16A.8 THERMAL COMFORT AND ENERGY SAVING IN THE HOTEL INDUSTRY

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ABSTRACT

The hotel industry is one of the most energy-intensive subsectors of the tourism industry, with about 50% of the overall energy consumption due to space conditioning. The thermal comfort standards applied in defining the required levels of thermal comfort in hotels have a substantial effect on the overall energy use in this sector.

This paper discusses the influence on energy consumption and environmental degradation of thermal comfort standards typically used in the hotel industry. Possibilities of using the adaptive approach in dealing with thermal comfort issues in hotels are discussed. The environmental, economic and social benefits of energy conservation and energy efficiency in the hotel industry are highlighted.

1. INTRODUCTION

Among commercial buildings, lodging facilities are unique with regard to operational schemes, the type of services offered, as well as the resulting patterns of natural resource consumption. Hotels constitute "a refuge far removed from the caves of everyday life", as G. B. Shaw once expressed. They are designed to provide multi-facetted comfort and services to guests frequently accustomed to, and willing to pay for exclusive amenities, treatment and entertainment. Comfortable indoor environments, safety and reliability are some of the amenities valued by guests. State-of-the-art technical infrastructure is typically utilised in hotels to provide high levels of comfort, including thermal comfort.

Many of the services provided to hotel guests are highly resource intensive, whether it concerns energy, water or raw materials. As a consequence, hotels have been found to have the highest negative impact on the environment of all commercial buildings, with the exception of hospitals (Rada 1996). In view of the globally growing environmental degradation, the need for effective measures is being increasingly endorsed by both guests and industry. Approximately 40 percent of more than 3000 respondents to a hotel industry survey confirmed using different quantitative measures of environmental performance, including those relevant to energy use and water consumption, waste disposal, as well as volume and treatment of wastewater (Vögl 1998).

Space conditioning (heating, cooling and ventilation for the purpose of maintaining high standards of air quality and thermal comfort) typically accounts for about half the total energy consumed in hotels.

However, using energy-intensive space-conditioning systems does not by any means warrant absolute occupant satisfaction. Occupants/guests frequently complain about thermal discomfort, even where expensive and sophisticated systems are operated. Indeed, guests may be reasonably satisfied with the thermal conditions even where no advanced space-conditioning is applied.

Complaints most commonly relate to uncomfortable air temperatures (too high or too low), and the difficulty or impossibility of individual adjustment. The lack of air circulation, or – in the other extreme – drafts, as well as inadequate air quality are other frequent complaints.

The indoor temperature levels set to be maintained greatly influence the quantity of energy consumed in a building. The temperatures recommended by relevant standards are typically a function of the season of the year and relative humidity, and are usually fixed within a limited range. One should bear in mind that existing thermal comfort standards (ISO 7730, ASHRAE 55/92) are the outcome of experimental studies performed in strictly controlled environments and that their relevance to real situations has been questioned repeatedly. In reality, temperatures perceived as comfortable vary greatly depending on the activity performed, clothing worn, time of the day, a person's physical and emotional state, and other factors, not least the climate a person is typically accustomed to. Using general, narrowly fixed comfort temperature ranges for indoor applications thus appears rather questionable, especially against the increasing need of energy-efficiency and conservation.

Reductions in the temperature difference maintained between the outdoor and indoor environment could very positively contribute to reducing the energy bill of a facility, as well as to mitigating its overall environmental footprint, including the quantity of carbon dioxide emitted into the atmosphere. It has been shown that a 1°C decrease in indoor temperature approximately accounts for a 10% reduction in heating costs (Gillan 1999). Similarly, each degree that the water temperature in cooling systems is allowed to increase translates to energy savings of 5-10% (THERMIE 1994). A more flexible approach to thermal comfort management in the hotel industry would thus be attractive both environmentally and economically.

2. ENERGY AND COMFORT ZONES IN HOTELS

The accommodation industry constitutes one of the largest sectors of the travel and tourism industry.

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There is no recent detailed data on the size of the hotel sector but it can be reasonably estimated at the level of over 360 000 facilities and 30 million beds (IH&RA 2000; JLLSH 2001) worldwide. Premises located in Europe account for almost 50% of the overall global market (IH&RA 2000), and are estimated to consume 39TWh of energy annually (CHOSE 2001). North American hotels represent 22% of the market (IH&RA 2000), and in 1995 all lodging establishments in the United States together used 146.5TWh of energy, which accounted for 9.4% of the total energy consumed in commercial buildings in the US (EIA 1998). Electricity typically accounts for 60-80% of the energy consumed, while the balance is accounted for by fossil fuel use, mainly natural gas and oil (AH&LA 2001). Facilities located in cold climates tend to exhibit a higher share of fossil fuels in the energy mix (fuel-fired boilers for heating), while facilities in hot climates are more likely to have a higher electricity consumption, due to the prevalence of electric space cooling.

