BEDP ENVIRONMENT DESIGN GUIDE

ADJUSTING BUILDING THERMOSTATS FOR ENVIRONMENTAL GAINS

Rosemary Kennedy, Wendy Miller, Jennifer Summerville, Maree Heffernan and Susan Loh

DES 71: Adjusting Building Thermostats for Environmental Gains – Understanding the Issues; and

DES 72: Adjusting Building Thermostats for Environmental Gains – A Pilot Study

This summary covers both of these companion papers.

Summary of

Actions Towards Sustainable Outcomes

Environmental Issues/Principal Impacts

- There has been increasing reliance on mechanical heating, ventilation and air-conditioning (HVAC) systems in order to achieve thermal comfort in office buildings.
- The internationalisation of thermal comfort standards has resulted in the same universal standard for internal temperatures summer or winter, regardless of location or climate.
- The extensive overuse of air-conditioning in warm climates not only isolates us from the external environment, but is generally dependent on non-renewable energy, which results in higher GHG emissions.
- Personal control, access to outside air, air movement and thermostat settings can all make a difference to the comfort, real or perceived, of office workers, but frequently these are out of the control of occupants.

Basic Strategies

In many design situations, boundaries and constraints limit the application of cutting EDGe actions. In these circumstances, designers should at least consider the following:

- Raising the summer thermostat setting 2°C could achieve energy savings of approximately 6 per cent, resulting in a corresponding reduction in greenhouse gas emissions and water use in cooling towers.
- If an adjusted thermal comfort standard is accepted, it could potentially be achieved without any capital expenditure, and significant reduction in plant size may be possible for new works including the retrofit of existing buildings.
- Communication with occupants provides an effective means to isolate the cause of their thermal discomfort.
- Temperature monitors can be placed in problem areas to gain hard data on mechanical performance, and allow for remediation of defective systems.
- Use timers, seal unwanted air-leaks and tune air-conditioning plant to improve efficiency.

Cutting EDGe Strategies

- Facilities maintenance staff who are trained to 'interpret' occupants' complaints are in a better position to identify mechanical problems and resolve them satisfactorily.
- Communication and change management are an important part of managing occupant satisfaction.
- Encourage a dress code that is both acceptable for the workplace and climatically responsive (suits are not cool!).

Synergies and References

- ASHRAE, 2004, ANSI/ASHRAE Standard 55-2004, *Thermal Environmental Conditions for Human Occupancy*, American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta, Georgia, USA.
- Aynsley, R, 2007, TEC 25: Circulating Fans for Summer and Winter Comfort and Indoor Energy Efficiency. *BEDP Environment Design Guide,* Australian Institute of Architects, Canberra.
- Centre for Subtropical Design, 2007, *Same Latitude New Attitude: Reducing greenhouse gas emissions in institutional offices through positive adjustment of thermostat settings*, Queensland University of Technology, viewed December 2008: http://eprints.qut.edu.au/archive/00012896.
- *BEDP Environment Design Guide:* DES 57: Comfort in Buildings – Applying an Adaptive Model
- *BEDP Environment Design Guide:* TEC 25: Circulating fans for Summer and Winter Comfort and Indoor Energy Efficiency.
- Ministry of the Environment, Government of Japan press release on *Coolbiz* and *Warmbiz* programs, refer to: www.env.go.jp/en/press/2005/0428b.html and http://www.env.go.jp/en/press/2005/0427a.html

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ADJUSTING BUILDING THERMOSTATS FOR ENVIRONMENTAL GAINS – UNDERSTANDING THE ISSUES

Rosemary Kennedy, Wendy Miller, Jennifer Summerville, Maree Heffernan and Susan Loh

There has been increasing reliance on mechanical heating, ventilation and air-conditioning (HVAC) systems to achieve thermal comfort in office buildings. The use of universal standards for thermal comfort adopted in air-conditioned spaces often results in a large disparity between mean daily external summer temperatures and temperatures experienced indoors. The extensive overuse of air-conditioning in warm climates not only isolates us from the vagaries of the external environment, but is generally dependent on non-renewable energy. A pilot study conducted at the Queensland University of Technology (QUT) involved altering the thermostat set-points to two or three degrees above the normal summer setting in two air-conditioned buildings during the subtropical summer. This paper presents the findings of the research that led to the formulation of the test study. The findings of the test study are printed in the companion paper DES 72: Adjusting Building Thermastats for Environmental Gains – a Pilot Study.

