Office building characteristics and the links with carbon emissions

Article *in* Structural Survey · May 2006

DOI: 10.1108/02630800610678887

2 authors:

Sara J. Wilkinson
University of Technology Sydney

Richard G. Reed
Reed Property Insights

Office building characteristics and the links with carbon emissions

Sara J. Wilkinson, *Faculty of Architecture, Building and Planning, University of Melbourne, Melbourne, Australia*

Richard G. Reed, *Faculty of Architecture, Building and Planning, University of Melbourne, Melbourne, Australia*

Abstract

Purpose – The purpose of this paper is to present research which analysed energy consumption in the Melbourne central business district (CBD) office stock and examined all buildings to identify CO_2 emissions in 2005. The rationale was that, by profiling a large group of buildings, it would be possible to identify characteristics of the stock. For example, do older buildings typically emit more CO_2 per square metre than newer buildings?

Design/methodology/approach – This research conducted a detailed analysis of all Melbourne CBD office stock to identify which patterns and trends emerged regarding building characteristics and carbon emissions. The study examined variables such as building size, number of employees, occupancy levels, physical characteristics and building age.

Findings – By examining all office stock and aggregating data, the results confirm that it is possible to identify general physical building characteristics and carbon emissions. This research confirmed that clear relationships existed within the Melbourne CBD office stock in terms of building size, age and the density of occupation in relation to CO_2 emissions.

Originality/value – Practitioners can apply this knowledge to the professional advice they give to clients to assist in achieving increased energy efficiency in the office stock, for example in refurbishment being conscious that smaller buildings will be generally less energy-efficient than larger ones.

Introduction

This research analysed energy consumption in the Melbourne central business district (CBD) office stock and examined all buildings to identify CO_2 emissions in 2005. The rationale was that by profiling a large group of buildings, it would be possible to identify characteristics of the stock. For example, do older buildings typically emit more CO_2 per square metre than newer buildings?

There were numerous challenges and limitations encountered during this research, with the first linked to gaining access to the research population. Second, the timeframe for the research July 2005 to January 2006 was relatively short. A third limitation was the reluctance to divulge information about energy use. Finally there were barriers to incorporating other variables, such as, embodied and transport energy, though it is acknowledged that these variables will have an effect on total overall carbon emissions related to buildings.

Why Melbourne?

Australia has higher per capita emissions than the USA, furthermore Victoria has the highest emissions in Australia – thus Melbourne has very high CO_2 emissions with an upward trend. The Chief Scientist of Australia stated that 50 percent reductions in CO_2 emissions are required by 2050 with changes to behaviour, practice and the adoption of state of the art technology (*Australian Financial Review*, 2005). Melbourne is similar to other global cities in terms of building stock and the findings are relevant to other cities. The City of Melbourne in recognition of the issue has set goals to achieve zero net greenhouse gas emissions by 2020 (City of Melbourne, 2003).

Commercial buildings and climate change

In Victoria, 12 percent of greenhouse gas emissions come from commercial buildings (DSE, 2005) and previous research concluded that though available means of reducing energy consumption exist, the business as usual scenario will not deliver sufficient reductions (Australian Greenhouse Office, 1999). Therefore steps are needed to promote wider acceptance and uptake of measures to reduce CO_2 emissions from buildings (DSE, 2005). Australian office markets have less than 3 percent added to the overall stock annually (JLL, 2005) thus replacement is slow. Like many cities, Melbourne has an ageing stock where scope for energy efficiency improvements is high, since the average age of office stock is 31 years and the average period since construction or refurbishment is 17 years. Many office buildings were built before 1960, require refurbishment to remain competitive and offer substantial scope for improvements to energy efficiency (JLL, 2005). Since 1995 refurbishments accounted for 60 percent of all CBD completions (JLL, 2005) and although offices require major refurbishment every 20-25 years, many owners opted for minor refurbishments to lower capital expenditure and avoid access problems (JLL, 2005). Refurbishment drivers are reducing vacancy rates, improving rental levels, upgrading assets, and offsetting obsolescence; in essence they are financial (Burton, 2001). With energy efficiency included in the Building Code of Australia since 2005 most stock is inefficient as a minimum energy standard is new to the regulations. Furthermore it is not possible to deliver sufficient reductions in CO_2 emissions to meet targets or address climate change through reliance on building regulations.

Energy efficiency in office buildings

There are many measures that can made to the building fabric and services to reduce energy consumption – for example, lighting systems offer great potential with less than a 2.5 year payback (AGO, 1999). Similarly there a variety of measures tenants can adopt to increase efficiency. An analysis of a client's interest in the building is needed, such as whether the time frame is short, medium or long term, as well as if their budget will affect what measures may be adopted. Another critical factor is the physical characteristics of the building. In other words, buildings have different energy characteristics that have to be fully considered, such as plan shape, and energy efficiency, alongside indoor environment quality (Burton, 2001) and occupant comfort.

One can adopt a “low tech” or a “high tech” approach to refurbishment. The high tech approach relies heavily on technology to deliver energy efficiency and energy consumption is many times higher than the natural approach (Burton, 2001) though noted it is not always appropriate to use a natural approach due to the embodied energy in many high rise offices. Many buildings are a blend of the two. Other related issues include increasing indoor air quality, decreasing the risk of legionnaire's disease, reducing nitrous oxide emissions due to acid rain, and increasing recycling opportunities (Burton, 2001).

