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

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- *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

BEDP ENVIRONMENT DESIGN GUIDE

ADJUSTING BUILDING THERMOSTATS FOR ENVIRONMENTAL GAINS – A PILOT STUDY

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 result 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 external environment, but is generally dependent on non-renewable energy.

This paper discusses a pilot study which involved altering the thermostat set-points to 2-3°C above the normal summer setting in two air-conditioned buildings during a Brisbane subtropical summer. It was expected that this minor temperature change would reduce energy usage for air-conditioning which would in turn, reduce greenhouse gas emissions. The aim of this project was to measure the social, economic and environmental value of a different approach to thermal comfort, facilities management, corporate culture and acceptance of the benign subtropical climate.

This paper presents the findings of the research, including 'lessons learned' and a set of strategies that may be used by facilities managers who adopt a similar initiative, to ensure that users of buildings are positively engaged and consistent protocols are communicated to all stakeholders. The research that informed this study is discussed in the companion paper DES 71: Adjusting Building Thermostats for Environmental Gains – Understanding the Issues.

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. This research 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.

Objective

This pilot 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 hermostat set-points by 2-3°C could bring about significant change in reducing GHG emissions. It was decided to limit this study to temperature band adjustment, even though other factors such as air-velocity are known to be a significant determinant of comfort, because conventional centrally-controlled HVAC systems typically limit occupant interaction to adjusting the thermostat temperature setting in a space (Aynsley, 2007). Together with this technical adjustment, occupants' responses were monitored and the findings of both the energy usage and survey results were documented. This paper reflects the findings of this research (refer to references for details of full report).

Method

Surveys were taken periodically of workers in the buildings to assess their comfort levels during a four month period to analyse users' physiological and psychological responses. Qualitative methods including interviews were also used to measure the acceptance of appropriate climate responsive clothing as business attire. Internal and external temperature, humidity and air movement were measured. Data collected was also used to compare weather data and energy use of the buildings from the same period in the previous year.

The multi-disciplinary project team, encompassing the disciplines of architecture, engineering and humanities, as well as Facilities Management (FM) staff, undertook the following tasks:

- *Review of current research* – to identify research on the effects of adjusting thermostats on energy usage and how occupants respond to such an action.
- *Participant response and survey analysis* – to evaluate building users' responses, both physiological and psychological.
- *Promotional and communication strategies* – devised materials and implemented strategies to encourage active participation of stakeholders.
- *Resource Usage* – Monitoring and measuring ventilation and cooling cycles, and electricity use during the study period.
- *Analysis of the data* – for comparison with previous summer energy use, including weather data for each period.
- *Determining energy savings* – in MWh, and corresponding greenhouse gas emissions reductions in $CO2$ – e (carbon dioxide equivalent). (Carbon dioxide equivalent is a

measure of the integrated effect of the major greenhouse gases which include methane, nitrous oxide, perfluorocarbons, hydroflurocarbons, and sulphur hexafluoride) (DEH, 2006)

- *Analysis of dollar savings* – in comparison with total building energy costs with a view to the potential to fund further resource efficient energy management activities on QUT campuses.

2.0 PROJECT SETTING

The Queensland University of Technology (QUT) is located in Brisbane and operates 4 campuses with over 3,000 staff and 38,000 students. Brisbane has a subtropical climate characterised by warm and humid summers with mild and dry winters.[1] The research was carried out at QUT's main campus at Gardens Point in Brisbane's CBD and predominantly involved the staff and buildings of the Faculty of Built Environment and Engineering (BEE). Although the thermostats were altered in only two buildings, all staff of the BEE Faculty's 8 buildings were invited to participate in the feedback surveys, offering a control group of staff occupying unaltered buildings.

The Test Buildings

The two buildings used for the alteration of the thermostat set points were selected on the basis that their use was predominantly an office use, and they are both fully air-conditioned.

Building D was completed in 1999 and provides 6,205 m^2 total useable floor area over five levels. The building envelope consists of a reinforced concrete frame, with fully glazed north and south walls. East and west walls are glazed above 900mm off-form concrete upstands. Perforated metal screens are fixed to all elevations. Some windows are openable and this was constant in both the study and the control season prior. Internally, HVAC services and the underside of off-form concrete slabs are exposed. Building A was constructed circa 1919 and also has a concrete frame with 2,197m^2 useable area over three levels. External walls are double cavity masonry, and the large single glazed windows face north and east and are unshaded. The building air-conditioning system was retrofitted. The interior spaces included a combination of open plan workstations, individual offices, lecture rooms, meeting rooms, a photocopying/resource centre and a cashier's office.

