Melbourne City Council CH_2

AESY820000

Productivity Benefits at CH_2

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design advice

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design analysis

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September 03

AESY820000/REP010B

EXECUTIVE SUMMARY

This report looks into the potential financial savings which are expected to be achieved as a result of the improved indoor environmental quality provided by the CH2 design for MCC. In estimating these financial savings, this report compares the current MCC design, which includes the provision of 100% fresh air, displacement ventilation and chilled ceilings, with what is considered standard practice services design in Australia – a VAV (Variable Air Volume) system.

This report finds that a significant proportion (about 30%) of sick leave can be attributed to problems with the indoor environment and indoor air quality. It is also noted that a small proportion of staff turnover (up to 2%) is due to dissatisfaction with the indoor environment. Estimates in this report suggest that a productivity improvement from 1% to 4.9% is possible as a result of indoor air quality, air delivery and thermal comfort improvements.

The report draws on HR reporting from Melbourne City Council to identify the annual expenditure on employees, the rate of sick leave and the annual staff turnover rate. These figures are used to identify the exact cost of these issues to MCC.

An investigation into research carried out on the quality of the indoor environment has provided data on expected improvements in contraction of respiratory illness (such as the flu) within the office, reduction in stress and improvements in performance as a result of initiatives which will be included in the MCC design. These benefits have been quantified against the costs to MCC of sick leave and staff turnover to obtain estimated annual cost savings which should be obtained as a result of the improved design.

For all productivity and sick leave benefits, two estimates have been provided in this report – a conservative and an optimistic estimate. The conservative estimate is the minimum gain that should be expected from the proposed design. The optimistic gain represents the sort of savings that are feasible where current research on productivity is extrapolated literally.

Once the capital costs and ongoing energy consumption of both options is taken into account, the Net Present Worth of both cases is calculated over 5, 10 and 20 years. The report finds that using conservative estimates, after 10 years the NPV (Net Present Value) of each option is approximately the same. After 20 years, the CH2 design provides a net saving (in present dollar terms) of 58% over the VAV system (over $2,000,000). Using the optimistic figures, the proposed CH2 design recovers the additional capital outlay when compared with a typical VAV system after 3 years, and pays for the entire services component of the building in productivity savings after 7 years.

These results vindicate the actions which are being taken to improve the indoor environment of the new CH2 building at MCC. Particularly given that the outcome analysing conservative productivity gain estimates, and also given that this report does not factor in costs such as staff overheads or societal costs such as the impact of Sick Building Syndrome on the health system, there is a clear and important benefit to be achieved from incorporating the healthier design option.

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1 INTRODUCTION

This report is designed to provide a comprehensive quantified analysis of the expected productivity gains likely to result from the CH2 design when compared with a standard VAV system.

The first part of the report looks into the reasons for lost revenue in an office environment – sick leave, staff turnover and reduced productivity. It briefly analyses the causes of sick leave and staff turnover, and attempts to divide these issues into those which are affected by the indoor environment and those which are not.

The report then briefly looks at the MCC CH2 design, and follows with an in-depth analysis of studies which have investigated the correlation between the provision of a good indoor environment and cost savings through productivity increases or reduced sick leave.

Once the potential savings are fairly estimated, a full cost benefit analysis, incorporating capital costs, energy costs and productivity savings is included at the end.

1.1 Sources of Information

A large amount of reference material has been investigated as part of this report and these sources are described throughout the report.

Information regarding the staff costs, rates of sick leave and staff turnover were obtained from the 3rd quarter MCC human resources report for 2003.

Information regarding the projected capital cost of the designs was obtained from Lincolne Scott, Melbourne. Information regarding energy consumption was obtained from other AEC reporting carried out for MCC.

1.2 Limitations

It is important to note that every effort is made to provide realistic, conservative estimates of productivity gains. However productivity benefits, reasons for sick leave and staff turnover are varied and changeable and rely on many factors. This should be kept in mind if these figures are to be used for more than an indication of the overall cost of each design option.

Date	25 September 2003	
Revision and Status	Draft – Second Revision	
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2 APPROACH

In order to quantify the improvements in the health comfort and productivity of employees at MCC as a result of a better indoor environment, the first issue to consider is where these factors can be quantified and to identify the causes and the costs of a poor indoor environment.

This chapter creates a brief breakdown of quantifiable opportunities to improve productivity and save operating costs through a better environment. It sets the framework under which actual cost savings can be calculated.

2.1 Statistics for Melbourne City Council

AEC have fortunately been provided with some important information regarding the rates of sick leave and staff turnover for Melbourne City Council. The total labour budget for MCC is also provided. These items will be used to quantify the monetary benefits possible at CH2.

For the purposes of this study, only permanent employees will be considered. This is because permanent employees make up over 90% of the MCC workforce, and because non-permanent employees do not necessarily receive sick leave entitlements.

2.1.1 Expenditure on staff

At MCC in the actual budgeted expenditure on permanent staff was $33,112,000 for 870 permanent staff. As it is understood that there will be approximately 500 staff at CH2, this value is prorated to reflect the expenditure on MCC staff which will be working at the CH2 building. This is estimated at $18,965,000 per annum.

The annual budgeted expenditure on staff overheads was an additional $9,265,000. This will not be taken into account at this stage, nor will the effect on other employees of employees being inactive or not at work.

2.1.2 Annual cost of absenteeism

For absenteeism, it is fairly reasonable to say that the cost of an employer of someone not being at work is 100% of the cost of employing them for that time.

The absenteeism rate for the March Quarter of 2003 was 3.23%, similar to that for the two previous quarters. This will therefore be the assumed value for the current rate of absenteeism amongst MCC staff. Note that this does not include absenteeism due to OH&S claims and workplace-related injury.

Therefore, assuming that productivity is zero when workers are absent, the total annual cost of absenteeism at CH2 (assuming status quo) can be valued at $612,569.

2.1.3 Annual cost of staff turnover

Staff turnover or churn creates costs associated with finding, interviewing and training new employees. Studies tend to offer a wide range of values on the cost of this figure.

Most of the studies read place a very high value on the cost of staff churn.

> *"Research undertaken by the Council for Equal Opportunity in Employment (CEOE), for example, reveals that labour turnover costs can range from between 50 and 130 percent of an incumbent's salary." (Equal Employment Opportunities Government Website, Australia)*

"If it costs a month's salary to find and retrain a new employee (and it can cost a lot more) and if your staff turnover is 25%pa (and it can be a lot higher), staff turnover will cost 25% of your wages bill. So it's worth doing what you can to reduce it. You can never measure how much, lower staff turnover can save you. But it can make a dramatic difference to your balance sheet." Australian Financial Services Directory

"The cost of replacing an employee ranges from 29% to 46% of the employee's annual salary... In its survey, the average voluntary turnover rate was 13%." (Dimensional Directions Consultancy)

"The most conservative direct-cost estimate of replacing each employee, which includes costs associated with recruitment, orientation, training, and ramp-up speed, was 50% of the average salary. Some companies have reported replacement costs as high as 125% of salary." (Superb Staff Services Consultancy)

For the purposes of this study, it is best to be conservative, so it will be assumed that the cost of staff turnover is 15% of the salary of those staff. In addition, only the employee initiated staff separation rate will be used for this analysis, because the intention is to identify the savings in reducing the cost of employees who leave because they are unhappy with the work environment, not because they have been fired or made redundant.

Therefore, for CH2, it is again noted the annual wages expenditure is estimated at $18,965,000. The staff turnover rate or "employee initiated separation rate" is 11.61% per quarter. Assuming the cost of replacing those employees is 15% of their salary, the quarterly cost of employee initiated staff turnover is $330,275.

Therefore the annual staff turnover costs are estimated at $1,321,110.

2.2 Reasons for Sick Leave

The reasons for sick leave are complicated and poorly documented, both by the private and public sectors. Generally, reasons for sick leave can be divided into the following:

- Illness contracted in the office (including flu, viruses, colds, etc)
- Illness contracted outside the office (such as sports injuries, accidents, flu and colds caught at home, etc)
- Work-related stress
- Non-work related stress
- Lack of motivation
- Other factors

The breakdown of these factors is difficult to assess. Some studies have attempted to do so, and these findings are discussed below.

Australian Bureau of Statistics

The ABS did not provide exhaustive data on the causes of sick leave, but these results were available from the 1995 census.

"In 1995, 10% of all employees (652,000 people) took sick leave for their most recent absence from work in the two-week reference period. This proportion was similar in 1993 (9%). In both years, just over 60% were away from work for

one whole day or less and less than 2% were away for 10-14 whole days. In 1995, 7% of employees who took sick leave stated that their main reason for doing so was something other than attending a medical or dental appointment, or their own ill health, physical disability, or pregnancy."

Absence management in the Australian Public Sector (Auditor General Report)

These extracts are from the Auditor General's report on Absence Management in the Public Sector. There is a case study including MCC in the report.

"One APS agency found that employees aged 60 years and over and those aged under 25 years were the most likely to take sick leave, taking three times and double the levels respectively of the amount of sick leave taken by other age groups during 2001–02. It also found that female employees took 16 per cent more sick leave and 28 per cent more carer's leave than male employees. Another study, covering public and private sector employees, found that females took about 25 per cent more sick leave than males."