Keywords

air-conditioning, commercial buildings, climate appropriate clothing, greenhouse gas emissions reductions, occupant behaviour, thermal comfort

1.0 INTRODUCTION

There is an increased awareness that global climate change is occurring, and that it is strongly related to greenhouse gas (GHG) emissions in the atmosphere, particularly due to the burning of fossil fuels for energy production. Most existing office buildings in Australian urban centres rely on electricity supplied from coal-fired power stations to operate lighting, equipment and HVAC systems. Research for this study was driven by the acknowledgement that many office workers may feel powerless to do anything about reducing GHG emissions in their workplace. It is recognised that holistic and multi-disciplinary approaches to solutions are required to address both the causes and effects of climate change. However, in this pilot study, the researchers sought to investigate one approach where building owners and occupants may be able to collaborate to achieve reductions.

This research project set out to confirm whether a "no capital cost" approach to reducing a building's energy consumption such as simply adjusting air-conditioning thermostat set-points by one or two degrees could bring about significant change in reducing GHG emissions. The companion paper describes the results of a pilot study where occupants' responses were monitored and the findings of both the energy usage and survey results were documented. This paper discusses the findings of the initial research to give an understanding of the issues around thermal comfort in commercial office buildings.

2.0 ENERGY USAGE IN THE COMMERCIAL BUILDING SECTOR

Increased urban air temperature, relative to surrounding rural temperatures (known as the Urban Heat Island Effect), has been attributed to increased urbanisation and some of the contributing factors include higher density of buildings and paved surfaces as well as *"artificial heat…released into the urban atmosphere by combustive processes from vehicles, industrial activities, and commercial and domestic air conditioning"* (Suppiah and Whetton, 2006). The Bureau of Meteorology reports that peak demand for electricity is magnified in many Australian cities by the urban heat island effect (BoM, 2007). Not only is the heating and cooling of commercial buildings in urban centres being implicated as one of the contributors to 'heat islands' in cities, but, in turn, contributes to further increases in energy use and GHG emissions in this sector.

The former Australian Greenhouse Office (AGO) reported in the National Greenhouse Gas Inventory that the "commercial sector has the highest share of energy supplied as electricity and consequently the highest emissions intensity." (DEH, 2006) This picture becomes grimmer as the AGO also projects that "GHG emissions from the operation of commercial buildings will increase by a staggering 94 per cent during the period 1990 2010." (Building Commission, 2007)

3.0 THERMAL COMFORT STANDARDS

It has been accepted industry practice in the design of commercial or institutional buildings in Australia and many parts of the world that internal spaces need to be conditioned (heated or cooled) to between 21ºC and 24ºC, using international standards for thermal comfort endorsed by ASHRAE (American Society of Heating, Refrigeration, and Air-conditioning Engineers, ASHRAE-55-1992) and ISO (International Standards Organisation, ISO 7730). The methodology generally adopted by HVAC practitioners encompasses air temperature, mean radiant temperature, air speed and humidity, but lacks any recognition of cultural or regional differences in attitudes about comfort or preferences for specific thermal conditions (Brager and de Dear, 2003).

