detailed reports and future results may be downloaded from the internet: www.enbau-monitor.de.

Keywords: Office buildings; Energy monitoring; Passive cooling; Thermal comfort; User behaviour

1. Introduction

1.1. Energy use in office buildings

Numerous office buildings of the 1980s were designed to isolate the internal conditions from the outdoor climate as far as possible; this at the cost of high energy consumption. Thermal and visual comfort as well as the air quality was guaranteed through extensive technical building services for heating, ventilation, air-conditioning and lighting (HVACL). The high investment and running costs were accepted to ensure that even extreme indoor conditions caused by generously glazed building envelopes could be controlled. In combination with the space demand of the wiring for communications technology of that time – double floors and suspended ceilings – it is quite common for technical services to occupy 20–30% of the building volume (Leibundgut, 2000). The main share of the electricity consumption is due to the HVACL facilities, not the office equipment (Weber, 2002).

Despite the heat generation associated with high electricity consumption within the building (internal heat gains), the space heating demand in mid- and north

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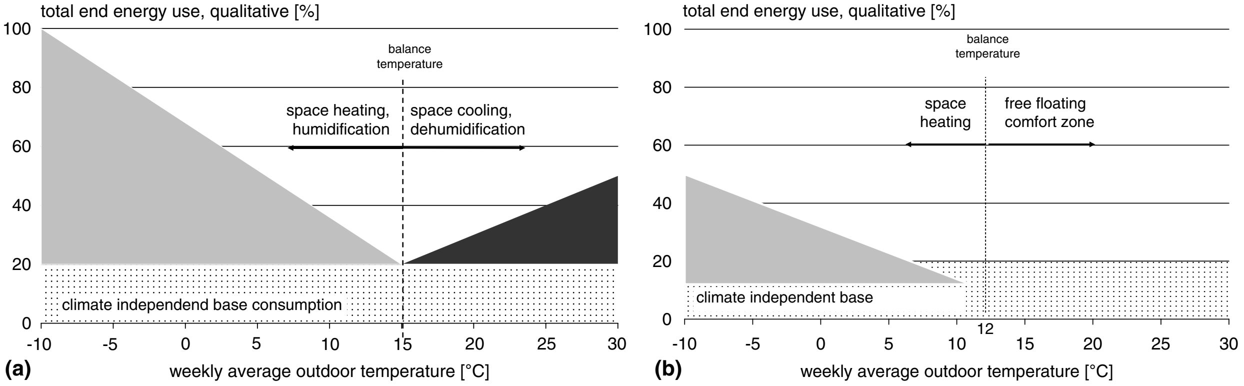

Fig. 1. Qualitative profile of the energy consumption of a "conventional building" (a) compared to a "lean building" (b) in mid-European climate, the so-called ET-diagram (E, energy; T, temperature).

European climate still dominates the over all energy figure. This is due to the high proportion of glazing and the usually high air exchange rates (⩾2 ACH). Fig. 1a gives a qualitative impression of a typical energy consumption profile as a function of the outdoor temperature, the so called ET-diagram (E, energy; T, temperature): in addition to a base energy load which is nearly independent of the weather, there is a contribution for heating and humidifying below the "balance temperature", and for cooling and dehumidifying above it. The balance temperature is defined by that outdoor temperature at which thermal losses are balanced by the internal and solar gains. The base load is mainly caused by office equipment and the idling consumption of building services technology. The waste heat associated with the base load affects the position of the balance temperature: the higher the base load, the lower the balance temperature. Due to the decoupling of the room air from the building mass – suspended ceilings, double floors, lightweight walls – and the maintenance of constant indoor conditions throughout the whole year, there are hardly any days when there is neither active heating nor cooling.

1.2. Thermal comfort and health

The diverse technical approaches to achieve a good indoor climate were often accompanied by complaints from office workers about many types of discomfort and dissatisfaction, which are summarised as the "Sick Building Syndrome". One German investigation of this phenomenon, the so-called "ProClima-Project" (Bischoff et al., 2003), reaches the conclusion that although buildings with air conditioning maintain an objectively better – according to EN ISO 7730 – indoor climate, they are subjectively rated lower than naturally ventilated working conditions by the majority of persons questioned. The rating is significantly affected by:

- the degree to which an individual can determine the conditions prevailing at his workplace,
- the degree of maintenance of the technical service systems.

Today an increasing fraction of office buildings are being constructed or retrofitted which allow individuals to control their own indoor climate to a large extent, and which replace almost complete isolation from the weather outdoors by a moderate interaction. Day lit workplaces and the option for natural ventilation are typical characteristics. However, a combination of integrated measures to achieve the so-called "passive cooling" is a pre-requisite if summer comfort is to be ensured without actively cooling or dehumidifying the inlet air (Santamouris and Asimakopoulos, 1997; Zimmermann, 2003). This type of building concept has become known as a "lean building", due to the smaller volume of the service equipment required, Fig. 1b. The task is to design buildings such that, even when the weather outdoors varies greatly, the indoor conditions remain within a well-defined *comfort zone*, which meets the expectations of the occupants. These expectations can be defined for a free running environment according to prEN15251 by three comforts classes using an adaptive approach, Fig. 2 (prEN 15251, 2005). In this case the comfort temperature is related to the monthly mean ambient temperature with a more (class C: ±4.2 K) or less (class A: ±2.5 K) wide comfort range.

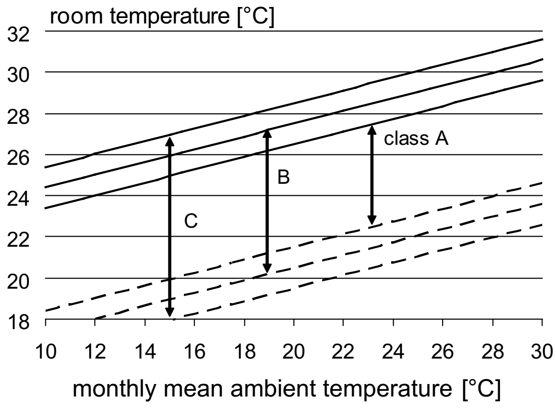

Fig. 2. Thermal comfort classes according to the draft European standard prEN15251 for free running indoor environments during summer operation (prEN 15251, 2005).