"Such absences are costly. The direct remuneration cost of sick leave in 2000 in Australia was calculated at an average of $1550 per employee. A more recent US survey found that the average per-employee cost of unscheduled absence in that country during 2002 was $1360 (US$789). However, in many workplaces the real cost of unscheduled absence does not only lie in the payment of sick leave entitlements but in the replacement of essential staff and the difficulties the actual absence causes through disruption to production/operation. According to US industry estimates, when these other factors are taken into account, the real costs associated with employee absence can be up to three times higher than the total direct costs to employers."

"Any examination into unscheduled absence needs to ascertain the underlying reasons for it. Research indicates that there is no one key factor that determines absence behaviour in organisations."

"To some extent this is reinforced in a recent US survey, which found that personal illness accounted for only one-third of unscheduled absence, with the other reasons covering: family issues (24 per cent); personal needs (21 per cent); stress (12 per cent) and entitlement mentality (10 per cent). Pinpointing the underlying cause(s) is one of the keys to reducing unsatisfactory absence levels, whether relating primarily to the organisation and/or the individual concerned."

World Health Organisation, Report on Men's Health in Austria

Whilst this report is about health in Austria, the source is a fairly reliable one. This puts sick leave as caused by respiratory illness at 40%.

"Sick leaves are primarily due to respiratory illnesses (about 40 %). These rank second among occupational illnesses, after noise damage. The consequences of work and sport accidents cause twice as many sick leaves among men as among women and rank third among the reasons for sick leave. Disability pensions and early retirement are above all due to illnesses of the musculo-skeletal system, the other major causes being cardiac and respiratory diseases, and psychological disabilities."

In summary, for the purposes of this report, the following breakdown for the reasons for sick leave will be used.

Cause for sick leave	Relevance to CH2 indoor environment quality (IEQ)	% Sick leave attributed to this cause	Annual Cost due to this cause of sick leave
Illness caused by office environment	Usually caused by poor IEQ	25%	$153,142
Illness caused by home environment	Not related to office IEQ	10%	$61,256
Injury caused by office environment	Marginal association with office IEQ	5%	$30,628
Injury caused by non-office environment	Not related to office IEQ	10%	$61,256
Stress related to work	Partial link to office IEQ	20%	$122,513
Non-work related stress	Marginal link to office IEQ	20%	$122,513
Other reasons	Not related to office IEQ	10%	$61,256

The above table will be referenced when quantifying possible benefits from improving the indoor environment.

2.3 Reasons for Staff Turnover

Just as with sick leave, the reasons for staff turnover are complex and varied. These range from retirement to opportunities arising at other companies, problems with other staff, dissatisfaction with job, displacement caused by spouse or family moving interstate or overseas, and, possibly, dissatisfaction with the office environment, part of which is associated with the indoor environment.

There is much evidence to show that staff that are physically comfortable are more likely to be satisfied and stay with their current employer. Therefore it is reasonable to apportion a percentage of the cost of staff turnover to a poor work environment, or, in the case of CH2, to apportion a saving in the cost of staff turnover to an improved work environment.

Due to the range of reasons for staff turnover, however, this percentage will be set at a fairly low level. For the purposes of this study, it will be assumed that a maximum of 5% of staff turnover could be avoided if the occupants were more satisfied with their work environment.

This represents a potential annual saving of $66,055 in voluntary staff turnover costs, if the office environment is significantly improved.

2.4 Methodology for Productivity Measurement

The above factors only account for the costs of employee absence or turnover caused by a poor indoor environment. The next chapter provides more detail regarding estimates about productivity improvement whilst at work as a result of an improved indoor environment. For the purposes of this study, the annual expenditure on staff will be used as the benchmark for measuring productivity. Note that this means that for each 1% improvement in productivity, MCC will save $189,650 per annum on the cost of its CH2 employees.

3 ASSESSMENT OF RESEARCH

There are a large number of initiatives which are proposed for the CH2 development which are expected to provide a significant improvement in occupant productivity when compared with typical office buildings in Melbourne. This chapter briefly discusses these initiatives, and follows this with a discussion on research which compares productivity increases with improvements in indoor air quality. An estimate on the overall cost saving from productivity improvements is included at the end.

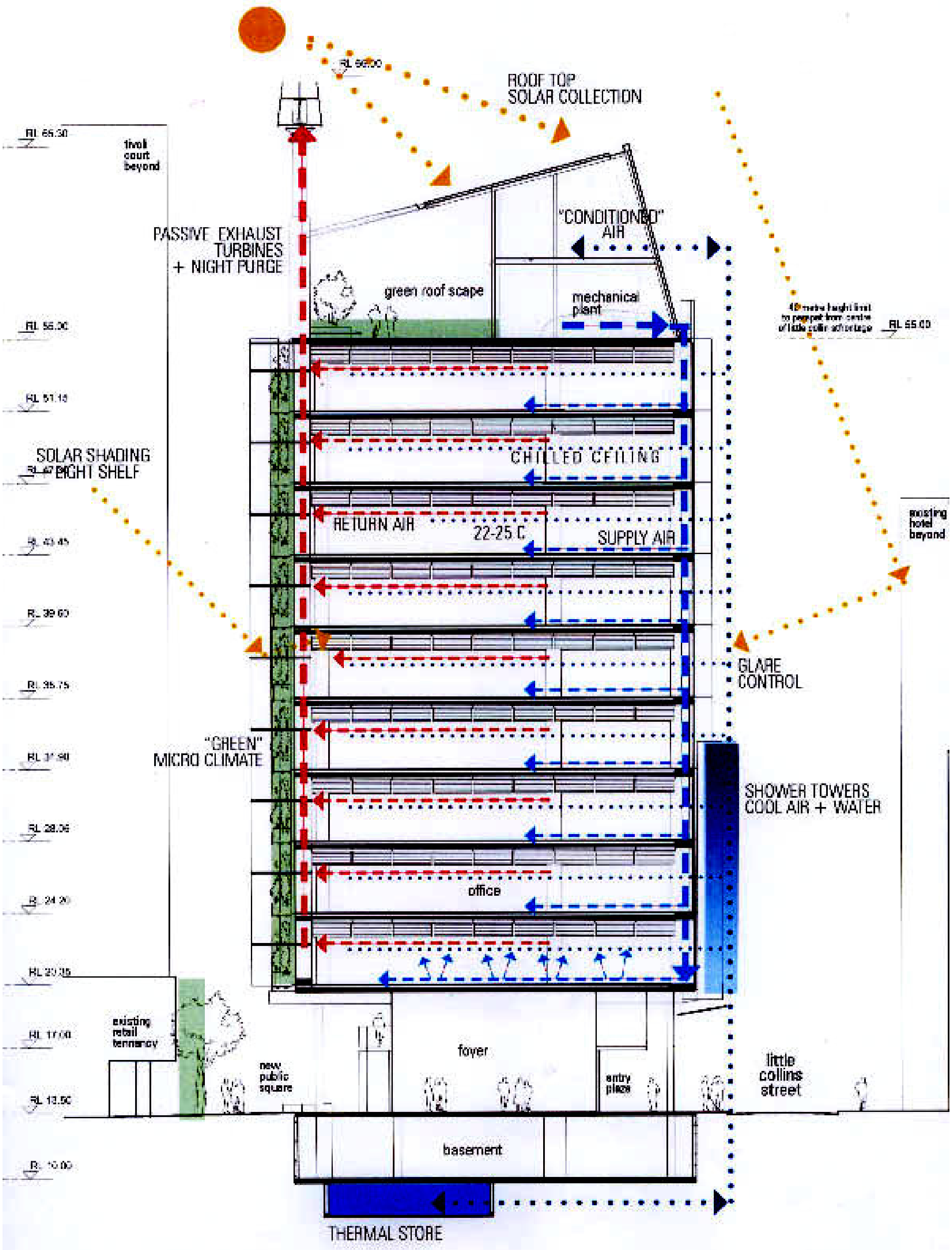

Figure 1: Schematic of CH2 including flow of supply and return air

There are a number of very important indoor air quality issues which have been incorporated into the CH2 design. Figure 1 shows some of the features which are incorporated in the building.

3.1 Minimum fresh air

The minimum fresh air is the amount of air provided to the occupants of an artificially conditioned building. It is usually described in litres of air per second per person occupying the building.

3.1.1 Provisions at CH2 compared to standard practice

Most new office buildings conform to the Australian Standard AS1668.2 with regard to minimum outside air in offices. Generally, for a typical office building, the standard allows for 7.5l/s/person. CH2 will provide 22.5l/s/person, a threefold increase against the standard office development.

One of the reasons why this practice is not common in Australia at present is the perceived increase in energy and operational costs associated with supplying a higher proportion of outside air (which needs more cooling or heating than recirculated air). One of the advantages of the CH2 design is the use of chilled ceilings, which account for most of the cooling load, instead of the supply air. Because the chilled ceiling panels are cooled by water, rather than air, significant energy savings have been obtained through reduced fan costs. In addition, because the chilled ceilings do most of the cooling, the fresh outside air does not need to be cooled as much (or heated as much) to maintain comfortable conditions, inside, thereby further reducing the energy requirements.