The prevalence of fossil-fuel generated power and the (still) marginal utilisation of renewable energy resources translate into significant emissions of particulates, nitrogen and sulphur oxides and other air pollutants, both locally and globally. Secondary pollution in the form of acid rain causes the acidification of lakes and soils, with negative effects on flora and fauna, human health and man-made structures and products. It is estimated that a typical hotel releases about 160 kg CO_2/m^2 of room floor area annually, which is equivalent to about 10 tons of CO_2 per bedroom per year (BRESCU 1993). Globally, the hotel industry is responsible for the emission of at least $130 \cdot 10^6$ tons of CO_2 annually. In addition, the accidental release of freon-based refrigerants, still commonly found in HVAC systems used in hotels, is a serious threat to the ozone layer.

The need for a more sustainable utilization of energy in the hotel sector needs to be seen in the light of growing concern about the state of the natural environment, as well as a result of increasing energy prices. Energy expenses vary depending on the region as well as type of the hotel. Energy costs expressed in terms of gross hotel revenue currently range from 3-5% for limited-service hotels, to 4-6% for typical full-service properties, and are expected to increase in the future (Pateman 2001). The energy expenses of some historic, luxury and/or urban-boutique hotels are predicted to reach up to 10% of their gross revenue (Pateman 2001). In the mid 1990's the energy expenditure in American hotels was at the level of US$ 2.08 billion, equivalent to 5.2% of the gross revenue of the entire lodging industry (Wu 1997), while at the end of the millennium the energy utility bill of the sector rose to approximately US$ 5 billion (Pateman 2001).

Approximately half the total energy used in hotel facilities is consumed by systems and processes responsible for space conditioning (heating, cooling, ventilation and air conditioning). Many of the HVAC systems were specially created or redesigned for the needs of the hotel industry (McDonough et. al 2001). Although hotels (especially those with a lower rating) frequently rely on natural ventilation as a source of fresh air and cooling, sophisticated space conditioning techniques are becoming increasingly common, and often indispensable to satisfy the needs of different thermal zones within hotel facilities. The design of adequate and reliable hotel HVAC systems is a challenging task, typically accounting for 10-12% and 16-18% of capital construction costs for guest rooms and public spaces, respectively (Rutes et al. 2001).

Guest rooms account for 65-85% of the total area of hotels, depending on the type of facility (Lawson 2001), and are in general characterised by energy consumption profiles difficult to predict. Guests are frequently given full control over indoor thermostat settings, individual air conditioning units, as well as operable windows and doors, and these are typically used with little or no concern for energy conservation. Windows and doors are frequently left wide open while cooling or heating systems are operating at full load. Also many (rented) rooms remain unoccupied for prolonged periods of time during the day, while HVAC systems are left running, often at maximum load. While air quality and thermal comfort obviously need to be high whenever a room is occupied, loads should be adjusted to reasonable levels when the room is unoccupied.

Public areas, such as lobbies, conference rooms, dining areas, bars, banquet and disco halls, as well as recreation/sport and health facilities are particularly challenging from thermal comfort and air quality aspects. Systems installed in these enclosures must be able to respond quickly to fluctuating numbers of occupants, and diverse thermal comfort requirements. In addition, service areas, including kitchens, laundries, machine rooms, etc., typically need to be isolated from public and service areas, e.g. to prevent the transport of odours.

The types of systems installed in a hotel facility, as well as the levels of thermal comfort provided are closely related to the hotel rating, see also Table 1.

Table 1. Minimum HVAC-system requirements for hotels according to World Tourism Organisation (as cited in Lawson 2001)

Hotel rating	Service provided
*	Heating or fan cooling when necessary
**	Heating or fan cooling when necessary. Central heating and comfort cooling seasonally available.
***	Central heating and comfort cooling seasonally available. Individual heat control in bedrooms. Temperature maintained within the range of 18-25°C.
**** and *****	Central heating and comfort cooling available in entire premise. Individual heat and air conditioning control in all rooms. High quality equipment with very low noise emission level.

3. THERMAL COMFORT STANDARDS

Standards concerning thermal comfort relevant for the hotel industry include ASHRAE Standard 55/92 (currently being revised), as well as ISO Standard 7730. The general recommendations in Standard 55/92 relevant to acceptable thermal comfort ranges have been slightly modified by industry to better suit the requirements in various spaces (Table 2).