Natural methods include daylighting, insulation, solar gain, opening windows, solar shading; and cooling using thermal mass. High tech approaches to energy efficiency include artificial lighting, artificial heating, artificial cooling, artificial ventilation; and sophisticated control systems (such as Building Automation Systems (BAS), intelligent facades). Owners can consider the performance of the façade, either incorporating shading devices or low emissivity glazing to improve efficiency. The incorporation of BAS is an opportunity to improve the building management system to operate plant and services more efficiently with less waste (JLL, 2005). High efficiency chillers and variable speed drives on fans also reduce consumption. There are many properties that can be categorised as "offices" although each varies considerably in size, age, design and can be solely occupied by service industries or comprise mixed use (e.g. office and residential). It is a complex procedure to quantify the emissions from the office stock – Burton (2001) identified four typologies (see Table I).

Another classification is to consider the different physical characteristics, say a heavy weight structure has high thermal mass whereas a skin orientated building has low thermal mass; the different thermal qualities affect energy efficiency. Furthermore, internal layout, cellular space as opposed to an open plan layout can affect energy consumption. Burton (2001) classified generic office building types (Table II).

Melbourne CBD comprises a varied stock featuring all types in Tables I and II and each building presents different challenges in respect of improvements in energy efficiency – for example, owners may seek to refurbish single floors or to refurbish for a short-term life of five-to-ten years although other owners may consider 25 year refurbishments or to strip a property back to the frame. Melbourne CBD has a range of Victorian commercial buildings constructed of traditional load-bearing construction several storeys high. Some properties are heritage listed which places restrictions on alterations to the buildings. On the other hand there is a variety of twentieth-century stock, ranging from low rise to skyscraper heights exceeding 55 floors. The skyscraper stock has a variety of cladding consistent with architectural preferences prevailing at the time of construction – such materials have varying thermal properties that render some buildings more efficient than others, e.g. glass curtain walling is less energy efficient than natural stone panels. In addition, office buildings vary in size on the floor plate ranging from deep to narrow plan, with both types having different energy efficiency characteristics.

Methodology

This research sampled all office buildings and a comprehensive database was compiled, analysing characteristics including age, net lettable area and gross floor area, as well as examining the physical location of each building and calculating electricity and gas usage. The data are based on reliable sources of information based on individual buildings, with the results being valid and reliable.

The main data file was partly compiled with reference to two databases. There were access issues to resolve and extensive data "cleaning" with the two primary databases being the "Census of Land Use and Employment" (CLUE) and "Cityscope". CLUE is an information system about land use, employment and economic activity across Melbourne (www.melbourne.vic.gov.au/clue), produced by the City of Melbourne – for this research the 2005 version was used. Most importantly, CLUE contains information about floorspace, employment, car parking, property and space use. After many meetings with the stakeholders, full access to the data was negotiated, with information aggregated so individual buildings could not be identified.

Cityscope is a commercial database comprising the "most detailed, accurate and extensive CBD property information available" (Cityscope, 2005). The data include street frontage, zoning information, site area, detail of development applications, building progress and completion, complete title details and property details such as building services. Over 3,000 Melbourne CBD properties are in the database which is updated annually. The research was supported by the 2005 version.

Another data source used a questionnaire to establish building energy consumption and use. Within the process of examining detailed property markets and individual buildings there are challenges faced in accessing data perceived as sensitive. Therefore to access data, researchers often have to compromise on the depth of information to access data, and this was the case with the survey. The initial survey was more detailed but after piloting, it was considered either unlikely that respondents would have the time to compete the survey or alternatively they would not have access to the required information. In the property field researchers are confronted with response rates issues and access to respondents. For the purposes of this research the Property Council of Australia (PCA) was a gatekeeper for building owners. After consultation with property consultants, the researchers considered it unlikely building owners would divulge data about energy, especially if there was even a remote possibility their building would be identified as a "guzzler". Although energy efficiency does not appear to adversely affect property values, there is a perception this is changing (RICS, 2005). To overcome this barrier the team negotiated access via the PCA who are trusted custodians of data. To ensure the highest return rate possible, PCA distributed the survey to members with a covering letter explaining issues of confidentiality of data supplied.

After the office building database was constructed, an industry accepted greenhouse rating tool converted consumption into carbon emissions. All data were obtained from reliable sources and verified, using information from the following: Australian Energy report 05.9, (ABARE, 2005), Australian Building Greenhouse Rating (www.abgr.com.au), AGO, 2004, Stationary Sector GHG Emission Projections, Vicpool Information Bulletin 3, p. 43 (ESC, 2001), Department of Infrastructure, 2005, *Energy Retail Tariffs for 2005* (ESAA, 2005a), *Electricity Gas Australia* (ESAA, 2005b), 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 percent, B Grade – 2 percent, C Grade – 1 percent and D Grade – 0 percent. The survey buildings had higher levels of green power however the researchers felt that the sample was biased to buildings where more green power was used – references to other sources confirmed this view and indicated general uptake was lower. All buildings on the data file were processed to calculate carbon emissions.

With reference to the direct survey, a cross-section of office building owners and PCA members in Melbourne were contacted. In total 26 questionnaires were distributed and 14 returns were received, a response rate of 54 percent. All non-office property that included less than 50 percent of a core office component removed from the data file. Importantly, this survey ensured that the primary database was accurate and reliable.