3.1.2 Findings of research about minimum fresh air rates

There is a reasonable amount of research which has been carried out into the effects on fresh air supply on productivity. Key findings extracted from these papers are included below, with the most poignant outcomes highlighted.

The effects of outdoor air supply rate in an office on perceived air quality, sick building syndrome (SBS) symptoms and productivity. (December 2000)
Wargocki P, Wyon DP, Sundell J, Clausen G, Fanger PO.
International Centre for Indoor Environment and Energy, Technical University of Denmark, Kongens Lyngby, Denmark. pw@et.dtu.dk

> *"Perceived air quality, Sick Building Syndrome (SBS) symptoms and productivity were studied in a normally furnished office space (108 m3) ventilated with an outdoor airflow of 3, 10 or 30 L/s per person, corresponding to an air change rate of 0.6, 2 or 6 h-1. The temperature of 22 degrees C, the relative humidity of 40% and all other environmental parameters remained unchanged. Five groups of six female subjects were each exposed to the three ventilation rates, one group and one ventilation rate at a time. Each exposure lasted 4.6 h and took place in the afternoon. Subjects were unaware of the intervention and remained thermally neutral by adjusting their clothing. They assessed perceived air quality and SBS symptoms at intervals, and performed simulated normal office work. Increasing ventilation decreased the percentage of subjects dissatisfied with the air quality (P < 0.002) and the intensity of odour (P < 0.02), and increased the perceived freshness of air (P < 0.05). It also decreased the sensation of dryness of mouth and throat (P < 0.0006), eased difficulty in thinking clearly (P < 0.001) and made subjects feel generally better (P < 0.0001). The performance of four simulated office tasks improved monotonically with increasing ventilation rates, and the effect reached formal significance in the case of text-typing (P < 0.03). For each two-fold increase in ventilation rate,*

> *performance improved on average by 1.7%. This study shows the benefits for health, comfort and productivity of ventilation at rates well above the minimum levels prescribed in existing standards and guidelines.*"

This well-respected paper and body of research is one of the most-quoted pieces of work on the effect of fresh air rates on productivity. The most important finding is summarised in the last sentence – that each two-fold increase in ventilation rate equates to an average productivity improvement of 1.7%.

Health and Productivity Gains from Better Indoor Environments and Their Implications for the U.S. Department of Energy
Fisk, W.

> *"A large multi-year investigation by the U.S. Army (Brundage et al. 1988) determined that clinically-confirmed rates of acute respiratory illness with fever were 50% higher among recruits housed in newer barracks with closed windows, low rates of outside air supply, and extensive air recirculation compared to recruits in older barracks with frequently open windows, more outside air, and less recirculation."*

The abstract from this report is also quoted below. Whilst the findings from an army barracks may not seem to correlate well with an office, they are useful because they eliminate many of the variables which make comparing indoor air quality of office environments possible such as external activities, diet, and transferral of illness through relatives, other people, etc. The increase shown in illness from lower rates of air supply is significant.

> *"Another study investigated symptoms associated with infectious illness among 2598 combat troops stationed in Saudi Arabia during the Gulf War (Richards et al. 1993). The study results suggest that the type of housing (air-conditioned buildings, non-air-conditioned buildings, open warehouses, and tents) influenced the prevalence of symptoms associated with respiratory illness. Housing in air-conditioned buildings (ever versus never housed in an air-conditioned building while in Saudi Arabia) was associated with approximately a 37% greater prevalence of sore throat and a 19% greater prevalence of cough."*

Again, similar to the above, this comparison is important because it shows the impact of lower fresh air rates on a reasonably constant subject group. An increased prevalence of sore throat and cough were found amongst occupants housed in buildings with poor ventilation rates.

> *"Drinka et al. (1996) studied an outbreak of influenza in four nursing homes located on a single campus. Influenza, confirmed by analyses of nasopharyngeal and throat swab samples, was isolated in 2% of the residents of Building A versus an average of 13% in the other three buildings 10 (16%, 9%, and 14% in Buildings B, C and D, respectively). After correction for the higher proportion of respiratory illnesses that were not cultured in Building A, an estimated 3% of the residents of Building A had influenza, a rate 76% lower than observed in the other buildings. The total number of respiratory illnesses (i.e., influenza plus other respiratory illnesses) per resident was also 50% lower in Building A… The ventilation system of Building A supplied 100% outside air to the building (eliminating mechanical recirculation) while the ventilation systems of the other buildings provided 30% or 70% recirculated air."*

The above research from another paper shows a correlation between the likelihood of contagious illness and the ventilation (minimum fresh air) rate. Note the building with 100% outside air had a significantly lower transferral of illness than the other buildings with recycled air.

> *"The objective data reviewed… suggest that SBS symptoms are associated with decrements on the order of 2% to 3%. Based on these data, we assume a productivity decrease caused by SBS equal to 2%, recognizing that this estimate is highly uncertain. This 2% estimate is the basis for… economic calculations."*

This is an important analytical outcome and provides an additional benchmark for determining the impact of SBS (often caused by low ventilation rates) on productivity.

Review of Health and Productivity Gains from Better IEQ
Fisk, W.
Indoor Environment Department, Lawrence Berkeley National Laboratory, Berkeley, California

> *"The available scientific data suggest that existing technologies and procedures can improve indoor environmental quality (IEQ) in a manner that significantly increases productivity and health. While there is considerable uncertainty in the estimates of the magnitudes of productivity gains that may be obtained, the projected gains are very large… Productivity gains that are quantified and demonstrated could serve as a strong stimulus for energy efficiency measures that simultaneously improve the indoor environment."*

This is a reference to another paper by the same author, written slightly earlier with similar findings.

Ventilation and health in non-industrial indoor environments: report from a European Multidisciplinary Scientific Consensus Meeting (EUROVEN)
P. Wargocki, J. Sundell, W. Bischof, G. Brundrett, P. O. Fanger, F. Gyntelberg, S. O. Hanssen, P. Harrison, A. Pickering, O. Seppänen, P. Wouters

> *"Based on the data in papers judged conclusive, the group agreed that ventilation is strongly associated with comfort (perceived air quality) and health [Sick Building Syndrome (SBS) symptoms, inflammation, infections, asthma, allergy, short-term sick leave], and that an association between ventilation and productivity (performance of office work) is indicated. The group also concluded that increasing outdoor air supply rates in non-industrial environments improves perceived air quality; that outdoor air supply rates below 25 l/s per person increase the risk of SBS symptoms, increase short-term sick leave, and decrease productivity among occupants of office buildings"*

The above list of authors is a comprehensive "who's who" of experts on the indoor environment. The finding in the last sentence is a very important one, which clearly links minimum outside air rates with productivity.

Risk of sick leave associated with outdoor air supply rate, humidification, and occupant complaints.
Milton DK, Glencross PM, Walters MD.
Harvard School of Public Health, Boston, Massachussets, USA. dmilton@hohp.harvard.edu

> *"We analyzed 1994 sick leave for 3,720 hourly employees of a large Massachusetts manufacturer, in 40 buildings with 115 independently ventilated*

work areas. Corporate records identified building characteristics and IEQ complaints. We rated ventilation as moderate (approximately 25 cfm/person, 12 ls^{-1}) or high (approximately 50 cfm/person, 24 ls^{-1}) outdoor air supply based on knowledge of ventilation systems and CO2 measurements on a subset of work areas, and used Poisson regression to analyze sick leave controlled for age, gender, seniority, hours of non-illness absence, shift, ethnicity, crowding, and type of job (office, technical, or manufacturing worker). We found consistent associations of increased sick leave with lower levels of outdoor air supply and IEQ complaints. Among office workers, the relative risk for short-term sick leave was 1.53 (95% confidence 1.22-1.92) with lower ventilation, and 1.52 (1.18-1.97) in areas with IEQ complaints. The effect of ventilation was independent of IEQ complaints and among those exposed to lower outdoor air supply rates the attributable risk of short-term sick leave was 35%. The cost of sick leave attributable to ventilation at current recommended rates was estimated as $480 per employee per year at Polaroid. These findings suggest that net savings of $400 per employee per year may be obtained with increased ventilation."

This is an excellent piece of research into productivity costs associated with poor ventilation rates. This study found an annual potential saving of US$400 per person from increasing the fresh air rate from 12l/s/person to 24l/s/person.

An epidemic of pneumococcal disease in an overcrowded, inadequately ventilated jail.

Hoge CW, Reichler MR, Dominguez EA, Bremer JC, Mastro TD, Hendricks KA, Musher DM, Elliott JA, Facklam RR, Breiman RF.

Respiratory Diseases Branch, Centers for Disease Control and Prevention, Atlanta, GA 30333.