2.1 Survey Design

With the knowledge gathered from the literature review described in the companion paper, the project team incorporated a questionnaire into the study to investigate both physiological and psychological responses to the buildings' indoor environments.

The Questionnaire

A short questionnaire investigating levels of comfort and related circumstances was administered to building occupants on a fortnightly basis via email from a project-specific address. The survey included questions that enabled exploration of the relationship between levels of comfort and:

- the age and gender of respondents
- participant location by building and office
- survey submission times
- respondents' level of clothing including footwear (see Aynsley 2007, EDG TEC 25 Table 3 for clothing insulation values of summer clothing ensembles)
- mode of transportation to work
- usual method of transport and length of trip
- access to and use of air-conditioning in homes and car
- activity levels – previous 10 and 30 minutes (see Aynsley 2007, EDG TEC 25 Table 2 for metabolic rates associated with various activities)
- internal and external mean temperatures

Beyond being a data collection instrument, the frequent questionnaire served several functions.

- As a feedback tool it enabled the project team to monitor general levels of comfort and manage FM intervention if required (for example, a non-functioning supply air vent could be remedied etc).
- It raised occupants' awareness of features of their office environment that impact on both their personal preferences for thermal comfort and on environmental sustainability.
- It also positively engaged occupants by allowing them to suggest ways to improve both their thermal comfort and alternatives for reducing energy usage.

As a change management tool, the questionnaire proved particularly useful. 106 staff of a possible 330 occupying the 8 buildings responded to the survey. Of the 106 respondents, 47 per cent were male and 53 per cent female. In total 273 responses were submitted over the course of four months. Prior to the commencement of the pilot study, a range of comments was received, from occupants of the test buildings expressing a variety of responses to the proposal. These ranged from concerns that increasing the thermostat setting to 25 degrees would result in significant discomfort, to welcoming the thermostat adjustment in anticipation of enhancing their thermal comfort at work. During the pilot study, respondents were also able to provide feedback via the survey submission. Comments referring to four central themes – office temperature, clothing, building features and environmental sustainability were received more frequently in the first month of the project than in the following three months. At the conclusion of the project, despite initial concerns expressed about the project, invitations

1 S V Szokolay (1983) gives mean maximum temperature as 25.4°C and mean minimum as 16.0°C in Climatic Data and its use in Design. Canberra: RAIA. See also Bureau of Meteorology website for climatic information at http://www.bom.gov.au/climate/averages/tables/cw_040214_All.shtml

to all faculty staff to participate in focus groups attracted only two staff members from one of the 2 subject buildings.

2.2 Change Management

Thermostat Set Point Adjustment

The set-point for Buildings A and D was raised from 23°C to 25°C on 11th December 2006, one week after notifying staff that the thermostat would be adjusted to a cooling set point of 25°C.

Monitoring

Feedback received on thermal discomfort led to data monitors being placed in some individual offices as follows:

A105 – small cashier's office with no exterior windows ($9m^2$)

A204 – open plan office with external windows on the northern side ($111m^2$)

A312 – open plan office with external windows on the northern side ($110m^2$)

D318 – small office with fully-glazed wall to the south, but no operable windows ($13m^2$)

D521 –small office with fixed windows on the western side ($12m^2$)

The thermal monitors were in place for 28 to 56 days between late January and late March. Office data was analysed for 8am – 6pm only, to reflect usual occupancy parameters. The 9am and 3pm data shown in the table below was calculated as mean, maximum and minimum as recorded every 10 minutes between 9-10 am and 3-4 pm respectively, to correlate with Bureau of Meteorology data. Despite the adjusted thermostats being set to trigger the HVAC to cool once 25°C was reached, the thermal monitors showed the mean maximum temperature for each of the monitored offices was in some cases 1.3 to 6.9 degrees higher again (refer to Table 1). Together with elevated RH readings (Design RH=50 per cent), this indicated problems with the design and/or tuning of the HVAC system.

Building D remained on 25°C set point until the first week in April. Building A was changed to 24°C on 24 January 2007 due to a high number of combined formal and informal complaints from staff about thermal comfort.