Throughout, the team used local experts, stakeholders and practitioners to validate the data and the collection approach and process. Expert questioning and advice was received from a Steering Committee comprised of academics and practitioners from two UK Universities as well as property consultants, namely King Sturge. The data were subjected to the reliability and accuracy tests prior to commencing the statistical analysis including ensuring the database was error-free, examining the data for anomalies such as differences in data from different sources; and contacting survey respondents to correct anomalies.

Data analysis and findings

The data analysis is divided into two sections based on different influencing factors affecting the relationship between energy consumption and office buildings. The analysis examined variables that distinguish one building from another and used 2005 as the base year. The main data file profiled the stock in terms of size; age; employees and occupancy (hours per week). The variables above were cross tabulated with the following outputs: total actual emissions (kg/CO_2/per year), total energy consumption (MJ/M^2), Energy per person (Mj/per person/per year), emissions per person (KgCO_2/per person/per year) and area per person (M^2/person).

Building size

As listed in Table III each office building was separated into a classification based on gross lettable area (GLA): under 4,999m^2, between 5,000 and 10,000 m^2, or in excess of 10,000 m^2. As expected the group with the largest number of buildings have the smallest GLA (under 4,999 m^2), although larger buildings contain the highest proportion of area.

When examining total actual emissions and building size (Kg/CO_2/per year) in 2005 a positive relationship existed between the larger buildings (GLA in m^2) and total actual emissions produced (tonnes of CO_2 per year) on an aggregate basis in 2005 – refer to Figure 1. This result is as expected since larger buildings contain half of GLA, however larger buildings emit 3.5 times the amount of total actual emissions than smaller buildings, followed by medium-size buildings with the lowest aggregate emissions.

Referring to the actual energy consumption (total energy consumption and building size (MJ/m^2) overall smaller buildings consume a larger proportion of energy. In conjunction with the above findings it can be concluded that larger buildings are the least energy efficient although from a conversion perspective the smaller buildings consume a large amount of energy but have lower emission levels. There are influencing factors that could affect this relationship, including the lower grade of facilities available with smaller buildings (e.g. fewer lifts, limited air-conditioning) and the inherent higher levels of obsolescence.

Based on a comparison of office buildings on a per person basis (energy per person and building size – MJ/per person/per year), to permit a direct comparison between individual office buildings categories, smaller office buildings consume less energy followed by larger buildings and then medium-sized buildings. A major contributing factor affecting smaller buildings would be the larger proportion of older stock in the category, which can be linked to higher levels of obsolescence. The level of emissions on a "per person" basis (emissions per person and building size ($KgCO_2$/per person/per year) is highest for smaller buildings, followed by medium sized and then larger buildings. On a "per person" basis, smaller sized buildings consumed the most energy and produce the highest level of emissions (Figure 2).

When considering area per person and building size (m^2/person), smaller buildings have the highest ratio of office worker to net lettable area (Figure 3), followed by medium-sized and then large buildings. Based on this measure, smaller buildings are the least efficient – this could be linked to higher actual vacancy rates than typically reported. Another factor that may affect this ratio, is the higher level of efficiency when leasing larger buildings, i.e. larger buildings have a higher degree of flexibility and can accommodate a variety of tenants with different space needs.

Building age

When age and total actual emissions (Tonnes/CO_2/per year) were cross tabulated, newer buildings produce the lowest CO_2 emissions. It can be hypothesised this is due to lower or negligible obsolescence in contrast to older buildings. Buildings in the ten to 25 years old category produced the higher emissions although decreasing, rather than increasing, as the building grow older. It should be noted this analysis was based on aggregate CO_2 emissions, and therefore conclusions about the efficiency of older buildings cannot be drawn in isolation. On a direct comparison approach a per square metre basis (total energy consumption and building age (MJ/m^2) aggregate older buildings consume more energy than aggregate newer buildings (see Figure 4). This can be directly attributed to the positive correlation between age and obsolescence, with older buildings severely disadvantaged due to varying degrees of unavoidable obsolescence including functional, economic and technological.

On a comparative "per person" basis (energy per person by building age – MJ/per person/per year) older buildings consume more energy as the buildings continue to age. An older building in excess of 50 years old consumes at least twice the amount of energy on a "per person" basis than a building less than 50 years old. Amongst other factors this reflects the enhanced energy efficiency of newer buildings due to less obsolescence and higher demand.

When examining emissions per person and building age ($KgCO_2$/per person/per year) it is clear that buildings between ten and 50 years old emit less CO_2 emissions per person per year. With reference to buildings less than ten years old, there will be higher emissions "per person" when a building is relatively new and prior to achieving a true 100 percent occupancy (as opposed to a reported low vacancy rate). However older stock, in excess of 50 years of age is typically poor grade, may have poor standards of maintenance, poor condition of services and plant, and inefficient space utilisation. Generally new buildings less than ten years old have the most inefficient use of office space on a per m^2 per office worker basis, when analysed using area per person and building age. This may be linked to the time required to achieve full occupancy for new buildings, which returned an area per person ratio almost twice the ratio of buildings aged between ten and 50 years. On the other hand, buildings over 50 years recorded an increase in the area per person ratio due to higher vacancy rates resulting from substantially less demand.