Table 2. Design temperature and humidity standards for hotel spaces (based on CIBSE recommendations as cited in Lawson 2001)

Type of space	Temperature, °C	
	Heating (winter)	Cooling (summer)
Guest rooms	24	20-22 (daytime)
Restaurants	21	22±1
Conference rooms	20-21	22±1
Lobby, foyer	18-20	27±1
Corridors, stairs	20	23±1
Activity areas	12-16	
Changing areas	26-28	
Pool area	27-28	
Other areas	24-26	
Computer etc. equipment, stores	18-20	27±1
Kitchens	15-18	23

Despite relatively detailed recommendations concerning suitable levels of indoor temperatures in hotel facilities, the relevance and applicability of current standards has been widely questioned. Field investigations on thermal comfort perception have indicated that theoretical, laboratory based thermal comfort models do not always hold in real situations. Recent investigations have shown that the difference between temperatures recommended by ASHRAE and those described as acceptable by occupants can amount to as much as 5°C (deDear & Brager 2002), suggesting that the adaptive approach to managing thermal comfort may prove to be more appropriate than what is recommended by current standards.

4. ADAPTIVE APPROACH

The concept of adaptive approach to thermal comfort emerged from a series of field studies performed world-wide, indicating discrepancies between temperatures prescribed by standards as comfortable, and those perceived by occupants as acceptable. It was observed that people tend to adjust their behaviour attempting to restore thermal comfort when the latter is decreased in some way. This observation lead to the conclusion that humans are remarkably capable of adapting themselves and their behaviour to changing indoor environments (as they commonly do under varying outdoor conditions), provided that the changes are not extreme, and the occupants are given sufficient time for the adaptation. A correlation between acceptable indoor temperatures and mean outdoor temperatures was established. As a result, a revision of existing standards has been proposed that would account for the human ability to adapt.

Numerous studies and surveys dealing with the perception and management of indoor thermal comfort have been carried out in varying environments. The applicability of the adaptive approach has also been tested in different types of buildings. However, as yet, no detailed investigations have looked into its potential for indoor environments in hotels and other hospitality facilities.

While the benefits of adopting a more flexible, adaptive approach to thermal comfort management in hotels may seem obvious (decreased energy demand and costs, simpler/smaller systems, fewer emissions and thus lower overall environmental impact), more research is necessary to understand how, and to what extent such an approach would be suitable for hotel environments.

In Singapore an investigation was performed to study the and thermal acceptability data based on climate chamber studies performed by de Dear (28°C, RH60%) were compared. New indoor comfort space conditions were suggested at 26°C, RH60%. The office building investigated was 12-storey high, with a total air-conditioned area of 6300m^2. The DOE-2 code was used for estimating the energy consumption, and the simulations were performed at 23.5°C and 26°C, respectively. The simulated annual energy consumption is presented in Table 3.

Table 3. Annual energy consumption in an air-conditioned office building at different indoor temperatures (Sekhar 1995) acceptance of higher indoor space temperatures as related to thermal comfort, as well as the resulting energy savings (Sekhar 1995). Indoor climate conditions typically found in Singapore (23.5°C, RH70%),

Energy end-use	Annual energy consumption, MWh	
	23.5°C	26°C
Space cooling	248	216
HVAC auxiliaries	107	76
Lights	227	227
Total	583	519
Percentage energy saving		
Cooling		13%
Total		11%

A reduced energy consumption, preferably supplemented by the utilisation of renewable energy resources, along with a more widespread application of bioclimatic design, would all have a positive environmental impact. It has been estimated that the release of almost 6 million metric tonnes of CO_2 could be avoided (EPA 2002), if the energy efficiency in American hotels were increased by an average of 30%. A smaller amount of fossil fuels burned would further result in reduced problems with local particulate pollution, as well as lower emissions of sulphur and nitrogen oxides.

More energy-efficient space conditioning could be achieved with maintained or improved thermal comfort, while resulting in lower energy bills and maintenance costs. As mentioned previously, a 1°C decrease in room temperature (during the heating season) is equivalent to approximately 10% lower heating costs (Gillan 1999). An additional lowering of temperatures in unoccupied rooms, can result in heating energy savings in the range of 20-30% (THERMIE 1994). It was further shown that thermal satisfaction in guests can reduce maintenance costs by up to 20% (ASHRAE Transactions 1998 as cited in Levy 1998).

Unfortunately, hotel management are not always as appreciative of adopting methods and technologies promoting energy conservation as they seem to be susceptible to new trends in accounting or security systems. The mistaken perception that energy saving is inherently complicated and prohibitively expensive, is still widely prevalent. On the contrary, it has been shown that modest capital expenditure and good housekeeping can, e.g., result in 20-30% savings on energy bills (Gee 1999). If a similar increase in profits were to be achieved by more conventional means, such as increased sales, the turnover would need to increase by around 12-15% (Gee 1999).