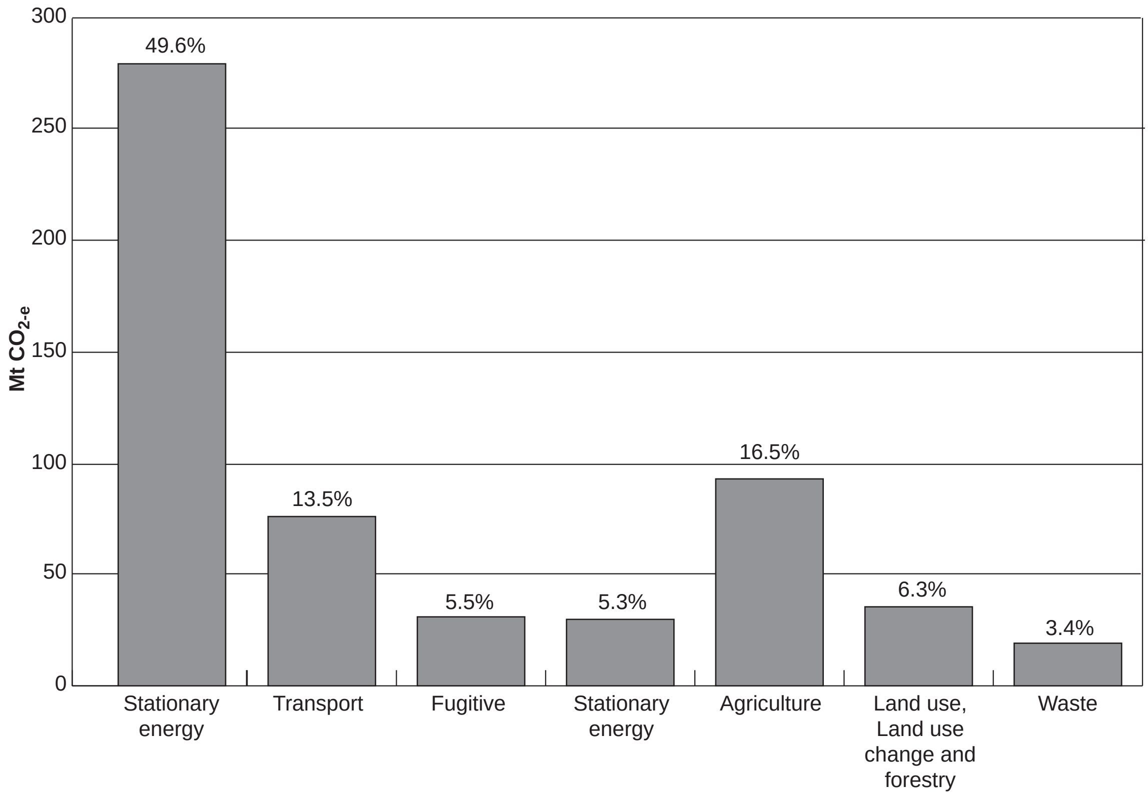

Figure 1. $C0_2$ equivalent emissions by sector showing stationary energy as highest in 2004 in Australia

(Source: National Greenhouse Gas Inventory – Department of Environment and Heritage & AGO, 2006)

While the ASHRAE standard 55-2204 now recognises a more wholistic approach to thermal comfort known as the Adaptive Comfort Standard, which recognises the external climatic environment rather than relying on a static laboratory condition, industry continues to adopt the approach that assumes that 'comfort' is universal (without regard to gender, age, race, level of activity, acclimatisation), that thermal variation outside of the band is undesirable, and that occupants of buildings want neutral, dry, still air. The HVAC systems in the buildings which were the subject of the study described in this paper, and many similar existing commercial buildings, embody the methodology of universal comfort standards.

3.1 Social and Cultural Influences on Perceptions of Thermal Comfort

Methods used to date for defining thermal comfort have placed a reliance on laboratory testing. This has led to a 'one size fits all' method of determining air-conditioning temperature and totally ignores the importance that social and cultural influences have on determining comfort level.

Cultures in the Middle East, for centuries, have ritually migrated within the house to spaces that are built either for the winter or summer season. Similarly, communities in hot climates often cease heavy exertion during the hottest time of the day (siesta) and work later in the evening. This kind of connection to natural seasons and diurnal changes seems lost to modern city living where we do not even dress for the season. A six month study of clothing behaviour of office workers in Sydney found that "clothing insulation was constant year-round, having no correlation with outdoor temperatures" (Brager and de Dear, 2003). The traditional business suit used by most male workers which has become the normal standard of clothing in offices around the world does not respond to local climate, thereby perpetuating a global standardisation of indoor thermostat setting, and internal climate conditions in commercial office buildings often contrast strongly with the natural outdoor conditions.