Number of office employees

When examining total actual emissions and number of employees (Tonnes/CO_2/per year) on an aggregate basis, office buildings with over 500 employees collectively emit the most tonnes of CO_2 per year (see Figure 5). However the level of emissions reduced in line with fewer employees, where office buildings with less than 100 employees released the least emissions. It was concluded that office buildings with more employees produce less emissions on an aggregate basis.

With reference to energy consumption based on the number of employees (MJ/M^2), buildings with 50 employees or less consumed the most energy, although the large number of these buildings should be noted. Buildings with most employees (i.e. in excess of 500 employees) were fewer in number but also had the lowest energy consumption levels – this relationship reflected the higher economies of scale. To facilitate a direct comparison, the energy consumption of office buildings was examined on a per person basis (MJ/per person/per year) and buildings with fewer employees (50 and under) consumed more energy per person, being as many as three times more than larger office buildings and this is a reflection of the higher economies of scale with larger buildings.

When examining the relationship between emissions per person and number of employees ($KgCO_2$/per person/per year), higher emissions were associated with buildings containing fewer workers although office buildings with over 500 employees had the lowest emissions. This relationship can be attributed to the ability of newer, more energy efficient buildings to contain more office workers, as well as the economies of scale associated with larger buildings. When area per person and number of employees (M^2/person) were cross-tabulated the results showed an inverse relationship between the number of employees in an office building and the average area per office worker. Based on these results it can be argued that primarily due to economies of scale, large users of office space are more efficient on a “per worker” basis.

Building occupancy (hours per week)

When examining total actual emissions and building occupancy (Tonnes/CO_2/per year) office buildings with 51 to 55 hours of occupancy per week emit the least tonnes of CO_2 on an aggregate basis, as shown in Figure 6. The total energy consumption and building occupancy (MJ/M^2) showed buildings with less than 51 hours of occupancy per week had the highest aggregate energy consumption. As the hours of occupancy increases, the total level of energy consumption increases and this suggests the aggregate sum of buildings with higher building occupancy have both the lowest energy consumption but also the higher level of emissions. Buildings with lower occupancy hours emit a higher proportion of emissions. The energy consumption per person and building occupancy (MJ/per person/per year) cross tabulation confirmed that as the hours of occupancy in a building increased there was a decrease in the energy consumed per person. Thus, buildings with over 55 hours per week of building occupancy were over six times more efficient than buildings with less than 51 hours of building occupancy per person per week.

The emissions per person and building occupancy (KgCO_2/per person/per year) suggested a negative correlation between the hours of occupancy per worker per week and the level of emissions per worker. Thus, buildings with lower hours of occupancy per worker have higher CO_2 emission levels. When area per person and building occupancy (M^2 per person) were cross-tabulated the results showed that as occupancy hours "per person" basis increases, the area used per office worker decreases. This has implications for energy efficiency in office buildings, after considering the dual advantages of a building with a higher density of workers combined with longer occupancy hours.

Conclusion

This research identified important characteristics of the building stock in Melbourne CBD with regard to energy consumption and CO_2 emissions. These can be summarised as follows:

- Higher energy use and CO_2 emissions are positively associated with smaller buildings (less than 4,999m^2).
- As office buildings increase in age, energy use and CO_2 emissions increase dramatically.
- The level of emissions is linked with the amount of office space per worker, where higher levels of occupancy are associated with lower emissions.

This research confirmed that clear relationships existed within the Melbourne CBD office stock in terms of building size, age and the density of occupation in relation to CO_2 emissions. Practitioners can apply this knowledge to the professional advice they give to clients to assist in achieving increased energy efficiency in the office stock, for example in refurbishment being conscious that smaller buildings will be generally less energy efficient than larger ones. With reference to further research, the next stage is to apply Burton's typologies and types (Tables I and II) to the data and examine the effect of CO_2 emissions, which in turn will provide practitioners in the marketplace with this additional valuable information.