BACKGROUND. In the United States many correctional facilities now operate at far over capacity, with the potential for living conditions that permit outbreaks of respiratory infections. We investigated an outbreak that was identified in an overcrowded Houston jail after two inmates died of pneumococcal sepsis on the same day. Outbreaks of pneumococcal disease have been rare in the era of antibiotics. METHODS. We assessed risk factors for pneumococcal disease in both a case-control and a cohort study. Ventilation was evaluated by measuring carbon dioxide levels and air flow to the living areas of the jail. The extent of asymptomatic infection was determined by culturing pharyngeal specimens from a random sample of inmates. Type-specific immunity was determined with an enzyme immunoassay. RESULTS. Over a four-week period, 46 inmates had either acute pneumonia or invasive pneumococcal disease due to Streptococcus pneumoniae serotype 12F… Carbon dioxide levels ranged from 1100 to 2500 ppm (acceptable, < 1000), and the ventilation system delivered a median of only 6.1 ft3 of outside air per minute per person (9.3l/s/person) (interquartile range, 4.4 to 8.5 ft3; recommended, > or = 20 ft3). The attack rate was highest among inmates in cells with the highest carbon dioxide levels and the lowest volume of outside air delivered by the ventilation system (relative risk, 1.94; 95 percent confidence interval, 1.08 to 3.48)… CONCLUSIONS. Severe overcrowding, inadequate ventilation, and altered host susceptibility all contributed to this outbreak of pneumococcal disease in a large urban jail.

The above excerpt is the abstract from this document. Amongst the key findings was the realisation that, in areas where ventilation was poor, airborne disease spread much faster than in areas with good ventilation rates. This may seem to be unrelated to the office environment, but the risk of an airborne illness being spread around the office and affecting a significant percentage of staff will have very significant productivity implications on the business.

Building-associated risk of febrile acute respiratory diseases in Army trainees.
Brundage JF, Scott RM, Lednar WM, Smith DW, Miller RN.
Division of Preventive Medicine, Walter Reed Army Institute of Research, Washington, DC 20307-5100.

> *"…We hypothesized that energy conservation measures that tighten buildings also increase risks of respiratory infection among building occupants. At four Army training centers during a 47-month period, incidence rates of febrile acute respiratory disease were compared between basic trainees in modern (energy-efficient design and construction) and old barracks. Rates of febrile acute respiratory disease were significantly higher among trainees in modern barracks (adjusted relative risk estimate, 1.51; 95% confidence interval, 1.46 to 1.56), and relative risks were consistent at the four centers. These results support the hypothesis that tight buildings with closed ventilation systems significantly increase risks of respiratory-transmitted infection among congregated, immunologic ally susceptible occupants."*

The results from this study support other research indicating that low ventilation rates in buildings increase the risks of respiratory infection being transmitted between people. As noted before, because the study was conducted at an army barracks, the errors on the research are smaller.

Indoor Air Quality Position Document (Approved by ASHRAE Board of Directors June 28, 2001)

> *"While ventilation is not the only determinant of IAQ, perceived air quality and health outcomes generally improve as ventilation rates increase (Seppanen et al. 1999). In current practice, minimum ventilation rates are recommended by ASHRAE Standard 62. Interpreting more recent research, there are health, productivity and perception benefits from increasing ventilation rates above the current ASHRAE values (Apte et al. 2000; Milton et al. 2000; Sundell et al. 1994; Wargocki et al. 2000)."*

This reference is very important, particularly given that current ASHRAE ventilation rates are significantly higher than the Australian Standards already, and that this document predicts even more productivity gains from further increases to ventilation rate.

NSW Standing Committee on Public Works Report, Sick Building Syndrome, 2001

> *"There is considerable evidence that a significant proportion of office workers are affected by SBS"*
>
> *"SBS is a health problem that needs to be addressed"*
>
> *SBS in offices is caused by "low outside (or fresh) air ventilation rates… problems due to the design of HVAC systems… poor daylighting"*

This study is a very important document, because it shows that in the local context, the problem of lost productivity and health costs of the indoor environment is a serious one. The report indicates that costs associated with IAQ include reduced productivity. It quotes studies which show that buildings with good overall internal environmental quality can increase worker productivity by between 6 and 16%, as well as studies from the US Energy Management Institute, which suggests that the building environment can affect productivity by 1.5 to 5%.

In summary, the findings from this local research affirm the findings overseas which indicate that low ventilation rates decrease productivity.

US EPA Website

> *"As a result of the 1973 oil embargo, however, national energy conservation measures called for a reduction in the amount of outdoor air provided for ventilation to 5 cfm (approx. 7.5l/s) per occupant. In many cases these reduced outdoor air ventilation rates were found to be inadequate to maintain the health and comfort of building occupants... In an effort to achieve acceptable IAQ while minimizing energy consumption, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recently revised its ventilation standard to provide a minimum of 15 cfm (23 l/s) of outdoor air per person (20 cfm/person (30l/s/person) in office spaces)."*

As shown above, at its website the US EPA advocates a minimum outside air rate of 30l/s/person, by condoning the most recent revision of the ASHRAE guidelines. The justification is the health and comfort of the building occupants.

3.1.3 Summary

Based on the research discussed above and a range of other papers as well, there is sufficient evidence to conclude that productivity at MCC will be improved by this increased outside air rate when compared to a standard Melbourne office building.

The key improvements in productivity can be measured by the following quantifiable changes:

- A reduced rate of sick leave caused by respiratory illness (at least 50% based on the above data) and worker dissatisfaction (conservatively estimated at 5% based on above findings, an optimistic estimate would be 15%)
- An overall improvement in performance (a conservative estimate for overall improvement would be in the order of 0.5%, an optimistic estimated improvement would draw from Fanger's 1.7% improvement for every doubling of the fresh air rate – total improvement of 2.9%)
- A reduction in staff churn/turnover due to dissatisfaction with the office environment (conservative estimate of 5%, optimistic estimate of 20%)

These values will be incorporated into the data provided by MCC on existing staff sick leave, salary and churn rates, along with productivity benefits from other initiatives.

3.2 Ventilation efficiency and fresh air delivery

The ventilation efficiency of an HVAC design describes how well the fresh air that is being supplied to a space is provided to occupants of the building. Poor ventilation efficiency is common for buildings which use mixed air systems, because the fresh air from outside is first mixed with return air, and then mixed in with the air in the office space, before reaching the occupants, making the "freshness" of the air fairly low. The best ventilation efficiency is provided when the air being supplied is 100% fresh air, and when the supply is at the floor with the exhaust is at the ceiling. These systems are referred to as displacement ventilation systems.

Figure 2 below is a representation showing how the ventilation efficiency affects the air quality. Note that a dilution system has a low ventilation efficiency and the separation system has a high ventilation efficiency.

Figure 2: Representation of the difference between mixed air and displacement systems

3.2.1 CH2 design compared with standard practice

For most new office developments, the standard practice in HVAC design is the use of a VAV (Variable Air Volume) system. VAV systems draw a minimum amount of fresh air from outside (typically 7.5l/s/person) and mix that air with a variable amount of recycled air from the office. This air is then cooled or heated as appropriate and supplied to the space at relatively high velocities, in order to mix it thoroughly with the inside air and create a constant temperature.

Whilst this is good at reducing energy consumption, this delivery mechanism reduces further access to the fresh air being provided because it is mixed with so much of the existing air before making it to the occupant.

The system proposed for MCC is a displacement ventilation system. This means that less air is supplied at a lower velocity and warmer temperature (for cooling) via the floor. The air is then removed from the space via the ceiling. The air provided is 100% fresh air, so a very high proportion of the air that makes it to the occupant is directly from the outside. Pollutants from the space are removed via the ceiling and then ducts along the north façade, without being mixed with the rest of the building.

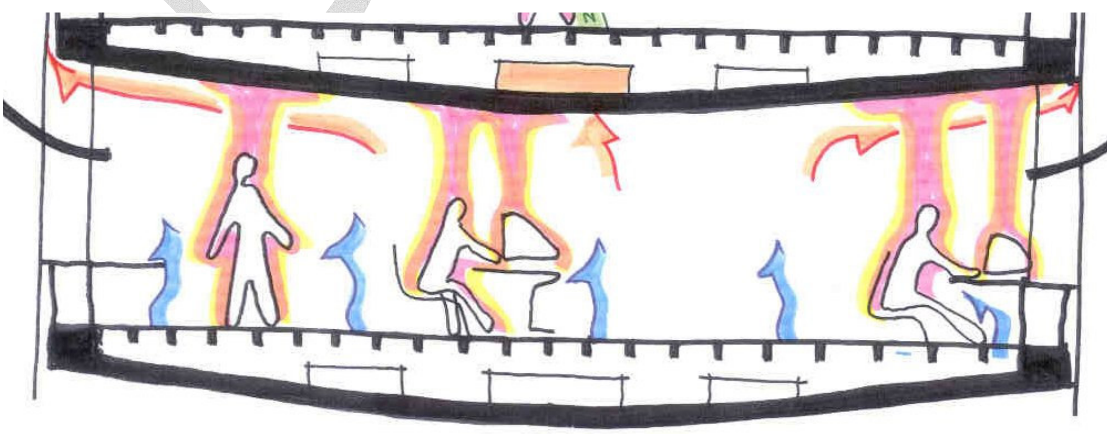

Figure 3: Representation of air and heat flow in the MCC displacement system

3.2.2 Findings of research about ventilation efficiency

Many of the findings which have been discussed with regard to minimum outside air rates are easily transferred to ventilation efficiency. The benefits of increasing the minimum outside air rate are improved further by better distribution and delivery of the outside air. Therefore, it is generally anticipated that increasing minimum outside air rates *and* using a displacement ventilation system would increase productivity and improve health and wellbeing over and above that which would be expected from just increasing outside air rates.

