

# Sustainability and office buildings – a detailed examination of CO<sub>2</sub> emissions

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## Abstract

This paper presents findings from a detailed examination of office buildings and their individual levels of energy consumption and CO<sub>2</sub> emissions based on five year time frames (2005, 2010, 2015 and 2020). The research profiles the energy efficiency of the office stock located in the central business district (CBD) or downtown precinct of Melbourne. It focuses on quantifying carbon dioxide reductions resulting from measures that can be made during in the 'in-use' or 'operational' phase of office buildings. Clearly there are a wide range of property professionals who already are, but many more who readily could be, involved in such work including developers, appraisers, building surveyors, facility managers, quantity surveyors and construction surveyors. In developed countries buildings offer considerable scope for meeting emission reduction targets through increased energy efficiency (BRE, 1996). Surprisingly 12% of all greenhouse gas emissions in Victoria, Australia are derived from commercial buildings (DSE, 2005). The research conducted a detailed analysis of all office buildings in the Melbourne downtown and examined variables such as size, number of employees, occupancy levels, visual appearance, and the age of each building, which in turn were used to calculate levels of energy consumption and carbon emissions. There were five (5) key findings produced with accompanying recommendations.

1. Emissions from office buildings will increase in the future if no action is taken.
2. The level of emissions is linked to the amount of office space per worker.
3. Higher energy use and CO<sub>2</sub> emissions are positively associated with smaller buildings but negatively associated with medium sized buildings.
4. As office buildings increase in age, energy use and CO<sub>2</sub> emissions increase dramatically.
5. Increased occupancy levels are linked to lower energy use and lower CO<sub>2</sub> emissions.

After analysing four (4) alternative scenarios based on (a) no change, (b) minor change, (c) intermediate change or (d) major change, it was recommended that the (c) intermediate change scenario should be adopted - this course of action incorporated a transition period and included increasing 'green power', increasing the number of employees per buildings as well as reducing electricity and gas consumption. It was concluded that the real estate industry and wider property market should adopt a proactive stance towards office buildings and climate change, which at times is stifled by lack of education and perception concerning the long term benefits of energy efficient office buildings. Fully *embracing and taking action* based on the findings of this paper will ensure that stakeholders and property professionals are genuine in their efforts to address this global dilemma as opposed to simply agreeing that a problem exists but it remains too difficult to address. To-date there has been much debate and promotion of policies to encourage the uptake of sustainability practices within the property sector, however immediate action is needed if targets are to be met. Note: acknowledgement is given to the RICS for research assistance.

## INTRODUCTION

The importance of climate change and the effect on the environment has continued to receive increased attention in wider society. While substantial focus is consistently placed on technological changes, such as the mandatory use of energy saving light bulbs, consideration must be given to other facets of the sustainable use of resources. To effectively conserve resources for each land use, attention must also be placed on ‘how’ the resources such as high rise office buildings are used on a ‘per person’ basis. To-date the vast majority of research into the relationship between office buildings and sustainability has either (a) examined individual office buildings in detail or (b) analysed multiple office buildings in downtown precincts in less detail (Reed & Wilkinson, 2005). This study differs considerably in that it conducted a large scale detailed investigation based on profiling the energy efficiency of *all office buildings* located in the Melbourne downtown precinct. This was undertaken by examining a wide cross-section of variables such as building size, number of employees per building, occupancy levels, visual appearance, and the age of each building – in turn each variable was used to calculate carbon emissions. The findings of this study have implications for all office building stakeholders, especially with reference to facility managers. With growing demand for research into office buildings and energy efficiency, facility managers are placed under increasing pressure to be fully conversant with buildings and levels of energy efficiency; this paper highlights the importance and relevance of this issue. The project was funded by the RICS Education Trust with the full report available at [www.rics.org](http://www.rics.org) (Wilkinson & Reed, 2006a).

As a starting point, the downtown precinct itself is of relevance because most major westernised cities have a central business district, often with an aging stock of high rise buildings (Jones Lang LaSalle, 2005). Furthermore there are other implications from central business districts due to the higher density of office buildings, with many having contributed to the provision of a poorer environmental quality for city workers and city dwellers. As cities expand, improving the quality of the downtown stock is important for all stakeholders, investors, occupiers, policy makers and society at large (Wilkinson and Reed, 2006b).