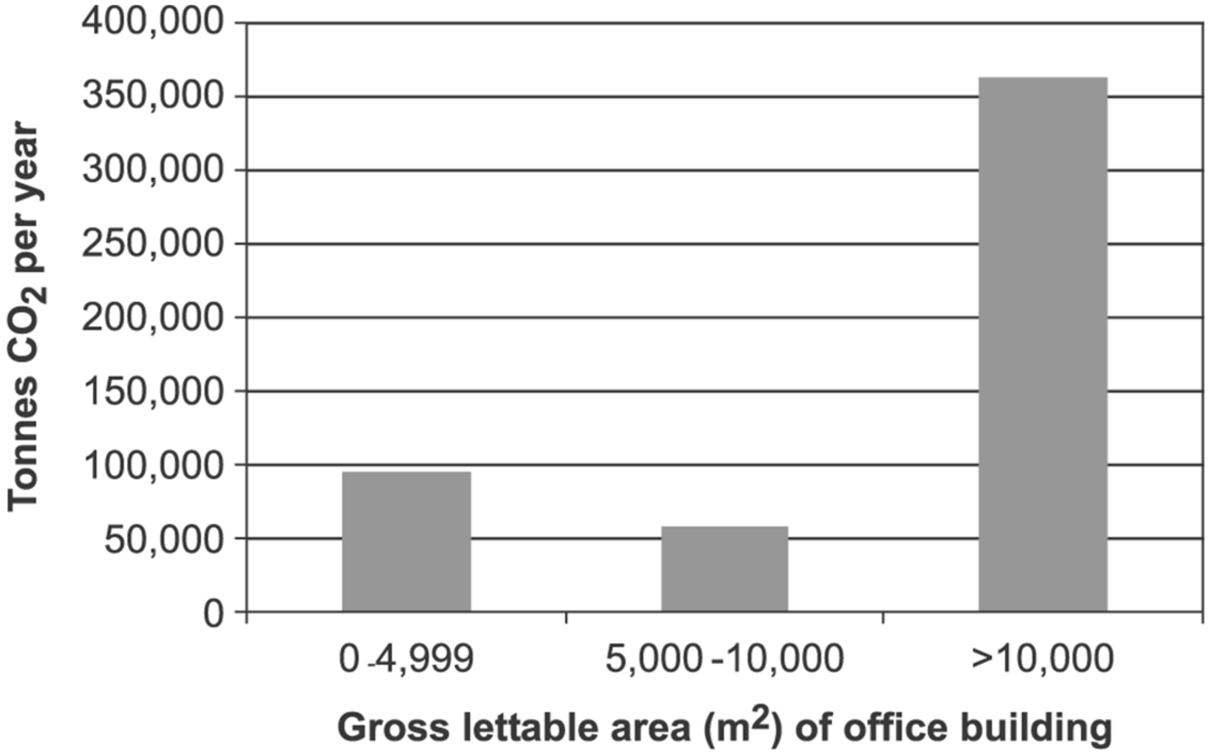

Figure 1*Total actual emissions for Melbourne office buildings by size (2005)*

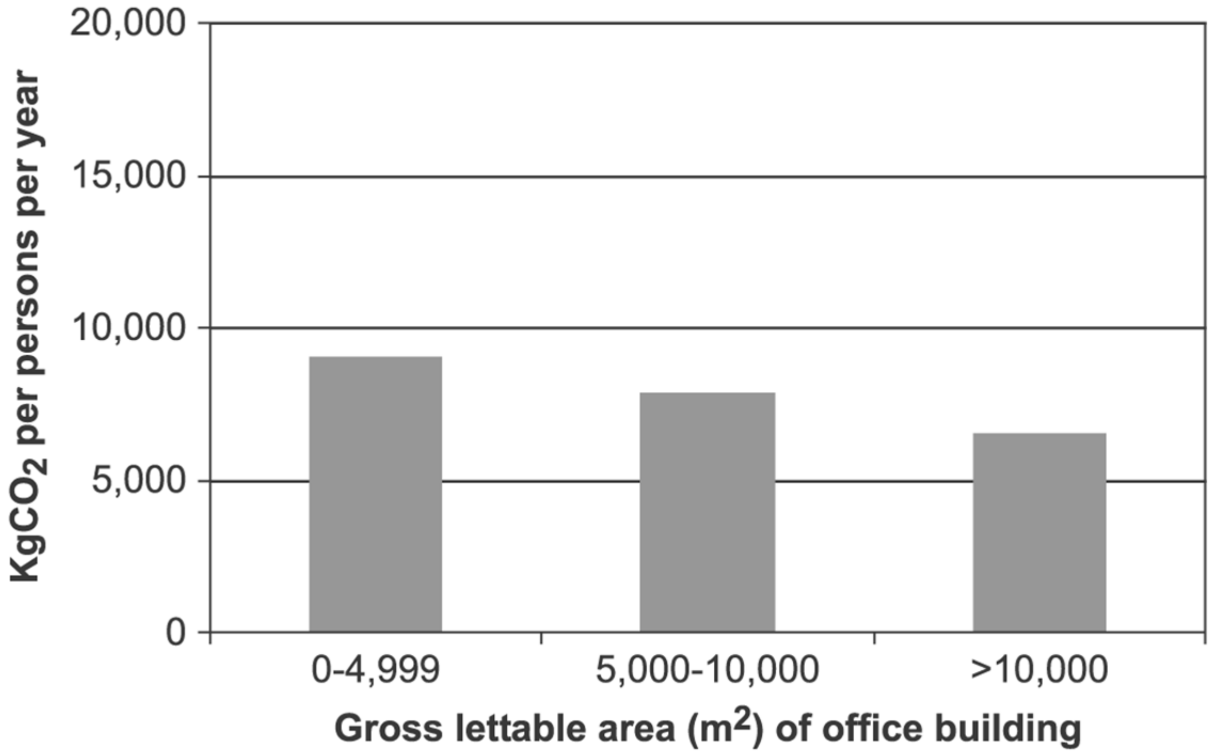

Figure 2*Emissions per person for Melbourne office buildings by size (2005)*