However, countries like Japan have started to see how entrenched notions about office clothing standards for males can be altered to help combat climate change. In a bid to reach its Kyoto Agreement targets, Japan has adopted a 'CoolBiz'[1] program. Under this program, all government offices were required to set the cooling thermostat to 28°C in summer (2-3 degrees higher than Japan's usual practice). The program was championed by former Prime Minister Mr. Koizumi, who signalled an acceptable change of business attire through his well-known "no tie and shirtsleeves approach" which has also

1 There is also a WarmBiz program that encourages heavier clothing in winter and building climate control systems are seasonally adjusted.

been adopted by Japanese cabinet ministers and other leaders of the movement (Mininistry of Environment, Japan 2005). A similar 12-month trial of a new parliamentary dress code was introduced in the Queensland Parliament and the thermostat set point raised to 25°C in summer as a water saving and energy saving measure. (Hon. P. Beattie, 2007)

3.2 Social Influences

Studies so far have pointed to the fact that social conditioning leads to physiological conditioning. Our expectations of a much cooler or warmer indoor environment in summer/winter respectively, have evolved to the point that Western societies' acceptable range has significantly narrowed.

Fishman and Pimberts' 1982 studies into the difference in thermal responses of occupants of air-conditioned and naturally ventilated offices, as cited in de Dear's 1998 report, revealed that people in air-conditioned offices "were less tolerant of higher temperatures and expected homogeneity in their thermal environment." De Dear also cites Rohles' (1977) studies which found that "Michigan subjects were more tolerant of high indoor summer temperatures (32ºC) than Texan subjects." This supports the notion that social conditioning could lead to physiological conditioning in that the "Texans took summer air-conditioning for granted and came to expect or even demand cooler temperatures" than their counterparts in cooler areas of the country. (de Dear et. al 1998)

Perceptions of Desirability

Brager and de Dear traced the formulation of American people's attitudes to air-conditioning back to marketing in the 1950's where increased post-war demand for air-conditioners could have been influenced by advertisements that linked air-conditioning to increased social status. Women whose homes were air-conditioned were portrayed as elegant and free from the toil of housework. People wanting a clean and healthy environment were targeted as providers of homes for happy families. The advertised images gave people "total mastery of the environment" so that "homeowners had the ability to maintain an indoor environment of constancy, independent of the natural diurnal or seasonal fluctuations outdoors". Ironically, pictures of air-conditioners beside elegant women sitting in the great outdoors overlooking mountains and the setting sun actually do not achieve what they claim to do, that is, have a more intimate relationship with nature. (Brager and de Dear, 2003)

Many real estate agents promote air-conditioning as adding to a property's value and whether this promotes or reflects our social values is debatable – however, the increased use of energy associated with this additional 'value' is growing rapidly. Chappells and Shove (2005) inform us that "in the UK air-conditioning is becoming common not necessarily for comfort but constitutes a signifier of 'quality' and prestige and part of property value."

This attitude seems to be reflected in the South-east Queensland real estate market, with many developers believing that they will be unable to sell or rent properties that are not air-conditioned, regardless of whether buildings integrate passive, low-energy strategies or not.

3.3 Cultural Preferences

Cultural perceptions also influence our thermal preferences. Stern (1992) as cited by Brager and de Dear (2003), found evidence in various studies to show that "comfort bands do vary across cultural groups." They also point out that the Japanese view artificial heating and cooling more in terms of heating/cooling the person as opposed to the American view of heating/cooling a space. The Japanese are perceived to readily adopt 'task ambient' (or individual) air-conditioning systems with more individual control as this seems a logical progression from the traditional Japanese residential heating system 'kotatsu' which is a personal heater placed under the dining table.

Loss of 'Sense of Climate'

The rapid increase of a global style of architecture for our commercial buildings with its inherent large internal air-conditioning load has not only resulted in increased energy use but has succeeded in distancing us from the natural world and the culture around us. Ken Yeang (a Malaysian architect renowned for bioclimatic design) believes that "by designing closer to climate, you are designing closer to culture".[2] Loss of regional distinctiveness and cultural diversity expressed in building design has commonly been connected to the dulling of our 'sense of place' but may also be blamed for the dulling of our 'sense of climate'. One of the various possible reasons could be the dulling of our senses by the thermal monotony of air-conditioned spaces which offer occupants no opportunity to respond to the changing climate outside.