The relationship between office buildings and financial considerations can not be ignored when an analysis of energy efficiency is conducted – practically all office buildings are operated with the goal of reducing operating costs if possible (accompanied by increased income for private sector buildings), although there clearly is a longer term trade-off with the overall capital value. For example an office building that is extremely energy efficient office building may require additional maintenance over time,

which would convert into higher risk and an overall lower capital value (Reed & Wilkinson, 2006). It must also be noted that real estate is considered a growth asset with two primary forms of income (Australian Property Institute, 2007). Firstly, capital growth is anticipated due to the interaction of supply and demand factors where land supply is limited and the structure itself is a hedge against inflation. Secondly, property owners receive a regular dividend in the form of rent from tenants who lease space. Nevertheless all forms of property are affected, and at times adversely, by varying degrees of obsolescence which in turn cause depreciation or a decrease in value to occur (Reed and Robinson, 2002). Depreciation and obsolescence are unavoidable and can have an adverse effect in determining the assessing the levels of risk associated with a building, which decreases the overall capital value of a building. However, if the rate of depreciation and obsolescence can be slowed due to less risk then the inevitable decrease in the overall capital value can be reduced. It is important to acknowledge that improvements in energy efficiency can seemingly achieve this goal as well as embracing sustainable practices, which in turn assist to address climate change.

### **Scope and Limitations**

Studies into energy efficiency often examine factors that relate to the consumption and emissions of CO<sub>2</sub>, however there are other aspects of energy efficiency that would be evaluated if additional resources were available. Two of these additional aspects are embodied and transport energy, which both require more attention than was possible to allocate in this study. Although preliminary investigations into these areas were undertaken during this research, this paper does not include direct reference to these areas. Note these areas will be incorporated into further research in this area and currently are restricted by data availability. This research evaluated the impact of green power in the reduction of CO<sub>2</sub> emissions, although the scope of this research did not consider micro-generation of energy though it is acknowledged as an emerging and important element of energy efficiency. Further research is recommended to identify the potential savings that can be made to the existing office stock.

### **METHODOLOGY AND DATA COLLECTION PROCESS**

This research adopted a unique approach with 100% sampling undertaken of all office buildings. To undertake this approach an expansive database was compiled based on visually inspecting every office building, analysing relevant characteristics for each building including age, net lettable area and gross floor area, examining the physical location of each building, and finally, calculating the usage of

electricity and gas for each building. A further dimension was to project the data via a longitudinal analysis over 5, 10 and 15 year timeframes. The advantage of this approach is the ability to examine change over time, which in turn presents alternative approaches to increasing office building efficiency resulting in varying levels of reduced CO<sub>2</sub> emissions. Importantly, the data employed in this research is based on reliable sources of information based on individual buildings without sampling only a portion of the office stock. Consequently the results are reliable and detailed, being designed to provide an invaluable insight into office buildings and climate change over time. The relationship between the sources of information and the stakeholders is illustrated in figure 1.

### **Sources of detailed building characteristics**

The main data file used was partly compiled with reference to existing databases. There were two primary databases referred to, although there were issues to resolve regarding access to the databases as well as extensive ‘cleaning up’ of data for this project. The two databases used were the City of Melbourne’s ‘Census of Land Use and Employment’ (CLUE) and ‘Cityscope’. The databases assisted profiling the office stock in Melbourne downtown precinct but did not include data about energy consumption or energy efficiency. CLUE is an information system about land use, employment and economic activity across Melbourne ([www.melbourne.vic.gov.au/clue](http://www.melbourne.vic.gov.au/clue)). Note: the information in this database was aggregated to a building level and not information was available that would permit identification of individual buildings. Cityscope information was used to compile part of the main data file of office buildings. It is a commercially available database and claims to be the ‘most detailed, accurate and extensive downtown property information service available’ in Australia (Cityscope, 2005). The type of office building data held on the database include parameters such as street frontage, zoning information and site area, detail of development applications, building progress and completion, title and property details such as building services. Over 3000 Melbourne downtown properties are included on the database which is updated annually. Cityscope was used with CLUE to provide data for the modelling and forecasting of baseline carbon emissions and energy efficiency for the downtown precinct. This research was supported by the 2005 version of Cityscope. Another key data source was a questionnaire survey to establish information regarding energy consumption and use within the buildings, as well as existing data about office buildings. The data collection process was assisted by a detailed survey of building owners. The survey provided supplementary information to support the data not available from other sources such as the CLUE and Cityscope databases.