Some research has been directed specifically on the productivity and health benefits associated with higher ventilation efficiency, or which have found that such systems improve productivity and occupant health over typical VAV systems. These papers are discussed below.

Quantification of the Benefits of Displacement Ventilation in Airborne Disease Control
Cullen, N.
Hoare Lea R&D

This paper uses the Wells-Riley model which is used to predict the number of new infections in susceptible people based on the number of infected people, the ventilation rate and the duration of exposure to ventilation. The theory was modified to account for the relatively low mixing of displacement ventilation compared with a mixed air system. This was done through a personal exposure index which is basically the ratio of contaminants in the return air to the supply air. A perfectly mixed VAV system would therefore have an index of 1 (but probably less because mixing is not perfect), whereas a displacement system would probably have an index of around 5 (5 times more contaminants in air leaving space compared with air entering space).

Unit Fresh Air rate (l/s/person)	No of susceptible people	No of people Infected according to the Modified Wells-Riley						
		Mixing Ventilation			Displacement Ventilation			
		Personal exposure index			Personal exposure index			
		0.6	**0.8**	**1.0**	**1.4**	**2**	**5**	**10**
7	67	39	32	27	21	15	7	3
5	67	47	40	35	27	20	9	5
12	67	27	21	8	13	9	4	2
16	67	21	17	14	10	7	3	2

Figure 4: Difference in infection rates between VAV systems and displacement systems

The above table helps show the difference between the standard practice VAV system with 7.5l/s/person fresh air and a displacement ventilation system with 16l/s/person fresh air (CH2 provides 22.5l/s/person). For the standard practice, the calculated rate of infection *for susceptible people* is around 32, or 47.7%. For the CH2 system, the calculated rate of infection is 2, or 3%.

This data was gathered from existing offices in Great Britain.

Based on this research the rate of infection of illness within the office is typically reduced from 45% to 2%.

3.2.3 Summary

Whilst the amount of specific research carried out to show productivity improvements as a direct result of displacement ventilation is not enormous, there is consistent and almost unanimous agreement that well-designed displacement ventilation provides the best indoor air quality of any HVAC system.

In the research that does exist, this is borne out in the significant reduction in infection rates between people that share a mixed-air indoor environment and people who share an indoor environment acclimatised by displacement ventilation.

This being the case, it is logical to extend slightly further the benefits associated with the provision of increased minimum fresh air. These might be summarised as follows:

- A further reduction in absenteeism caused by respiratory illness (overall reduction including increased minimum fresh air rate of 95%) and caused by dissatisfaction with work (overall reduction including minimum fresh air would be conservatively estimated at 10% and optimistically estimated at 25%)
- A further increase in productivity (additional 0.5% increase in productivity would be a conservative estimate, an additional 1% increase in productivity would be an optimistic estimate)
- An additional reduction in churn rate due to dissatisfaction with the office indoor environment (additional 5% as a conservative estimate, 20% as an optimistic estimate)

These findings will be collated at the end of the chapter.

3.3 Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (usually referred to as VOCs) have been the subject of some research of late and are often linked to the symptoms associated with Sick Building Syndrome.

VOCs are generally emitted from certain materials and finishes, many of which are common in typical offices. The following items can emit VOCs, depending on the specific make up of the material:

- Office internal finishes such as paints, adhesives and sealants;
- Carpet and carpet adhesives and underlays;
- MDF and other glued particleboard furniture;
- PVC finishes such as desktops and vinyl floor coverings;
- Desktop computers;
- Printers and photocopiers

There are many research papers which discuss the impact of VOCs on worker health and it has generally become accepted that exposure to VOCs internally should be minimised. This research is summarised below, along with some of the initiatives which have been adopted for CH2 to minimise the levels of VOC exposure.

3.3.1 Design Features to minimise VOCs at CH2

There are a large number of initiatives which have been committed to at CH2. These include the following:

- Use of low-VOC paints, sealants and adhesives internally to minimise the emission of VOCs from internal surfaces;
- Use of low-VOC recycled carpets to reduce VOC emissions from those surfaces;
- The use of flat TFT monitors as opposed to CRT monitors throughout the building
- Use of a thin-client network rather than individual PC boxes to each desk, minimising VOC emissions generated by computers and the materials they are made from;

- Provision of 100% fresh air and use of displacement ventilation which remove VOCs from the space quickly and prevent accumulation of pollutants;
- Provision of separate ventilation for photocopying and printing areas to minimise exposure of staff to ozone gas emissions from such machines.

All of these initiatives are expected to improve occupant health and minimise the amount of sick leave and losses in productivity caused by exposure to VOCs. Research which has been carried out to investigate this issue is discussed below.

3.3.2 Findings of Research on VOCs and indoor pollutants

Personal computers pollute indoor air
Zsolt Bako-Biró
International Centre for Indoor Environment and Energy

> *"Thirty female subjects participated in two 4.8 hour experimental sessions during which they assessed perceived air quality, other indoor environment factors and SBS symptoms. To modify the air quality in the experimental office, six "polluting" PCs were present behind a partition as an additional pollution source under one of the experimental conditions. The PCs were not present under the second condition."*
>
> *"When the PCs were present behind the partition the, subjects made significantly more typing errors during word processing"*
>
> *"The performance of text typing showed a decrease of 1.2% when PCs were placed behind the partition."*

This research therefore indicates a potential productivity gain from a reduction in the amount of PC equipment operating in an office space. In this experiment, the improvement was measured at 1.2%.

New studies on emissions from electronic equipment
Pawel Wargocki
International Centre for Indoor Environment and Energy

> *"The results show that the air quality was significantly poorer in the offices in which PCs with CRT monitors were placed compared with the empty offices; this effect was independent of the number of hours the PCs had been in operation. In case of PCs with TFT monitors, their presence did not significantly affect the air quality in the rooms, even after 50 h of continuous operation."*
>
> *"The main source of pollution is probably electronic components placed on the CRT monitor. They operate at elevated temperatures (>60oC) (Figure 4) which are the driving force promoting release of odorous compounds, plastic additives and flame-retardants."*
>
> *"The present results further support the earlier observation that PCs may be an important, but hitherto overlooked, source of air pollution indoors. Especially PCs with CRT monitors can be strong indoor pollution sources and only recently, TFT monitors have begun to replace them."*

The findings of this additional research carried out at the centre for indoor environment and energy suggest that the main pollutant source from the computers in the first experiment is the CRT monitors, and that this equipment emits the larges amount of indoor pollutants and causes the greatest level of discomfort and reduced health.

Internal Environment and Health of Occupants
Dale Gilbert
Queensland Government Administrative Services Department, 1994

This paper summarises much of the research conducted into VOCs up to 1994 and places it into an Australian context. Generally he reveals that whilst the effects of VOCs are widely discussed, standards and limits on VOC emissions were yet to "guarantee the absolute exclusion of undesired effects at level below the guideline values".

Some other findings in Gilbert's paper are quoted below.

> *"Lars Molhave in his research on low level exposure to VOCs in the internal environment determined that many of symptoms experienced by occupants were similar to those stated as being attributable to SBS"*

> *"It has been suggested that formaldehyde may be the cause of Sick Building Syndrome since it irritates both the eyes and the upper or lower respiratory tract. It may also be responsible for allergic disorders including asthma"*

These findings hint at a strong link between SBS symptoms and the prevalence of VOCs and VOC emissions. More recent case studies have further supported these early findings.

3.3.3 Summary

The cost of incorporating these features (apart from the provision of 100% fresh displacement air) is not accounted for in the cost benefit analysis of this report and should be perceived as separate to the design of the HVAC system. It may be worth considering the benefits of these initiatives as a separate exercise.

It should be remembered, however, that whilst research regarding appropriate exposure levels to VOCs and their effect on productivity is still quite rare, the actual cost of implementing the low VOC initiatives for CH2 compared with the wide range of associated environmental benefits and potential for even small productivity gains and health benefits is miniscule.

It is anticipated that all of the initiatives undertaken to minimise VOC emissions will reimburse the upfront cost of such actions in reduced health impacts and productivity gains.

3.4 Thermal Comfort

The thermal comfort of a building is defined in the International Standard ISO 7730 (1993). Thermal comfort is primarily made up of six contributing factors:

- Air Temperature
- Radiant Temperature
- Humidity
- Air Velocity
- Clothing levels
- Activity rate

In a typical office building with a good VAV system, air temperature and humidity are the only factors that are adequately addressed by the HVAC design. Radiant temperature (primarily driven by the temperature of the ceiling and the floor) is not controlled, and air velocity can be erratic and cause discomfort, with many occupants often complaining about draught.

The fact that radiant temperature is not controlled is the most critical, as radiant temperature represents about 45% of the means through which we perceive what the temperature is.

3.4.1 Thermal Comfort initiatives at CH2

The thermal comfort is principally improved at CH2 through two key factors:

- The low velocity of the supply air, and,
- The radiant cooling from the ceiling panels.

Because air is supplied to the space at a low velocity at floor level, the problem of draughts at MCC will be significantly lower than for a typical VAV system. This will improve the level of comfort for the staff, particularly for those staff who are susceptible to draught or who find draught uncomfortable.