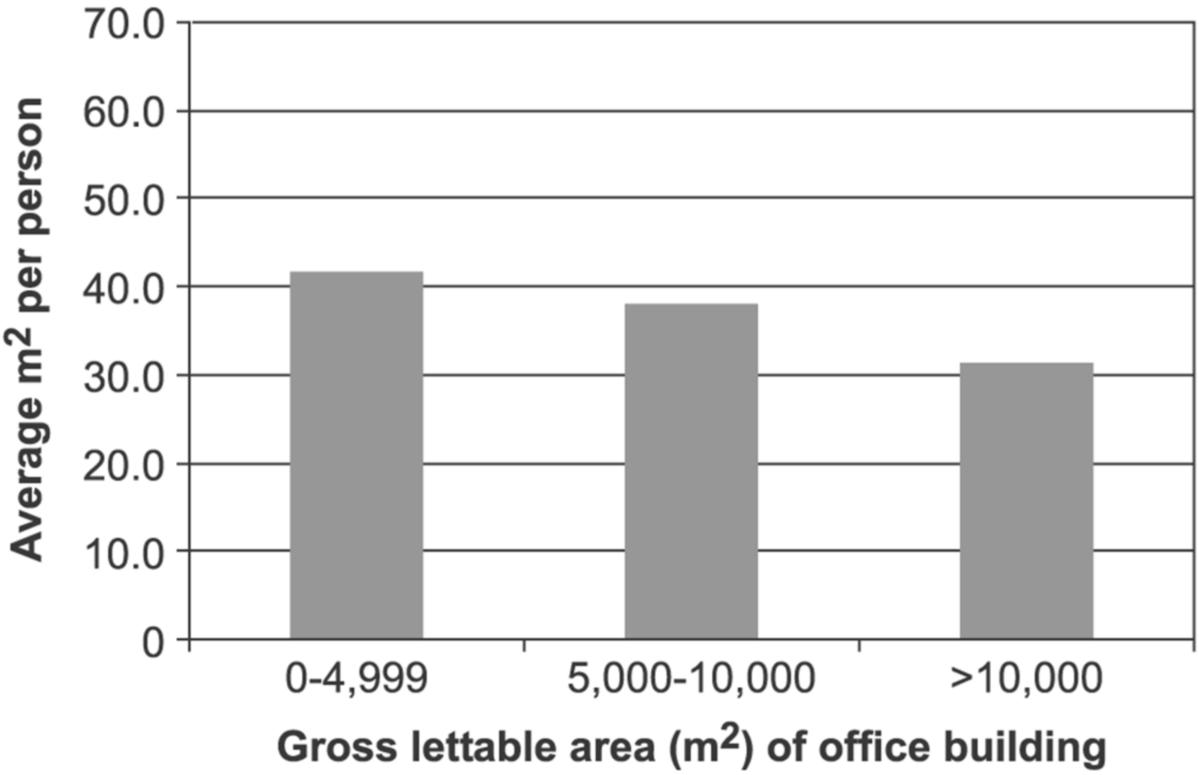

Figure 3*Area per person for Melbourne office buildings by size (2005)*

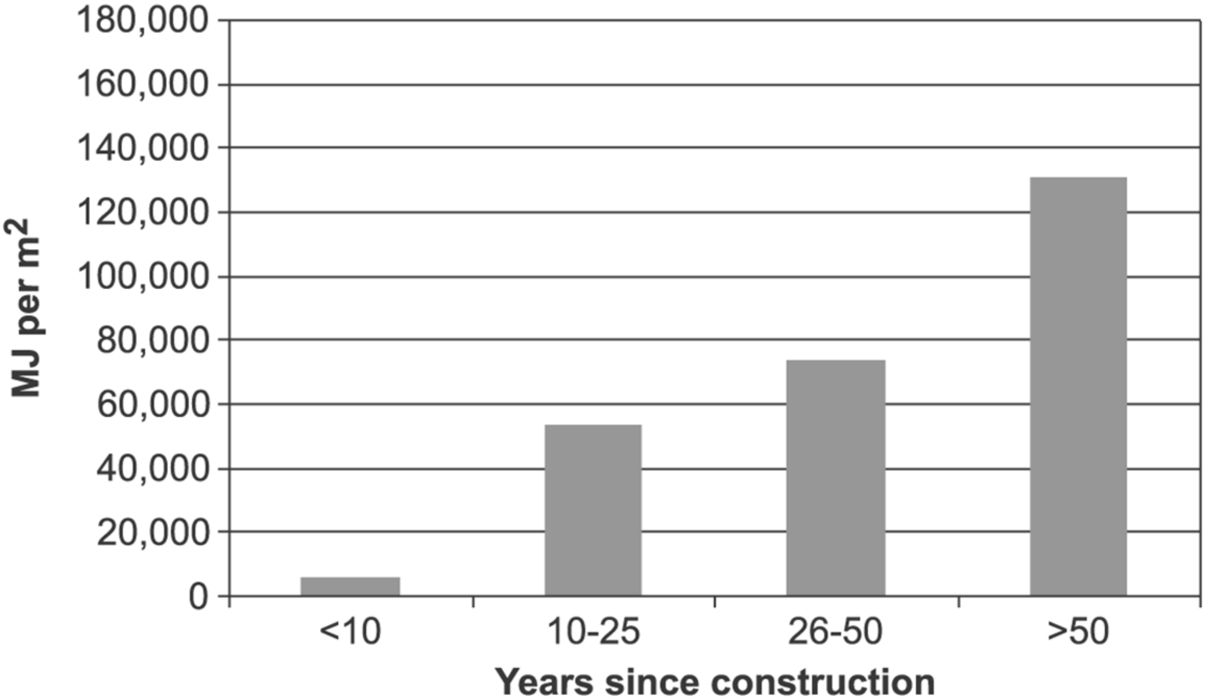

Figure 4*Total energy consumption for Melbourne office buildings by age (2005)*

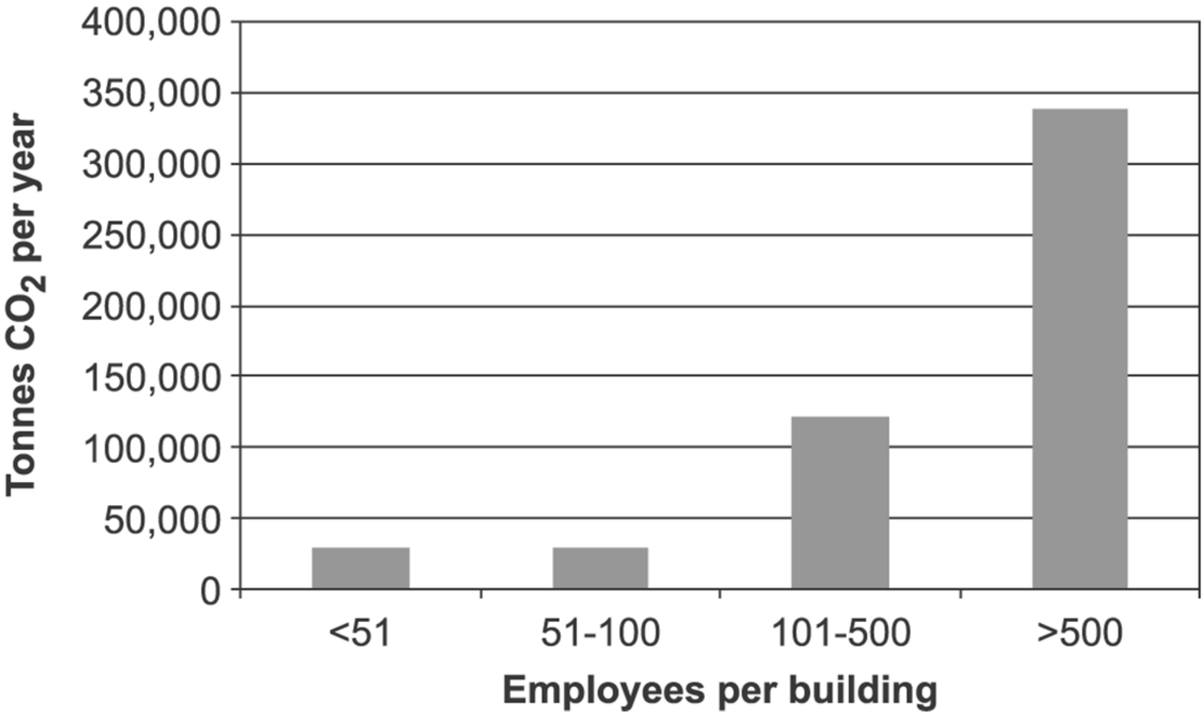