## **Carbon emissions**

After data was collected and the extensive database of all office buildings and their relevant characteristics was constructed, the research team used a greenhouse rating diagnostic tool to convert energy consumption into carbon emissions. All data used in this process was obtained from reliable sources and verified. This process was undertaken using information and data from the following ABARE, Australian Energy paper 05.9, Australian Building Greenhouse Rating ([www.abgr.com.au](http://www.abgr.com.au)), AGO 2004, *Stationary Sector GHG Emission Projections*, Vicpool Information Bulletin 3, 43, Department of Infrastructure. 2005. Energy retail tariffs for 2005, ESAA, *Electricity Gas Australia 2005*, OECD IEA 2005, *Electricity Information* (2003 data); and TXU - schedule of distribution use of system tariffs. With regards to green power, the following rates were adopted for the baseline data calculations: *Premium* and *A Grade* - 5%, *B Grade* - 2%, *C Grade* - 1%, and *D Grade* - 0%. The buildings in the returned surveys had higher levels of green power however the researchers felt that the sample was biased to buildings where more green power was used and references to other sources confirmed this view and indicated uptake across the stock was lower. All buildings on the main data file were processed to calculate carbon emissions.

## **Research process and data validation**

The research population for the profiling of stock comprised all Melbourne downtown offices. To ensure the validity of the database a direct survey was also conducted, where the research population for the questionnaire survey comprised a sample of owners of office property and Property Council of Australia members in Melbourne. It was envisaged that the owners would pass the survey to their facility managers, who in turn would return the completed questionnaire. In total 26 questionnaires were distributed to owners of Melbourne downtown office buildings in October and November 2005 by the Property Council of Australia in Sydney - 14 returns were received, a responses rate of approximately 50%. The databases were 'cleaned' by the researchers and all non office property that included less than 50% of a core office component was removed. This survey assisted to ensure the information relating to office buildings that was assembled in the database was accurate and reliable. The following steps were then undertaken:

**Stage 1** – Assemble a preliminary dataset of all Melbourne downtown buildings including non-conforming property (e.g. carparks and residential).

- Stage 2** – Add other information including details from the CLUE database concerning physical building characteristics and physical characteristics (note: this information was examined in an aggregate format and individual floors or tenancies could not be isolated).
- Stage 3** – With the assistance of GIS mapping and Cityscope, as well as individual inspections where necessary, each building was examined and the database was reduced from 1,354 properties to 328 office buildings with an office component of at least 50%.
- Stage 4** – Additional information relating to individual buildings was added to the database and resulted in comprehensive and detailed information set.
- Stage 5** – The results from the validation survey were input into the database and checked against the existing information.
- Stage 6** – Obtain rating for carbon dioxide emissions for all 328 downtown office building in the database. The AGR online diagnostic tool was used ([www.agbr.com.au](http://www.agbr.com.au)). The researchers entered data based on rated area, occupancy hours, number of employees, electricity and gas consumption per annum (kWh and MJ) and amounts of green power used. For each building the rates used for energy consumption were sourced from the PCA Benchmarks Survey of Operating Costs 2005 for Melbourne (PCA, 2005) on a pro-rata basis using current energy tariffs for Victoria.
- Stage 7** – An analysis of energy consumption and emissions for all 328 office buildings for all scenarios was conducted for 3 additional time periods, namely 2010, 2015 and 2020. The results formed the basis for profiling the office stock in 5, 10 and 15 years. During all stages the data was rechecked to ensure reliability and accuracy of data inputting.