Thermal comfort will also be improved through the use of chilled ceiling panels, which add a very important radiant cooling component to the space. The radiant cooling from the chilled ceiling panels addresses all components of thermal comfort in the space, which improves the overall satisfaction of the occupants and reduces the temperature at which the supply air must be provided.

Overall the CH2 building and services design is expected to provide an excellent level of thermal comfort. The research below discussed how poor thermal comfort may be responsible for SBS and losses in productivity.

3.4.2 Findings of research about thermal comfort

The principal source of research correlating thermal comfort and indoor climate to productivity is Professor David Wyon. Note that Wyon's research is not as conclusive as the research carried out into Indoor Air Quality and its effect on productivity. There is still a fair degree of controversy surrounding the perfect thermal conditions for maximum productivity. This is because it is not always agreed that perfect comfort conditions translate into maximum productivity. Wyon's research is discussed below.

Indoor Environmental Effects on Productivity
David Wyon
Address at 1996 IAQ conference

Some of the research cited in this paper shows a tendency for SBS symptoms to increase with temperature:

> *"Dryness and SBS symptoms increased markedly with air temperature in the range from 20° to 24°C… and in another study… virtually all SBS symptoms increased with temperature from a minimum at 20°-21°C, and the effect was widespread rather than confined to a few sensitive individuals: the proportion reporting headache and fatigue increased from 10% at 20°C to more than 60% at 24.5°C and other SBS symptoms, including skin problems showed similar effects."*

This argument is somewhat contradicted by the subsequent discussion regarding thermal comfort, for which temperature is only one factor. Wyon notes:

> *"Thermal comfort and measurement of the underlying state of heat balance are usually assumed to be able to identify different combinations of conditions*

> *at or close to thermal neutrality that will give rise to the same level of performance; no difference was found between two conditions of thermal neutrality with different clothing insulation and temperature"*

The text above would suggest that overall thermal comfort is the most important factor in determining productivity. However, Wyon also notes that

> *"The effects of heat stress on human efficiency are not always linear and (that conclusions from a collection of studies) invalidate the usual assumption that performance effects can always be deduced from studies of thermal comfort alone"*

This conclusion is based on a variety of experiments conducted in different countries, which showed that for different people, different temperatures and comfort conditions were considered acceptable. This conclusion would seem to suggest that it would be presumptuous to expect productivity improvements from a given thermal comfort range.

In addition, it is noted that at times, displacement ventilation systems can be detrimental to thermal comfort:

> *"Thermal gradients (such as in a displacement system) are only a problem because they lead to an increase in air temperature in the breathing zone. Even if the individual has a choice in the matter, it is an uncomfortable one… whichever is chosen, the end result is likely to be that productivity is reduced by vertical temperature differences."*

This conclusion is more relevant for systems which are solely displacement ventilation without the use of chilled ceilings. It is anticipated that chilled ceilings will alleviate the thermal comfort risks documented here. However, it would certainly be inappropriate, based on this research to assign an overall improvement in productivity to improved thermal comfort.

"Evaluation of association between indoor air climate wellbeing and productivity"
Professor Sten Olaf Hanssen
Healthy Buildings Workshop

> *"Professor Wyon claims that even within the commonly accepted thermal comfort zone, i.e. in which 80% of those present are satisfied with the ambient temperature, we risk reduced performance of between 5 and 15% in the average person's efficiency in reading, logical thinking and arithmetical tasks /6/. Thus, no great insight or expertise is needed to see that an office workplace can lose vast sums through reduced performance and productivity resulting from an unsatisfactory thermal indoor climate, mostly because wages figure so prominently in yearly costs."*

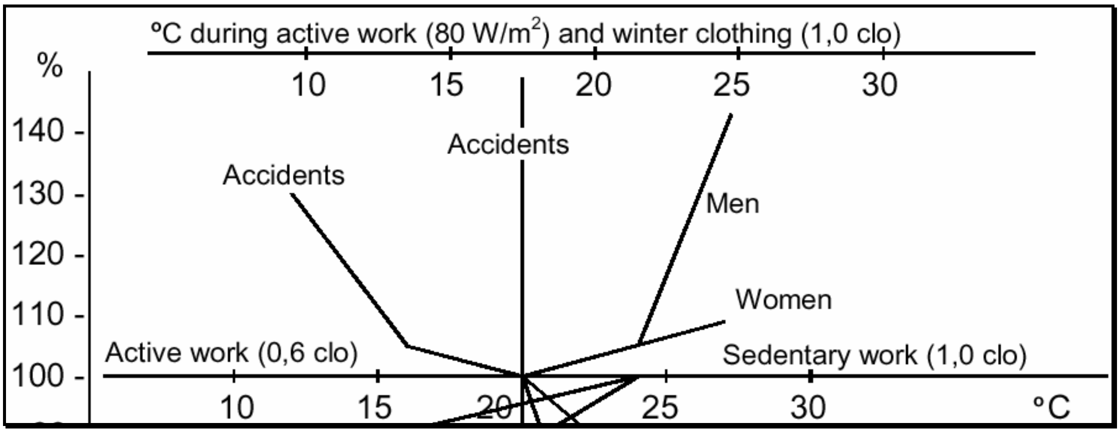

Figure 5: Likely increase in accidents due to temperature

Figure 5 shows the effect that a poor thermal comfort can have on accidents for workers undertaking slightly active work. Whilst this research used temperatures, the results would very fairly be translated into thermal comfort. The outcome of this research is that a work environment with poor thermal comfort will contain a greater risk of accidents for its occupants.

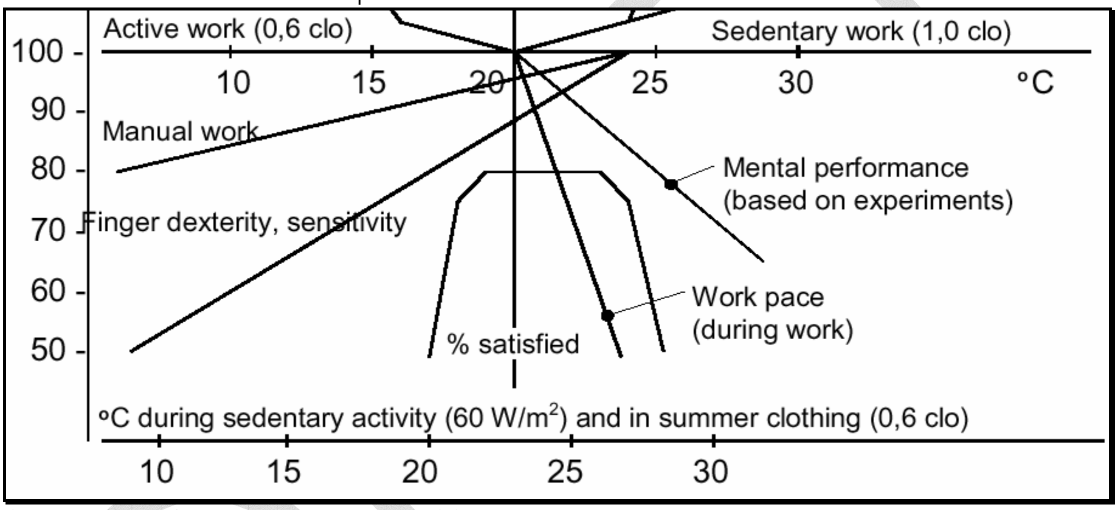

Figure 6: Effect of temperature on productivity

Figure 6 is from the same study, and shows how the effectiveness and productivity of office workers is affected by temperature and hence thermal comfort. Based on these outputs, mental performance and work pace (the basis on which these were calculated is described below) are significantly reduced when the temperature rises (and hence thermal comfort is reduced). It should be noted that similar reductions in productivity could also be anticipated from reductions in thermal comfort.

3.4.3 Summary

Based on the above research, it would appear that the evidence linking productivity improvements with good thermal comfort is quite weak, making it difficult to conservatively draw a reasonable conclusion or to justify the expense of improved thermal comfort on the basis of improved productivity. As a result, a conservative estimate for productivity gains associated with thermal comfort would be 0%. An optimistic assessment could associate a 1% gain in productivity as a result of the improved thermal comfort of the CH2 design.

3.5 Summary of Productivity Improvements

The conservative and optimistic productivity gains projected from the CH2 design when compared with a VAV system in a new building. Conservative gains represent benefits that should be expected from the new design, whilst optimistic gains represent gains which could feasibly be achieved based on all the research assessed.

Area for potential savings	**Conservative % improvement caused by new system**	**Optimistic % improvement caused by new system**
Sick leave due to Illness caused by poor indoor office environment	90%	95%
Sick leave due to Illness caused by poor home environment	0%	0%
Sick leave due to Injury at work	5%	10%
Sick leave due to Injury outside work	0%	0%
Sick leave due to stress at work	10%	15%
Sick leave due to stress at home	5%	10%
Staff turnover due to poor indoor environment at office (5% of total staff turnover)	10%	40%
Productivity improvements whilst at work	1%	4.9%

In reality, it is likely that the overall savings associated with the new CH2 design will fall somewhere between these two benchmarks.

4 COST BENEFIT ANALYSIS

In analysing the cost-benefits of the proposed CH2 as compared with standard office design practice, two scenarios are considered. The first examines the likely Net Present Value (NPV) using conservative productivity benefits and savings, whilst the second calculates the NPV using optimistic values for productivity gains.