Other Problems Uncovered

Staff discontent regarding extremely uncomfortable conditions in open plan offices in Building A in mid January culminated in a meeting of occupants and the project team. This led to FM investigating the building's BMS more closely whereby it was discovered that raising the set point (to 25°C) had unmasked pre-existing sensor calibration errors and control algorithm errors. The air-conditioning system in Building A was consequently re-commissioned, allowing the air-conditioning system to perform to its design parameters, at the new set point of 24°C. Complaints ceased immediately and there was a subsequent drop in the number of official (and unofficial) complaints from staff (21 compared to 25 for the same period the previous summer).

Staff Suggestions

The occupants of Building A also began to suggest other ways that the building could perform more efficiently to reduce energy usage, some of which involved voluntary change to their own behaviours such as keeping doors to naturally ventilated corridors closed, and other suggestions which involved changes to the building fabric such as the application of external sun shading devices which were outside the control of the research team's 'no-capital cost approach' but conveyed to QUT's Facility Management department.

2.3 Observations

Some observations from the survey conducted after the temperature set-points of thermostats were increased included:

- Over half of responses were from individuals wearing short-sleeved shirts (54 per cent) and long trousers (53 per cent). Approximately 8 per cent of responses were from individuals wearing a jumper or a jacket. This cross-section is representative of the standard attire of QUT staff.

Office Temperatures for period January – March 2007		Measured Temperature				
		Building A			Building D	
		A105	A204	A312	D318	D521
Daily	Min ºC	20.8	21.7	22.9	23.2	23.6
	Max ºC	27.1	31.9	31.1	29.5	29.5
9am	Mean ºC	25.2	26.7	27.4	27.4	27
	Min ºC	22	22.1	23.2	25.2	24.4
	Max ºC	26.3	30.3	29.5	28.7	27.9
	Mean RH	57%	56%	55%	51%	52%
	Max RH	67%	66%	65%	63%	65%
3pm	Mean ºC	24.4	25.9	25.5	26	26.6
	Min ºC	22.1	22.5	23.2	25.2	24.8
	Max ºC	27.1	30.7	30.3	29.1	28.3
	Mean RH	56%	57%	57%	54%	49%
	Max RH	63%	67%	62%	65%	57%

Table 1. Measured office temperature during test period
(Source: Centre for Subtropical Design, 2007)

- The most common methods of travelling to work were walking (44 per cent), bus (39 per cent), car (37 per cent) and train (29 per cent). Respondents tended to spend approximately 20 to 30 minutes either travelling by public transport or car or walking to work. Several people's journeys involve more than one mode of transport.
- Although most of the sample had air-conditioning in their homes and/or cars, most had not used it on the day of response. And while 78 per cent had air-conditioning in their cars, only 33 per cent used it on the day of response.
- Most of the sample had been sitting typing in the previous 10 minutes (76 per cent) and previous 30 minutes (59 per cent), with only 18 per cent walking around in the previous 10 minutes and 29 per cent walking around in the previous 30 minutes.
- Taking into account air temperature, air movement and humidity, participants generally found their office environments, to be quite comfortable, with approximately 57 per cent of participants finding their office environment to be slightly, moderately or very comfortable – see Figure 2.
- Respondents were also asked to describe whether they would like to be warmer or cooler, with 39 per cent of respondents identifying that they would like to be cooler, 21 per cent identifying that they would like to be warmer, and 40 per cent saying they would not like a change to how they are feeling.

Some correlations drawn from this survey include:

- ***Location*** – There was no significant association between general comfort levels and the participant's location in a building. This suggests that manipulating the HVAC thermostat settings did not significantly affect a participant's perception of comfort.
- ***Tolerance*** – Feelings of extreme heat or cold led to feelings of discomfort suggesting that the 'tolerance' for smaller temperature changes is an important area of investigation.
- ***Air movement*** – Perceptions of air movement are an important part of people's perceptions of comfort. Refer to Figure 2.
- ***Other variables*** – Comfort levels were not associated with age or gender; whether they had used air-conditioning on the way to work, the clothing worn or levels of activity prior to completion of the survey.