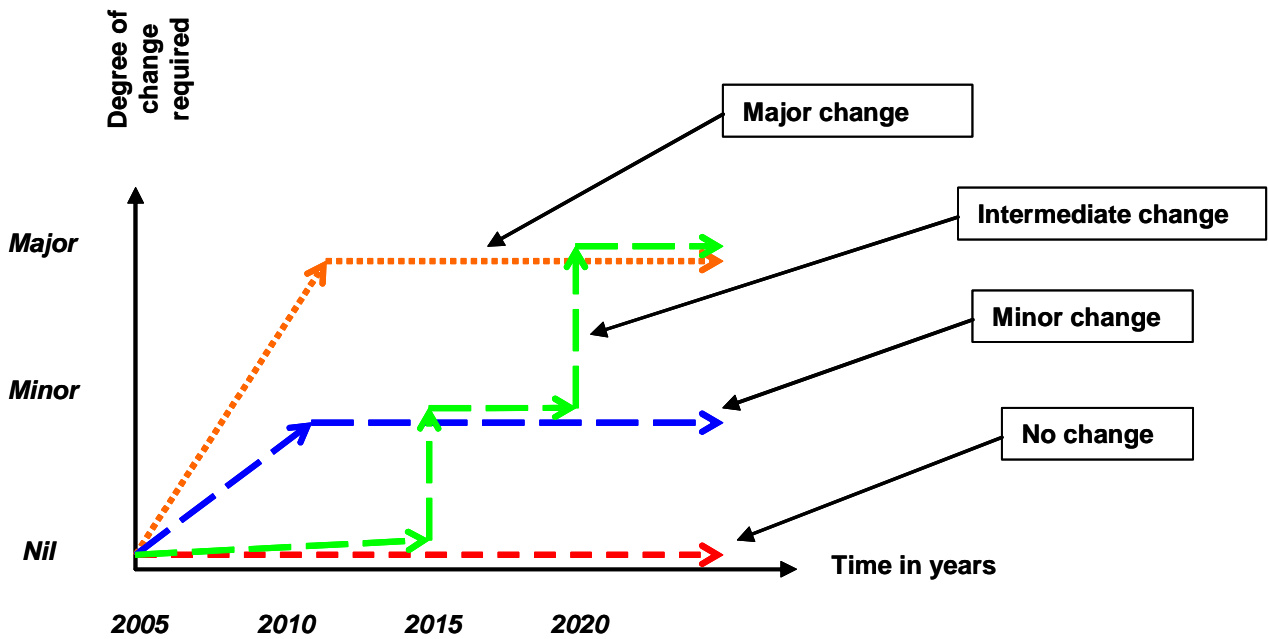
### **Forecasting and modelling the research scenarios**

This research adopted four scenarios; no change, minor change, intermediate change and major change – refer to the variables that were altered in three of the scenarios as listed in table 1. The intermediate scenario was designed as a hybrid between the minor and major scenarios, adopting a more realistic approach to the introduction of change into the office market. The intermediate approach commences with no change, then minor followed by major change. The three scenario time frames were 2010, 2015 and 2020 as highlighted in figure 1.

**Table 1. Variables altered in no change, minor and major scenarios**

Variable	Scenario 1 - no change	Scenario 2 - minor change	Scenario 3 - major change
Number of employees	-	Increase by 10%	Increase by 25%
Green power use by Grade (premium, A, B, C and D)	5%,2%, 1%, 0%	10%,5%, 2%, 1%	50%,25%, 10%, 5%
Electricity consumption (kWh)	No reduction	Less 10%	Less 25%
Gas (MJ)	No reduction	Less 10%	Less 25%

**Figure 1. Varying change over time for each scenario**



## KEY FINDINGS AND RECOMMENDATIONS

This paper has undertaken a detailed analysis of all office buildings in a global downtown precinct, namely Melbourne. It analysed the existing stock of office buildings as at 2005, as well over 5, 10 and 15 year time frames. There have been a number of key findings identified from the analysis in the preceding chapter that are listed below with accompanying recommendations. Consideration is given to three alternative scenarios based on the changes listed in table 5.

### **Key finding 1**

*Emissions from office buildings will increase in the future if no action is taken.*

There is clear evidence to indicate that, if remaining unchanged, emissions in the downtown office market will rise on both an 'aggregate' and 'per person' basis. These increases are due to the factors such as the ageing of the office stock over time and the volume of new stock under construction that will soon after be released onto the market. This finding is in line with historical trend in the downtown office market and as expected.