4.0 LOCAL VERSUS CENTRAL CONTROL OVER INDOOR CLIMATE CONDITIONS

Studies in thermal comfort and office productivity show that users' perception of personal control over their local indoor climate conditions affects their feeling of well-being, level of thermal comfort and productivity level (Leaman and Bordass, 2005). Building occupants know they cannot control the weather but perceive that they should be able to control indoor temperature as it is artificially produced or man-made.

4.1 Personal Control

Rowe (1995) in de Dear et al concluded from his studies that "people have a wider tolerance of variations in indoor thermal conditions if they can exert some

[2] Informal discussion at Australian Institute of Architect's continuing professional development seminar "Retrofitting using bioclimatic principles: looking for value adding" held in Brisbane 8 May, 2007.

control over them, and that a considerably higher level of satisfaction will be reached if occupants have means of controlling the upper and lower temperature limits." (de Dear et. al 1998). It would appear that an adaptive model of comfort, being one in which each occupant is able to customise their thermal comfort, as promoted by de Dear would be more useful in defining thermal standards as it acknowledges that occupants play an important role in creating their own thermal preferences.

Khedari 2000 and Nicol 1999, studies cited by Peterson et. al. (2006), show that "residents of temperate climates accept 27º to 30ºC as 'comfortable' in summer, and that native populations of tropical countries will accept over 33ºC if sufficient air flow is in their personal control." This study not only reveals the cultural differences in the level of acceptance of warmer indoor temperatures but also that higher/lower temperature settings can be used for air-conditioning set points if occupants are given some mechanism of personal control, such as operable windows, blinds, or under desk heater or small desk fan for local heating or cooling.

User Expectations

Further research by de Dear (2004) noted that "thermal environmental conditions perceived as unacceptable by the occupants of centrally air-conditioned buildings can be regarded as perfectly acceptable, if not preferable in a naturally ventilated building." He also concluded that "it was something about the actual context of the buildings in question, and in particular, the expectations that their occupants brought to those contexts." He noted that people who know that they do not have control over their air-conditioning temperature at work have the expectation that their thermal comfort will be automatically achieved at a constant level. On the other hand, people who worked in a naturally ventilated building know that the indoor climate will be more variable and that they need to be more actively engaged in making their indoor environment more pleasant.

4.2 Central Control

Though research shows that occupants are able to tolerate lower/higher indoor temperatures if given some degree of control over their indoor environment, contemporary buildings are still mostly constructed with centralised mechanical and electrical control. Bordass (1990) notes in his paper The Balance between Central and Local Systems that controls are not usually seen as part of the architectural design and engineers seldom design overall systems and outline limits with the user in mind. It is evident that end users are not consulted and therefore their needs are seldom addressed.

Bordass (2001) also notes that there is a lack of feedback on the energy performance or post occupancy evaluation of a building's system from the user (local control) to facilities management (central control). Air-conditioning set points are usually viewed as universal settings rather than adjusted to the building or its users. De Dear's and others research into Adaptive Comfort Standards, now represented in ASHRAE's thermal comfort standard (ASHRAE, 2004) encourages management with central control to have more of a connection with the users so that they have more local control. This in turn would promote happier occupants and a more productive workplace. Leaman and Bordass (2005) conclude that the absence of effective control adjustments to indoor climate in a building especially in generic space-planned offices makes the difference between tolerable comfort and dissatisfaction.

Management with central control should be encouraged to embrace a more customer oriented approach in finetuning the building systems. Bordass advises that:

> *"…we need appropriate technology, and not always advanced technology: BEMS (Building Energy Management Systems) don't run themselves: they need considerable effort at the design stage to make them user-friendly, care during installation and at handover, careful training, and constant vigilance during operation. They are a management tool and not a fit-and-forget item" (Bordass 1990*).