It is important to note that this survey was limited in a number of areas:

- the sample size was small
- a self-select sampling method was used where participants may have had particular motivations for participation
- participants could choose when they participated (e.g. a participant may have chosen to participate only when he/she felt uncomfortable)
- there was a lack of directly correlating internal and external temperature data which limited exploration of the relationship between perceptions of comfort and internal and external temperature changes
- there were uneven participant numbers in experimental and control buildings

Given these limitations the findings from the survey cannot be extrapolated beyond this sample. They do, however, suggest some important areas for future research such as research into indoor thermal comfort

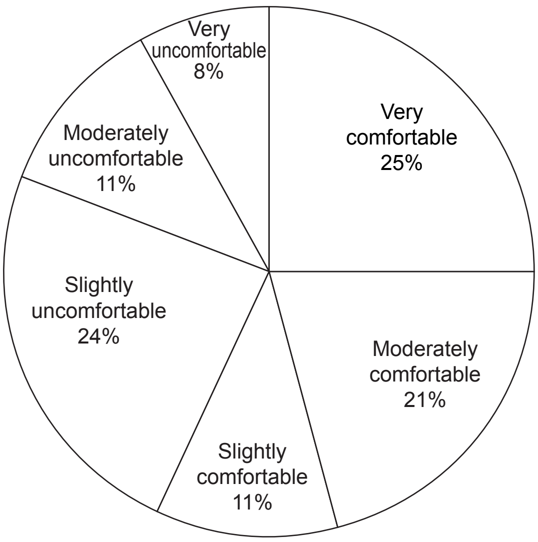

Figure 1. Level of general office comfort (n = 273)
(Source: Centre for Subtropical Design 2007)

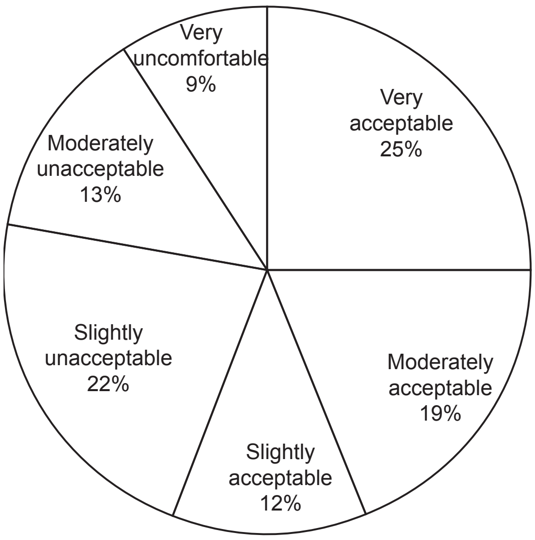

Figure 2. Level of acceptability of air movement (n = 273)
(Source: Centre for Subtropical Design, 2007)

in relation to occupant expectations; activity levels; past experiences; acclimatisation; age; gender; race; cultural influences; and cognition. For example motivation for behaviour change which may include environmental drivers such as environmental awareness or operational issues such as economic responsibility for energy bills.

Further study is also required into perceptions of fashion and comfort, and attitudes towards clothes/status and the adoption of climatically appropriate clothing for business.

3.0 MEASURING RESOURCE USAGE

In lieu of actual metered data (because the individual buildings did not have separate metering), QUT FM contracted a consulting engineer to undertake a series of energy simulations based on Building D, for three common occupancy types and temperature set points, to determine energy, water and greenhouse gas emissions from each variation. The aim was to produce energy and resource usage results that would be applicable to buildings at the University, not to simulate actual energy consumption of existing buildings.

Building D was classified as 80 per cent office space, 17 per cent lecture theatre/seminar rooms, and 3 per cent computer server rooms. Building A was classified as 84 per cent office space, and 16 per cent lecture theatre/seminar rooms. Internal loads for lighting, equipment and HVAC were nominated by the consultant to reflect typical university usage. Each occupancy type was modelled on three different set points:

1. Current – 23°C maximum/21°C minimum
2. Summer – 25°C maximum/21°C minimum
3. Winter – 23°C maximum/20°C minimum

Long term climate data for Brisbane was compared with actual weather data for the period of the project to determine if this summer was significantly hotter or colder than long term averages. This data was correlated to the measured temperature and relative humidity data collected from 5 offices in the affected buildings. Further information and associated tables and graphs can be accessed in the full report on QUT's eprints archive (http://eprints.qut.edu.au/archive/00012896).