### **Recommendation 1**

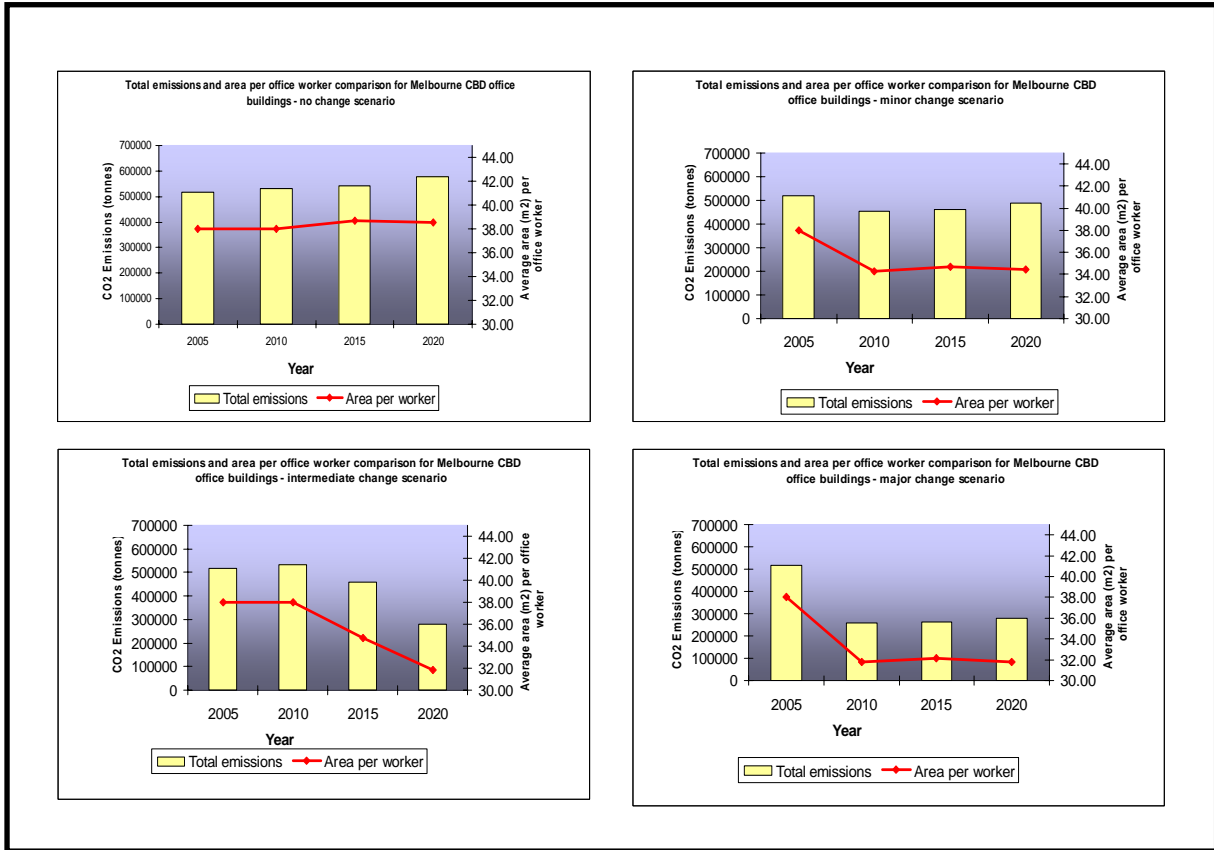
Steps need be taken to reduce the level of emissions from office buildings, and the best course of action would be to adopt the intermediate scenario. It is recommended that this process would commence with no change in the first five years (allowing a period of education in the industry), followed by a minor change in the next five years and then a major change over the ensuing five years. Following this course of action will result in a decrease in emissions using a gradual and viable approach.

### **Key finding 2**

*The level of emissions is closely linked to the amount of office space per worker.*

As emissions increase in 2005 and over the next 5, 10 and 15 years, there will also be a corresponding increase in the net lettable area per office worker. This relationship is also maintained for each of the four scenarios, with the correlation between emissions and area per office worker highlighted for each scenario in figure 2.

**Figure 2. Levels of emissions vs. amount of space per office worker for each scenario**



**Recommendation 2**

The density of office workers in each building should be increased on a ‘office worker per building’ basis. This can be achieved by undertaking one or more of the following steps.

- Ensuring that office buildings are fully let and vacancies are minimised at all times. .
- Decreasing the amount of office space that is leased although actually unused or empty.
- Increasing the ratio of office worker to floor space.
- Modifying the approach to using office space to increase efficiency.

**Key finding 3**

*Higher energy use on a ‘per person’ basis is associated with smaller buildings.*

Buildings with a gross lettable area under 5,000m<sup>2</sup> are the highest aggregate consumers of energy by gross floor area and on a ‘per person’ basis, as well as producing the highest level of emissions per

person. On the other hand, buildings with a gross floor area between 5,000 and 10,000m<sup>2</sup> use the least energy and have the lowest emission levels. Reasons for these results for each group are as follows:

- smaller buildings are usually associated with a high proportion of older stock that exhibit typically higher than average vacancy rates. This is partly due to the higher levels of obsolescence in this group, especially with regards to physical and functional use.
- in contrast to smaller buildings, increasing a building's floor area will raise the level of efficiency due to the enhanced economies of scale.

### Recommendation 3

The focus should be placed on encouraging the development of medium sized office buildings in global cities. In respect of energy consumption and efficiency, this group is the highest and best use of the land. This could be achieved by closely monitoring the supply of smaller and larger buildings and the effect on the aggregate amount of office space would be negligible.