Figure 5*Total actual emissions for Melbourne office buildings by number of employees (2005)*

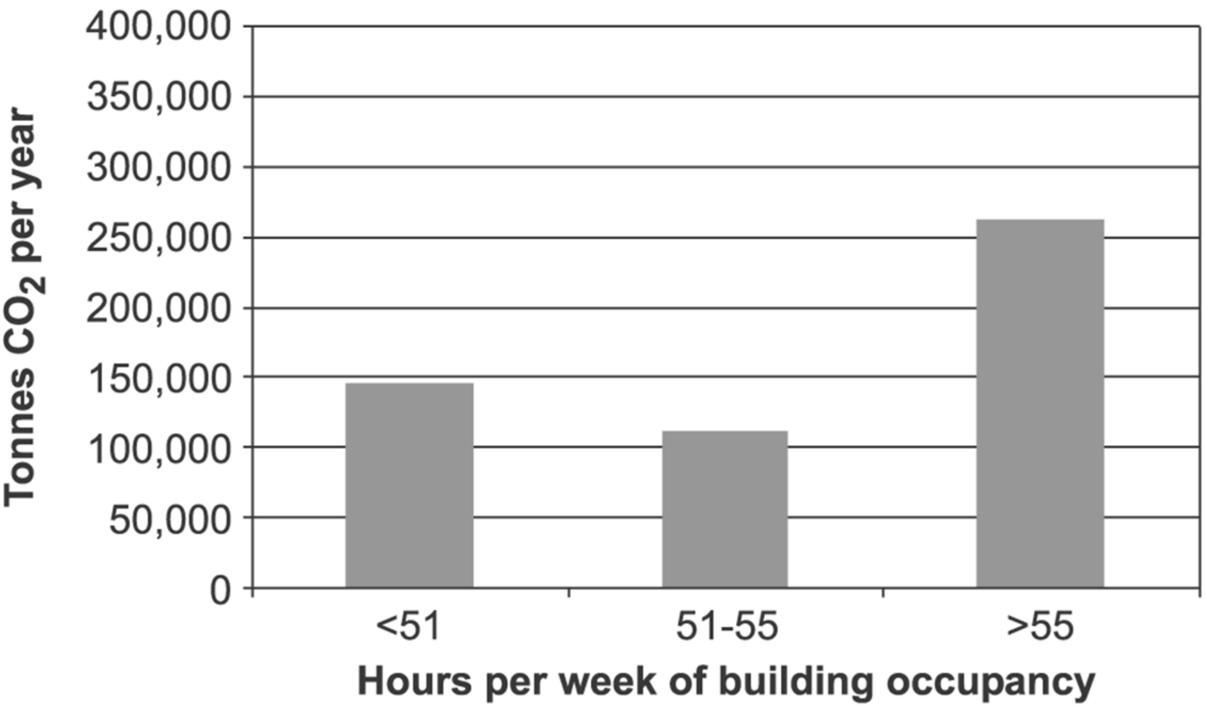

Figure 6*Total actual emissions for Melbourne office buildings by building occupancy (2005)*