3.1 Savings Analysis

Data from each of the modelled scenarios was used to determine for each occupancy:

- the total end use electricity per year (in MWh)
- the primary energy use (electricity sector efficiency of 0.32)
- greenhouse gas emissions (assuming 1.05 tonnes CO_2-equivalent per MWh)
- water usage (litres per day, then litres per year)
- annual electricity costs (assuming 8c/kWh)
- chiller plant capacity (size of plant needed to supply the required cooling)

The scenarios and occupancy types modelled are shown in Table 2. It is clear that, for all occupancy types, raising the summer thermostat setting 2 degrees would result in savings in end use energy of approximately 6 per cent, implying associated electricity cost savings to the consumer, primary energy savings, greenhouse gas emissions (CO_2) reductions, lower water use and reduction in the size of chiller plant which would be most appropriate for the modelled scenario. As chillers operate most efficiently when running close to their full capacity, this variable may need to be taken into account in a cost/benefit analysis of any decision to undertake a changed thermostat regime in an existing building.

Based on the typical occupancy usage of buildings A and D, this data was then used to calculate the savings in electricity usage, greenhouse gas emissions and costs that could be attributed to this project. This data is shown on Table 3.

		End use Energy (MWh/yr)	Primary Energy (MWh/yr)	CO_2 emissions (tonnes/yr)	Water usage (L/day)	Water (L/year)	Electricity costs ($/yr)	Chiller Plant Capacity (kW)
Lecture theatre 296m²	Current	32.51	101.58	34.13	33	8125	$2,600	76
	Summer	30.55	95.47	32.08	29	7150	$2,444	67
	Winter	33.30	104.06	34.96	33	8125	$2,664	76
Office 329m²	Current	35.86	112.05	37.65	20	4908	$2,868	46
	Summer	33.39	104.33	35.05	18	4485	$2,671	42
	Winter	35.78	111.80	37.56	19	4810	$2,862	45
Computer Lab 329m²	Current	133.50	417.19	140.18	50	17892	$10,680	64
	Summer	111.52	348.51	117.10	47	16529	$8,922	59
	Winter	116.44	363.88	122.26	50	17892	$9,315	64

Table 2. Resource usage per occupancy type under 3 HVAC operational scenarios

*For the purposes of this study, energy consumed was costed at 7.6c/kWhr

(Source: Centre for Subtropical Design 2007)

Indicative annual savings from summer thermostat setting at 25ºC	End use Energy (MWh/yr)	Primary Energy (MWh/yr)	Water usage (KL/yr)	Greenhouse gas emissions (tonnes/yr)	Electricity costs ($/yr)
Block A	13.64	42.63	3.51	17	$1,295
Block D	51.33	160.41	10.72	61	$4,646
Combined	64.97	203.04	14.23	78	$5,941
Saving	6-7%	20-21%	9.4%	7.6%	7.6%

Table 3. Estimated resource savings for Buildings A and D, QUT

(Source: Centre for Subtropical Design 2007)

The above indicates that there are quantifiable savings in end-use and primary energy, water use, GHG emissions and electricity costs that are significant enough for a building owner such as QUT, to justify further investigation into this simple method of energy savings via thermostat controls. These would be in addition to the usual Building Management System (BMS) control strategies, such as for example, shutting systems down when sensors detect unoccupied areas.

4.0 MAIN FINDINGS

Our initial question was whether GHG emissions reductions could be achieved in subtropical office buildings, at no capital cost, through adjustments to air-conditioning thermostats, and under conditions acceptable to both building owners and occupants. This pilot study has revealed that it is possible to achieve energy savings and GHG emissions reductions through this means, **with no significant impact on the thermal comfort of staff** provided that HVAC systems are operating as per specifications. As well as validating the incorporation of a change management strategy to maximise acceptance of change initiatives among builder users, this research confirmed that raising the summer thermostat setting 2°C would result in:

- reductions in GHG emissions
- operating cost savings to the building owner through lower electricity usage
- lower potable water usage.

Additionally, building owners may identify opportunities for further savings through:

- fostering staff behaviour change
- changes to procurement and maintenance practices
- potential reduction in capital expenditure on assets through reduction in chiller plant capacity for new or refurbished buildings.

If other big users of stationary energy were to adopt this approach as a first step in reducing demand for energy, the reduction in primary energy achievable could have significant implications for electricity generation and transmission/distribution infrastructure requirements.