### **Key finding 4**

#### ***Energy use and CO<sub>2</sub> emissions vary with the age of buildings.***

The age of a building is directly related to obsolescence levels, which in turn has an effect on energy efficiency and CO<sub>2</sub> emissions. Since new buildings incorporate the latest advances in technology and building design, as well as minimal physical and functional deterioration this results in lower aggregate emissions and aggregate energy consumption. The focus should be placed on a 'per person' basis, where there is a direct relationship between age and energy consumption.

### Recommendation 4

The focus should be placed on monitoring the proportion of older buildings in the downtown precinct. There appears to be a strong relationship between age and energy use, with newer buildings use the least energy and produce the least CO<sub>2</sub> emissions. Relevant bodies should consider using incentives (or disincentives not to redevelop) which would ensure the highest and best use of the downtown office stock is maintained at all times. When refurbishing stock a much greater emphasis should be placed on energy efficiency upgrades, especially when a building is at least 10 years old. However it should be noted that this research does not consider the embodied energy within buildings and it is possible that consideration of embodied energy would have some influence on this data.

## **Key finding 5**

***Increase the occupancy levels of downtown office buildings which is linked to lower energy use and lower CO<sub>2</sub> emissions.***

The number of employees in a building is positively correlated with energy use and energy efficiency, where buildings with more employees (but not necessarily floor area) have enhanced energy use and produce less CO<sub>2</sub> emissions. On the other hand, buildings containing fewer office workers have higher costs and emit more CO<sub>2</sub>. This relationship is adversely affected by buildings with 50 or less office workers and exhibit extremely poor use of resources. This finding does not conclude that buildings should contain more office workers on sliding scale, but rather that building contained a relatively small number of employees should be closely monitored.

### Recommendation 5

Careful monitoring of buildings with low occupancy (not vacancy) levels based on the number of office workers should be undertaken. Since energy consumption and CO<sub>2</sub> emissions are closely linked to this group, a scheme based on either incentives or disincentives (e.g. property rating or property taxation) to maintain low occupancy rates should be introduced as soon as possible.

## **CONCLUSION**

This paper has identified clear links between characteristics of office buildings located in a central business district *and* their respective consumption of energy plus levels of energy efficiency. To successfully accomplish undertake this task a comprehensive examination was undertaken of characteristics relating to all office buildings in the Melbourne downtown precinct including age, quality, floor area, energy use, number of employees and prevailing market conditions. Most importantly, a longitudinal analysis was used to profile the entire office stock during 2005 as well as 2010, 2015 and 2020. In order to understand the full implications of change, there were four (4) alternative scenarios introduced over this time period based on ‘no change’, ‘minor change’, ‘intermediate change’ or ‘major change’. This process produced results that were both reliable and accurate in respect of the energy consumption and CO<sub>2</sub> emissions for a global city.

The analysis produced five (5) key findings with accompanying recommendations for addressing the contribution of office buildings towards climate change. It should be noted that, in a similar manner to the broader real estate market, office markets are influenced by an extremely large number of factors

including prevailing market conditions, government policy, investor sentiment and overall market perception. Consideration should be given to these external influences when interpreting the key findings and recommendations, as well as observed variations between different global cities including characteristics such as age of stock and the highest and best use of limited downtown land. To comprehensively embrace change requires a whole of market commitment by all property players – anything less will result in a lack of understanding, disillusion and the type of fragmented approach that arguably exists today.

In the process of conducting this research there was evidence that hurdles still existed that would severely inhibit any attempts to fully embrace climate change. Part of the problem appears to be related to the nature of the real estate market and its highly competitive and complex nature. For example, the rate of response for the survey returns was unexpectedly slower than anticipated even though the respondents were fully conversant with the information required. The researchers argue this is indicative of the prevailing attitudes towards energy efficiency in a portion of the sector where serious concerns abound in the property market about the level of confidentiality with this information. To assist to overcome this barrier there is potential for facility managers to take an interest in energy efficiency, especially with regards to detailed record keeping and monitoring. Although this may be perceived as another ‘layer’ of unnecessary administration, there are substantial long-term dividends that will assist facility managers in their day-to-day work. Only after detailed records are made available can the operation of a building be closely monitored and adjusted to maximise energy efficiency. This may include the collection of unconventional data such as actual occupation levels and electronic light usage – only then will a truly accurate evaluation of the energy efficiency levels of a building be known.

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