It is anticipated the actual saving to MCC will fall between these two values, however given that research on the topic is still limited to mostly simulated experiments, it is feasible to conceive even better productivity benefits being attained in the long term.

4.1 Capital Cost Comparison

At the writing of this report, the capital cost estimates for the two services options, typical VAV and the CH2 system (including tenancy costs), were as follows:

Typical VAV at MCC	$3,743,695
CH2 design with chilled ceilings, displacement, 100% fresh air	$6,618,435

Note that the CH2 design at present is budgeted to cost almost twice as much as a typical VAV system.

4.2 Energy Cost Comparison

The CH2 design is predicted to have significantly lower energy requirements. The table below summarises the predicted energy consumption of the two options at this stage. Note that it is assumed the cost of gas will be $0.0141 per MJ and the cost of electricity will be $0.1396 per kWh.

Energy requirement	Typical VAV	CH2 HVAC design
Gas (MJ)	113,868	211.978
Electricity (kWh)	150,821	62,533

This shows that the annual energy consumption from the CH2 system will be around half that for the VAV system. The difference in maintenance costs between the two systems is assumed to be negligible.

4.3 Other Assumptions

The Discount Rate was assumed to be 7%. This is the rate of return that could be realistically achieved over the time period from money saved in capital costs in the present. Interest rates are currently quite low, and this may therefore be seen as a conservative figure (favouring the lower up-front cost option). However over a long period of time, this is considered to be a feasible average estimate. Note that the lower this value is assumed to be, the more favourable an option with a high capital cost becomes.

The Inflation Rate has been assumed to be 3%. This is the rate at which the cost of electricity, gas and wages will increase on average per year over the estimated time frame. A number of indicators suggest that this rate could be higher particularly for electricity and gas costs, however the more conservative estimate of 3% as been assumed for this analysis. Note that this higher the inflation rate, the more an option with a high capital cost but lower ongoing costs is favoured.

4.4 Conservative Cost-Benefit Analysis

The table below summarises the conservatively predicted annual productivity and sick leave differences between the CH2 design and a newly built office building with a VAV system.

Possible area of saving for MCC	Annual cost attributed to factor	Estimated % saving from improved indoor environment at CH2	Predicted annual saving
Illness caused by office environment	$153,142	90%	$137,827
Illness caused by home environment	$61,256	0%	$0
Injury caused by office environment	$30,628	5%	$1,531
Injury caused by non-office environment	$61,256	0%	$0
Stress related to work	$122,513	10%	$12,251
Non-work related stress	$122,513	5%	$6,175
Reduced staff turnover due to dissatisfaction with indoor environment (5% total turnover)	$66,055	10%	$6,606
Improved productivity (per 1% gain)	$186,950	1%	$186,950
Total Annual Saving			$351,340

As these values are very conservative estimates, they should be regarded as the minimum annual saving that will be obtained from improving the indoor environment at CH2.

The tables below provide cost benefit analyses over 5- year, 10-year and 20-year periods. Note that the CH2 design is expected to pay itself off after approximately 10 years. After 20 years, the overall present value cost benefit of the CH2 design is over $2 million.

These results are encouraging and show that even with conservative estimates on productivity gains, the CH2 design will comfortably pay itself off within the life of the MCC tenancy and probably provide substantial savings in reduced sick leave, staff turnover and improved productivity if the tenancy lasts longer than 10 years.

LIFE CYCLE COST ANALYSIS - CONSERVATIVE ESTIMATE WITH 5 YEAR TIMEFRAME

Project Name :	**Melbourne City Council**	Prep. by : ADC	Date : 15/08/2003
Project No :	AESY8200.00	Chkd by : MMC	Date : 15/08/2003
Building name:	**CH2**		

		Alternative No.1		Alternative No.2	
Discount Rate (%)	**7.00 %**	**Alternative No.1**		**Alternative No.2**	
Economic Life (Yrs)	**5 Years**	**Description**		**Description**	
		VAV		**CH2 Design**	
		Estimated Costs	Present Worth	Estimated Costs	Present Worth
CAPITAL COST					
A. Total Services Cost			$3,743,695		$6,618,435
TOTAL INITIAL COST			**$3,743,695**		**$6,618,435**
ANNUAL OPERATING COSTS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	4.47				
B. Gas (MJ=$0.0141)		$1,606	$7,171	$2,989	$13,350
C. Electricity (kWh=0.1396)		$21,055	$94,039	$8,730	$38,990
TOTAL ANNUAL OPERATING COSTS			**$101,210**		**$52,340**
PRODUCTIVITY SAVINGS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	4.47				
D. Total from reduced sick leave		$0	$0	-$157,784	-$704,731
E. Total from reduced turnover		$0	$0	-$6,606	-$29,505
F. Total from improved productivity		$0	$0	-$186,950	-$834,999
TOTAL ANNUAL OPERATING COSTS			**$0**		**-$1,569,236**
TOTAL OWNING PRESENT WORTH COSTS			**$3,844,905**		**$5,101,539**
% DIFFERENCE IN TOTAL COST (OVER 10 YRS)			**0%**		**33%**

Figure 7: Conservative cost benefit analysis over 5 years

LIFE CYCLE COST ANALYSIS - CONSERVATIVE ESTIMATE WITH 10 YEAR TIMEFRAME

Project Name :	**Melbourne City Council**	Prep. by : ADC	Date : 15/08/2003
Project No :	AESY8200.00	Chkd by : MMC	Date : 15/08/2003
Building name:	**CH2**		

		Alternative No.1		Alternative No.2	
Discount Rate (%)	**7.00 %**	**Alternative No.1**		**Alternative No.2**	
Economic Life (Yrs)	**10 Years**	**Description**		**Description**	
		VAV		**CH2 Design**	
		Estimated Costs	Present Worth	Estimated Costs	Present Worth
CAPITAL COST					
A. Total Services Cost			$3,743,695		$6,618,435
TOTAL INITIAL COST			**$3,743,695**		**$6,618,435**
ANNUAL OPERATING COSTS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	8.16				
B. Gas (MJ=$0.0141)		$1,606	$13,098	$2,989	$24,384
C. Electricity (kWh=0.1396)		$21,055	$171,767	$8,730	$71,217
TOTAL ANNUAL OPERATING COSTS			**$184,865**		**$95,601**
PRODUCTIVITY SAVINGS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	8.16				
D. Total from reduced sick leave		$0	$0	-$157,784	-$1,287,224
E. Total from reduced turnover		$0	$0	-$6,606	-$53,893
F. Total from improved productivity		$0	$0	-$186,950	-$1,525,165
TOTAL ANNUAL OPERATING COSTS			**$0**		**-$2,866,282**
TOTAL OWNING PRESENT WORTH COSTS			**$3,928,560**		**$3,847,754**
% DIFFERENCE IN TOTAL COST (OVER 10 YRS)			**0%**		**-2%**

Figure 8: Conservative cost benefit analysis over 10 years

LIFE CYCLE COST ANALYSIS - CONSERVATIVE ESTIMATE WITH 20 YEAR TIMEFRAME					
Project Name : **Melbourne City Council**		Prep. by : ADC		Date : 15/08/2003	
Project No : AESY8200.00		Chkd by : MMC		Date : 15/08/2003	
Building name: **CH2**					
Discount Rate (%)	**7.00 %**	**Alternative No.1**		**Alternative No.2**	
Economic Life (Yrs)	**20 Years**	**Description**		**Description**	
		VAV		**CH2 Design**	
		Estimated Costs	Present Worth	Estimated Costs	Present Worth
CAPITAL COST					
A. Total Services Cost			$3,743,695		$6,618,435
TOTAL INITIAL COST			**$3,743,695**		**$6,618,435**
ANNUAL OPERATING COSTS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	13.73				
B. Gas (MJ=$0.0141)		$1,606	$22,047	$2,989	$41,042
C. Electricity (kWh=0.1396)		$21,055	$289,114	$8,730	$119,872
TOTAL ANNUAL OPERATING COSTS			**$311,160**		**$160,914**
PRODUCTIVITY SAVINGS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	13.73				
D. Total from reduced sick leave		$0	$0	-$157,784	-$2,166,629
E. Total from reduced turnover		$0	$0	-$6,606	-$90,711
F. Total from improved productivity		$0	$0	-$186,950	-$2,567,125
TOTAL ANNUAL OPERATING COSTS			**$0**		**-$4,824,465**
TOTAL OWNING PRESENT WORTH COSTS			**$4,054,855**		**$1,954,884**
% DIFFERENCE IN TOTAL COST (OVER 10 YRS)			**0%**		**-52%**

Figure 9: Conservative cost benefit analysis over 20 years

4.5 Optimistic Analysis

The table below summarises the predicted annual cost savings which could possibly be achieved as a result of the proposed CH2 design when compared with a typical new VAV office building.