Significant environmental gains can be achieved by challenging the usual approach of providing comfort via universal standards. Strategies for finding energy savings have primarily focussed on physical engineering solutions but our research reveals that energy use can also be reduced through an understanding and response to the cultural and social influences of human comfort such as preferences for wearing seasonally appropriate clothing to work, and the desire for openable windows. By responding to these cultural and social issues, building owners, managers, and occupants can reduce the energy and water consumption of existing HVAC systems and demand better design in new buildings.

5.0 RECOMMENDATIONS

The 4 month pilot research project conducted at QUT confirmed a strong and significant relationship between the technical manipulations of the indoor environment of the office space concerned and the social responses to that technical adjustment. From the findings of the four month project a number of recommendations follow:

- Ensure HVAC systems are in good working order and operating correctly before commencing the adjustment.
- Commissioning processes must involve the occupants and some measure of whether the aim of occupant comfort is being achieved (as opposed to whether the HVAC system is performing to its engineering design parameters).
- Encourage alternative dress code that is both acceptable for the workplace and responds to local climate that would enable adjustment of thermostat set-points to reduce energy use.
- A change management process is essential to acknowledge social impacts of instigating energy saving measures in the work place, thereby achieving greater occupant engagement.
- Better informed end-users have a better understanding of how thermal comfort can be achieved in their space. Once informed, occupants are able to use their understanding of existing systems, and adapt their own behaviour.
- Better communication. Facilities maintenance staff who are trained to 'interpret' occupants' complaints are in a better position to identify the mechanical problem and resolve the issue satisfactorily.

Further recommendations for consideration are:

- ***Consider holistic opportunities*** and benefits in decision making because cost savings can be achieved through lowered water usage, use of electricity from renewable resources and capital savings benefits.

- ***Electricity from renewables*** – The cost savings generated through reduced energy usage could be put toward the increased cost of fully renewable electrical tariffs such as Green Power to further reduce GHG emissions, or as practised at QUT, cost savings are used to fund further GHG emission reduction strategies.
- ***Lighting and equipment heat load reduction*** – Further energy savings opportunities could be obtained through staff awareness that heat generated from computers and lights contribute to the internal heat load. Behavioural changes from staff and students such as switching off lights and computers in spaces that are not in use can minimise energy use.
- ***Integration of the architectural and mechanical services*** at the design stage which includes end-user requirements could lead to a better building design outcome. For example, holistic design solutions could incorporate fire engineered solutions for circulation spaces that allow for access to natural cross ventilation via corridors and stairwells.
- ***Establish a corporate environmental sustainability manifesto*** for the building tenant and owner organisations to implement a formalised approach to sustainability practices in its core business.
- ***Changes in procurement practices*** such as requiring the most energy efficient mechanical plant, and pursuit of passive systems to reduce overall energy demand and produce significant savings.
- ***Acknowledge the limitations of HVAC systems*** as they are not perfectly calibrated systems that continue to work all the time in the way that they may have been originally programmed.

6.0 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, this project provides 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, and until owners are motivated to undertake a complete refurbishment, it is important to examine affordable and achievable ways of reducing energy use which in turn reduces GHG emissions.

QUT's pilot project aimed to quantify whether building occupants of commercial buildings in a warm, humid, sub-tropical location would tolerate changes in the generally accepted industry standards for thermal comfort. It found that building occupiers can be meaningfully engaged in a change management process that delivers occupant comfort as well as financial and environmental savings. Coupled with additional behavioural and procurement/operational changes, these savings can be magnified.

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BIOGRAPHY

Rosemary Kennedy RAIA is the Director of the Centre for Subtropical Design, a partnership between QUT, Brisbane City Council and the Queensland Department of Infrastructure and Planning. Ms Kennedy is a Senior Lecturer in the School of Design. Her major research interests are sustainable urbanism and the exploration of higher density residential and mixed use typologies for compact urbanisation in warm climates, particularly regarding the ability of higher density options to produce acceptable or even desirable residential amenity in terms that integrate passive climatic design principles. Contact: csdenq@qut.edu.au.

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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.

Maree Heffernan is a psychologist who has worked in a range of applied and research roles that relate broadly to the theme of social change. Her work has been primarily focussed in the areas of the creative industries, housing, sustainability and, more recently, problem gambling.