The adaptive thermal comfort approach has already been successfully, although often unconsciously, incorporated, into eco-lodge-type accommodations. Eco-facilities typically cater to travellers with higher than average environmental knowledge and responsibility, prepared to forfeit a great deal of comfort and technical sophistication, including highly artificially conditioned indoor environments, for the sake of enjoying the locations visited at a low environmental cost. Expecting "ordinary" visitors to conventional hotels to promptly adapt to new outdoor and indoor climates is, however, likely to be somewhat more difficult. In the way the adaptive approach to thermal comfort is conceived, it appears to be best suited for indoor occupants accustomed to a specific outdoor climate and its variations. Travellers, however, often criss-cross time and climate zones over short periods of time, and the duration of their stays in climate zones appreciably different from their own may be too short for them to have a chance to adapt. Besides, travellers charged premium amounts for short-term hotel accommodation, typically expect a high level of comfort (including thermal comfort) and service in return.

In exceptional cases, people are prepared to spend appreciable amounts of money on accommodation in environments otherwise considered thermally or otherwise unsuitable, as e.g. in the case of the Ice Hotel in Jukkasjärvi in northern Lapland, Sweden. In this case, the craving for an utterly exotic experience is allowed to dominate, for a short time period (typically a day or two), over the desire for thermal comfort. Indeed, the lack of thermal comfort may be perceived as part of the thrill. The average hotel customer, however, is likely to expect reliable and reasonably controllable indoor comfort, and applying the adaptive thermal comfort in hotels may thus not be quite that easy, as e.g. in office buildings.

5. TECHNICAL SOLUTIONS

A compromise may perhaps be achieved by allowing indoor temperatures in hotels to vary more than this is "tolerated" by current standards, and to follow within certain boundaries the outdoor temperature variations, while enabling guests to exercise some degree of control (e.g. +/- 1^{o}C). Should guests require room conditions substantially different from those present, they could e.g. request the hotel staff to individually adjust the level of comfort to something more suitable. A more flexible approach to space conditioning is likely to result in lower overall energy consumption, especially if the default temperature set-points are conservative. In order to increase energy savings even further, HVAC systems should be operated at minimum/economy loads whenever rooms are unoccupied for prolonged periods of time. However, systems should be designed to re-establish acceptable thermal conditions reasonably rapidly. Technically, all of the above-mentioned solutions are possible, and relevant tools are commercially available on the market, including master card/electricity switches, precise thermostat controls, as well as computerised building management systems.

Occupancy sensors were tested in guest rooms in a hotel in Jamaica (Plant 1997). These devices operate on the same principle as master electricity switches, in that all but the most "vital" systems are shut off whenever sensors indicate vacancy. In the case of master electricity switches, most systems (except for minibars, electric sockets for chargers, and base-load space conditioning) are switched off when the guest removes the key card from its socket. By reinserting the key card, full control over all equipment is returned to the guest. In this Jamaican pilot project the air conditioning (AC) cost was reduced by approximately 30%, while the majority of guests remained entirely unaware that the settings of the room AC system had been changed and controlled during their absence (Plant 1997).

Computerised building management systems offer the most comprehensive and sophisticated control over the environment and energy consumption in various hotel spaces. These systems allow for full manipulation of temperature settings, operation of HVAC systems as well as control of other electricity-based appliances straight from the reception desk. Furthermore, when combined with the computerised reservation system, they allow for adjustment of the conditions in the rooms in accordance to predicted occupancy, thereby optimising the energy performance of the facility.

6. CONCLUSIONS

The accelerating environmental degradation of many sensitive natural (and urban) environments combined with increasing energy prices should both be convincing reasons to increase energy efficiency and to conserve energy and resources, not least in various sectors of the hotel industry. The adaptive approach to thermal comfort management has the potential to become a sensible option even in hotels. The environmental and economic benefits of more flexible thermal comfort standards are obvious, and technical solutions for this approach are commercially available. For lack of reliable data, there remains, however, a great uncertainty regarding the response of hotel customers to the adaptive approach. As in most other businesses, even in the hotel industry top priority is given to customer satisfaction. There is thus great concern that any environmental improvements or conservation measures implemented, shall not negatively affect customer comfort and satisfaction. The more daring and progressive players in the hotel industry are already trying to cater to a clientele with above average appreciation of and responsibility for the environment. There is hope that the great majority of less aware travellers may, over time, be persuaded and educated by successful cases and role-models. Adopting and adapting the adaptive thermal comfort model to the specific needs of the hotel industry would undoubtedly result in significant environmental and economic benefits for all stakeholders involved.

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