Possible area of saving for MCC	**Annual cost attributed to factor**	**Estimated % saving from improved indoor environment at CH2**	**Predicted annual saving**
Illness caused by office environment	$153,142	95%	$145,485
Illness caused by home environment	$61,256	0%	$0
Injury caused by office environment	$30,628	10%	$3,063
Injury caused by non-office environment	$61,256	0%	
Stress related to work	$122,513	15%	$18,377
Non-work related stress	$122,513	10%	$12.251
Reduced staff turnover due to dissatisfaction with indoor environment (5% of total turnover)	$66,055	40%	$26,422
Improved productivity (gain for each 1% improvement)	$186,950	4.9%	$916,055
Total Annual Saving			$1,121,653

It should be noted that these values are at the optimistic end of the scale for the above items. It is assumed that productivity benefits from improved air quality, delivery and thermal comfort are cumulative and as high as is documented in existing research papers. It should be noted that these productivity savings are a "best case" estimate, and that in reality, other factors will cause productivity gains to be lessened.

The tables below provide cost benefit analyses over 5-year, 10-year and 20-year periods. Using optimistic productivity savings, the CH2 design will repay the difference between it and a typical design after approximately 5 years, and after approximately 7 years, the productivity savings will have repaid the entire cost of the services design. After 20 years, the total present value cost benefit of the CH2 design is a surplus of over $8 million (achieved in productivity savings) compared with a net present cost of $4 million for the VAV option.

These results show how much a reasonable productivity gain could be worth to MCC. Whilst a productivity improvement of 4.9% is hopeful, it is certainly not unfeasible. The enormous savings that are therefore feasible indicate the value in choosing a system which has the capacity to improve the indoor environment and therefore working conditions.

LIFE CYCLE COST ANALYSIS - OPTIMISTIC ESTIMATE WITH 5 YEAR TIMEFRAME					
Project Name : **Melbourne City Council**		Prep. by : ADC		Date : 15/08/2003	
Project No : AESY8200.00		Chkd by : MMC		Date : 15/08/2003	
Building name: **CH2**					
Discount Rate (%)	**7.00 %**	**Alternative No.1**		**Alternative No.2**	
Economic Life (Yrs)	**5 Years**	**Description**		**Description**	
		VAV		**CH2 Design**	
		Estimated Costs	Present Worth	Estimated Costs	Present Worth
CAPITAL COST					
A. Total Services Cost			$3,743,695		$6,618,435
TOTAL INITIAL COST			**$3,743,695**		**$6,618,435**
ANNUAL OPERATING COSTS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	4.47				
B. Gas (MJ=$0.0141)		$1,606	$7,171	$2,989	$13,350
C. Electricity (kWh=0.1396)		$21,055	$94,039	$8,730	$38,990
TOTAL ANNUAL OPERATING COSTS			**$101,210**		**$52,340**
PRODUCTIVITY SAVINGS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	4.47				
D. Total from reduced sick leave		$0	$0	-$179,176	-$800,277
E. Total from reduced turnover		$0	$0	-$26,422	-$118,012
F. Total from improved productivity		$0	$0	-$916,055	-$4,091,496
TOTAL ANNUAL OPERATING COSTS			**$0**		**-$5,009,785**
TOTAL OWNING PRESENT WORTH COSTS			**$3,844,905**		**$1,660,990**
% DIFFERENCE IN TOTAL COST (OVER 10 YRS)			**0%**		**-57%**

Figure 10: Optimistic cost benefit analysis over 5 years

LIFE CYCLE COST ANALYSIS - OPTIMISTIC ESTIMATE WITH 10 YEAR TIMEFRAME					
Project Name : **Melbourne City Council**		Prep. by : ADC		Date : 15/08/2003	
Project No : AESY8200.00		Chkd by : MMC		Date : 15/08/2003	
Building name: **CH2**					
Discount Rate (%)	**7.00 %**	**Alternative No.1**		**Alternative No.2**	
Economic Life (Yrs)	**10 Years**	**Description**		**Description**	
		VAV		**CH2 Design**	
		Estimated Costs	Present Worth	Estimated Costs	Present Worth
CAPITAL COST					
A. Total Services Cost			$3,743,695		$6,618,435
TOTAL INITIAL COST			**$3,743,695**		**$6,618,435**
ANNUAL OPERATING COSTS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	8.16				
B. Gas (MJ=$0.0141)		$1,606	$13,098	$2,989	$24,384
C. Electricity (kWh=0.1396)		$21,055	$171,767	$8,730	$71,217
TOTAL ANNUAL OPERATING COSTS			**$184,865**		**$95,601**
PRODUCTIVITY SAVINGS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	8.16				
D. Total from reduced sick leave		$0	$0	-$179,176	-$1,461,743
E. Total from reduced turnover		$0	$0	-$26,422	-$215,554
F. Total from improved productivity		$0	$0	-$916,055	-$7,473,307
TOTAL ANNUAL OPERATING COSTS			**$0**		**-$9,150,605**
TOTAL OWNING PRESENT WORTH COSTS			**$3,928,560**		**-$2,436,569**
% DIFFERENCE IN TOTAL COST (OVER 10 YRS)			**0%**		**-162%**

Figure 11: Optimistic cost benefit analysis over 10 years

LIFE CYCLE COST ANALYSIS - OPTIMISTIC ESTIMATE WITH 20 YEAR TIMEFRAME					
Project Name : **Melbourne City Council**		Prep. by : ADC		Date : 15/08/2003	
Project No : AESY8200.00		Chkd by : MMC		Date : 15/08/2003	
Building name: **CH2**					
Discount Rate (%)	**7.00 %**	**Alternative No.1**		**Alternative No.2**	
Economic Life (Yrs)	**20 Years**	**Description**		**Description**	
		VAV		**CH2 Design**	
		Estimated Costs	Present Worth	Estimated Costs	Present Worth
CAPITAL COST					
A. Total Services Cost			$3,743,695		$6,618,435
TOTAL INITIAL COST			**$3,743,695**		**$6,618,435**
ANNUAL OPERATING COSTS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	13.73				
B. Gas (MJ=$0.0141)		$1,606	$22,047	$2,989	$41,042
C. Electricity (kWh=0.1396)		$21,055	$289,114	$8,730	$119,872
TOTAL ANNUAL OPERATING COSTS			**$311,160**		**$160,914**
PRODUCTIVITY SAVINGS					
Diffl.Escal.Rate (%)	3.00 %				
PWA with Escal Factor	13.73				
D. Total from reduced sick leave		$0	$0	-$179,176	-$2,460,376
E. Total from reduced turnover		$0	$0	-$26,422	-$362,817
F. Total from improved productivity		$0	$0	-$916,055	-$12,578,913
TOTAL ANNUAL OPERATING COSTS			**$0**		**-$15,402,105**
TOTAL OWNING PRESENT WORTH COSTS			**$4,054,855**		**-$8,622,756**
% DIFFERENCE IN TOTAL COST (OVER 10 YRS)			**0%**		**-313%**

Figure 12: Optimistic cost benefit analysis over 20 years

5 CONCLUSION

The scope of this report was to investigate the causes and the costs of sick leave, the potential benefits associated with the proposed Melbourne City Council CH2 design, and quantify those benefits in terms of net present value. It compares the proposed CH2 design with the sort of system which would be provided in a new A-grade office development.

The report draws from a wide range of sources to inform the final result. It uses internal human resources from Melbourne City Council to estimate the annual costs of sick leave and staff turnover. It draws from public and private sector reporting to understand the reasons for sick leave and staff turnover and finally, it draws from a wide range of papers and studies which investigate the correlation between the indoor environment and the prevalence of contagious illness, sick leave and productivity.

In the final analysis, two sets of figures have been used to estimate the annual savings from the CH2 design. One set is more conservative than any of the findings in any of the studies; the other is an optimistic appraisal drawing estimates for productivity gains directly from current research. The overall predicted reduction in sick leave is conservatively estimated at 26% and optimistically estimated at %. The overall predicted reduction in staff turnover is estimated between 0.5% (conservative) and 2% (optimistic).

The overall productivity gain is estimated to be between 1% (conservative) and 4.9% (optimistic). The optimistic value generates enormous savings when compared with the capital costs of the two systems and the annual electricity costs. However this should still be considered a feasible result, based on existing research on the issue.

Even considering conservative savings in staff conditions, sick leave, turnover and productivity, Melbourne City Council would save no less than $350,000 per annum. This is enormous when compared with the annual energy saving from the new design (a 38% reduction predicted at $9,478 per year).

Based on these annual savings, and the additional capital cost of the alternative system (estimated at this stage at a premium of $2,874,740), the proposed CH2 system is expected to recover the additional capital costs in less than 10 years, and could feasibly do so in less than 5 years. An analysis of the net present worth of both systems after 20 years shows the proposed design saving at least $2,000,000 in current dollar terms when compared with a standard air conditioning system.

Given this data, the generous weight of research indicating the possible productivity gains and the results from the conservative interpretation of that research with regard to productivity gains and sick leave savings, it is very easy to vindicate a decision to opt for the proposed design in spite of its significantly higher capital cost. Given the anticipated long term tenancy of MCC in CH2 and the potential for much greater productivity increases as a result of the proposed system, MCC could quite feasibly reimburse the entire cost of the system over the period of its tenancy.

Many claims are often made regarding productivity benefits in the workplace. This report shows that these productivity gains are realistic, and even when small, have the potential to provide large savings. To this end, and given a medium to long-term outlook, Melbourne City Council should be supported by all involved in its adoption of this design strategy.

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