Susan Loh, B Arch, B Arts (hons) is a lecturer at the School of Design, QUT, a researcher of living walls and author of an EDG paper on the topic. She works with the Centre for Subtropical Design, QUT. Contact: susan.loh@qut.edu.au

APPENDIX – OCCUPANT SURVEY

Same Latitude New Attitude Pilot Project

Comfort Questionnaire

Instructions:

Please complete the following questions by clicking on the appropriate button and/or entering text in the open-ended response areas. Once the questionnaire is completed click on the Green "Submit by Email" button at the end of the questionnaire and follow the on-screen instructions. An email will be automatically created when you select the return method (you can choose to send via a desktop email package such as Outlook or Eudora or via webmail). Please click the send button in your email package/web mail once the email has been created. All survey responses will remain confidential. Participants will remain anonymous and will be identified by an ID code.

Location & Date/Time

1. Building (Enter A, B etc):
2. Room Number or Area:
3. Date (Calendar will appear on-screen, please click on correct date):
4. Current Time (Please enter in 24hr format HHMM e.g. For 2pm enter 1400):

General Office Comfort (Temperature, Air Movement, Humidity)

1. How comfortable is your office **right now** ? (Please select the button that best applies)

☐ Very Comfortable ☐ Slightly Uncomfortable ☐ Moderately Comfortable
☐ Moderately Uncomfortable ☐ Slightly Comfortable ☐ Very Uncomfortable
☐ Slightly Comfortable

Thermal Environment in Your Office

1. Please choose the option that best describes how you feel at ***this moment***
2. Is the thermal environment acceptable to you?
   ☐ Unacceptable ☐ Acceptable
3. Please select the button that best represents *how you would like to feel at this moment.*
   I would like to be:
   ☐ Warmer ☐ No Change ☐ Warmer ☐ Cooler

Air Movement

1. How do feel about the air movement in your office **right now**?
2. I would like:
   ☐ More air movement ☐ No change ☐ Less air movement

Activity Level

1. What activities have you been engaged in (mark all that apply)?

1a. In the last **10 minutes:**
☐ Sitting quietly ☐ Sitting typing ☐ Standing still
☐ On your feet working ☐ Driving a car ☐ Walking around

1b. The **half-hour before that**:
☐ Sitting quietly ☐ Sitting typing ☐ Standing still
☐ On your feet working ☐ Driving a car ☐ Walking around

1b. The **half-hour before that**:
☐ Sitting quietly ☐ Sitting typing ☐ Standing still
☐ On your feet working ☐ Driving a car ☐ Walking around

continued over

Clothing

1. As clothing affects your thermal comfort, please indicate which articles of clothing you are currently wearing(Please click on check boxes to indicate that you are wearing this item)

☐ Slip/petticoat	☐ Camisole
☐ Singlet or Vest	☐ Pantyhose/stockings
☐ Socks (short)	☐ Socks (long)
☐ Sandals	☐ Semi-enclosed Shoes
☐ Enclosed Shoes	☐ Sleeveless Top/Shirt
☐ Short-sleeved Top/Shirt	☐ Long-sleeved Top/Shirt
☐ Dress	☐ Skirt
☐ Shorts	☐ 3/4 Length Trousers
☐ Long Pants/Trousers	☐ Tie
☐ Sweater/Cardigan (Light-Med weight)	☐ Vest
☐ Jacket/Coat (Med- heavyweight)	

Air conditioning Use

1. Do you have air conditioning installed in the following?(Click on all that apply)

☐ I have air conditioning at home in my bedroom ☐ I have air conditioning at home in my living area

☐ I have air conditioning in my car

2. Have you used air conditioning in your home or car TODAY? (If 'YES' Click on all that apply)

☐ Yes ☐ No

☐ At home in my bedroom ☐ At home in my living area ☐ In my car

Demographics (Please click on appropriate button)

1. Gender

☐ Male ☐ Female

2. Age

☐ Under 30 years ☐ 30 - 45 years ☐ 46 - 60 years ☐ Over 60 years

3. Transport

How do you usually get to work (mark all that apply)? How long does this usually take?

☐ Train	☐ Time in Minutes	☐ Bus	☐ Time in Minutes
☐ City Cat/Ferry	☐ Time in Minutes	☐ Car	☐ Time in Minutes
☐ Cycle	☐ Time in Minutes	☐ Walk	☐ Time in Minutes

Click on the "submit" button below when you have finished

Thankyou for your time!

(Source: Centre for Subtropical Design 2007)