5.0 BUILDING DESIGN

Brager and de Dear (2003) also suggest that another contributing factor to the increased use of air-conditioning was the rapid advancement in building technology and cheap energy supply after the Second World War. The ability to build large floor plates and curtain walls with sealed facades soon made mechanical air-conditioning necessary. This type of non-naturally ventilated building has to rely exclusively on a mechanical means to deliver a comfortable working environment. Perhaps this has evolved to our present day dilemma of being socially conditioned to expect an office indoor thermal environment that is unrelated to outdoor climates.

Leaman and Bordass (2005) advise that buildings with a management strategy developed at the outset of the conceptual design phase are more likely to perform better. A building will function more efficiently if ventilation strategies are integrated with the design process rather than treated as a separate element. Bordass (2001) notes that "it is easier to design a crude building and use air-conditioning to sort out the environment than it is to prepare an integrated design." Very often building design is split into architectural and building services with little integration between them. The management of the facilities or end-user requirements are often not well considered at the design level. Further, the misalignment between the design phase and a building's operation sometimes negates the original intent of the building design.

Leamann and Bordass (2005) also cite Edward Tenner's 'revenge effects' in buildings, where "technical elements often work reasonably well in isolation or in theory but when included as part of a wider system of operation induce inefficiencies which ultimately affect the ability of people to perform their work properly."

Leaman and Bordass (2005) note that naturally ventilated or **mixed mode** (systems that allow conditioned as well as outside air) buildings to be simpler for users to understand and operate so, in this way, the design intent is better communicated to users. "Because users understand better what ought to happen, they are more tolerant if actual performance does not quite live up to expectations." As the subtropical climate of South East Queensland lends itself to natural ventilation most of the year, it would be highly plausible that building occupants with local control will be more satisfied and productive at their workplace.

Comfort is not only determined from the nature of our physical environment but also from our attitudes. Our individual attitudes that have been moulded from our surrounding social values and our cultural milieu play a role more significant than is accounted for by architects and engineers who use the HVAC standards which are based on universal comfort assumptions to determine parameters for air-conditioning systems in commercial office buildings.

6.0 SUMMARY OF CURRENT LITERATURE

A review of current literature and research, as summarised above, supports the intricate relationship between the occupant's perception of thermal comfort and the provision of that comfort via the office's HVAC systems:

- *Thermal comfort for indoors* is difficult to define as a standard as it is perceived by occupants who are humans and thus variable in a biological and cultural sense. Application of universal air-conditioning temperature settings does not contribute to user satisfaction.
- *Social norms and cultural influences* define thermal comfort perceptions more strongly than previously realised.
- *Local vs. central control:* Current literature reveals that building designers struggle with providing enough local control for occupant satisfaction while maintaining adequate central control of the systems in order to run efficiently.
- *Building design:* A building would be able to offer its occupants better thermal comfort if architectural and mechanical elements were integrated in a responsive climatic design approach right from the beginning of the design process.

7.0 APPLICATION OF DATA

With the knowledge gathered from the literature review, the project team incorporated a questionnaire into the study to investigate both physiological and psychological responses to the indoor environment. Two buildings amongst a sample of 8 buildings were selected for a four month trial of a cooling set point of 25 ^{o}C over the 2006/2007 summer. The results of the research are explained in the companion paper.

8.0 CONCLUSION

Prevailing information on climate change compels us to investigate ways of saving energy in our buildings. Since existing buildings represent a substantial ratio of current building stock, the research project outlined in this and the companion paper provide relevant information on the methods and results of raising/lowering temperature set-points of commercial buildings that have mechanical air conditioning systems. Due to the large proportion of post-war buildings in operation as workplaces, it is important to examine ways of reducing energy use which in turn reduces our GHG emissions.

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BIOGRAPHY

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Dr. Jennifer Summerville is a sociologist who specialises in social sustainability and the built environment. Since 1999, Dr Summerville has been involved in a range of research initiatives investigating the social drivers and barriers to environmental sustainability. These projects have focused on issues such as community engagement, sustainable building, development communication, corporate social responsibility and the social aspects of triple bottom line reporting.

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