Typology	Characteristics
Micro city office building	Mega buildings, atria, "piazzas", streets and squares, internal primary and secondary "streets". Landscaped gardens and water features
Outdated buildings	Largely obsolete, e.g. much of 1960s European stock. Poor construction and poor workmanship, urgently requires retrofit/refurbishment (e.g. PCA Grade D stock in Australia). Redundant stock, e.g. other types such as railway yards and city factories
Hybrid office	Commercial and residential mix – returning to many European and Australian cities
Computer-based offices	Newest entrant to the market and currently more a concept than a "type". High tech using BMS/BAS and envelope to regulate and optimise internal environment. Hot-desking

Source: adapted from Burton (2001)

Table I.
Office typologies and characteristics

Table I*Office typologies and characteristics*

Type no.	Name	Characteristics
1	Domestic	Small with central vertical core. Rooms connected to core and external envelope. Skin-oriented
2	Spinal	Linear floor plan with central corridor access to cellular offices on outside. Heavyweight structure, higher storeys
3	Deep plan	Two examples: inner offices not related to skin; spinal buildings wrapped around a central core
4	Complex	Variation of Type 2 above comprises three linear blocks. Thermal mass, skin determines internal conditions. Lightweight (e.g. steel frame with exterior sandwich elements) – cannot store heat or cool, internal temperature follows outside temperature swings closely. Heavyweight – uses mass to store heat with much slower temperature swings

Source: adapted from Burton (2001)

Table II.
Office building types

Table II*Office building types*

Gross lettable area of buildings (m^2)	No. of buildings	Proportion of total stock (%)
0-4,999 m^2	157	35
5,000-10,000 m^2	60	15
Over 10,000 m^2	109	50
Total	326	100

Table III.
Breakdown of CBD office buildings according to GLA

Table III*Breakdown of CBD office buildings according to GLA*

References

Australian Bureau of Resource Economics (ABARE) (2005), Energy in Australia 2005, available at: http://abarepublications.com/product.asp?prodid=13278 (accessed January 15. 2006), .

Australian Financial Review (2004), "Dr Robin Batterham", No.9 September, .

Australian Greenhouse Office (AGO) (1999), *Australian Commercial Building Sector Greenhouse Gas Emissions 1990-2010. Executive Summary Report*, The Australian Greenhouse Office, Canberra, .

Australian Greenhouse Office (AGO) (2004), *Stationary Sector GHG Emission Projections: Department of the Environment and Heritage*, available at: www.ageis.greenhouse.gov.au (accessed January 15, 2006), .

Burton, S. (Ed.) (2001), *Energy Efficient Refurbishment*, James and James, London, .

City of Melbourne (2003), *Zero Net Emissions by 2020. A Roadmap to a Climate Neutral City*, City of Melbourne, Melbourne, available at: www.melbourne.vic.gov.au/rsrc/PDFs/EnvironmentalPrograms/ZeroNetEmissionsFull.pdf, .

Cityscope (2005), Cityscope Publications, Melbourne, .

Department of Infrastructure (2005), *Productivity Commission Inquiry Report No. 33*, Department of Infrastructure/Department of Sustainability & Environment, Melbourne, available at: www.ccnco.gov.au/inquiry/ncp/finalreport/supplement/supplement.pdf, .

DSE (2005), *Victorian Greenhouse Strategy Action Plan Update*, Dept of Sustainability and Environment, East Melbourne, VIC, .

ESAA (2005a), *Energy Retail Tariffs for 2005*, Energy Supply Association of Australia, Melbourne, available at: www.esaa.com.au/ (accessed January 16 2006), .

ESAA (2005b), *Electricity Gas Australia 2005*, Energy Supply Association of Australia, Melbourne, available at: www.esaa.com.au/ (accessed January 16, 2006), .

ESC (2001), *Vicpool Information Bulletin 3*, Essential Services Commission, Melbourne, available at: www.esc.vic.gov.au/apps/page/user/pdf/ESC_AnnualReport2001_02.pdf, .

JLL (2005), *Building Refurbishment – Repositioning Your Asset for Success*, Jones Lang LaSalle, Melbourne, March, .

OECD IEA (2005), Organisation for Economic Co-operation and Development/International Energy Association, Paris, .

RICS (2005), *Green Value: Green Buildings Good for Business*, Royal Institute of Chartered Surveyors, Coventry, available at: www.rics.org/greenvalue, .

Further Reading

Australian Buildings Codes Board (2001), *Energy Efficiency in Building Directions Report*, Australian Buildings Codes Board, Canberra, available at: www.abcb.gov.au (accessed 10 May, 2005), .

UIC (2005), *Australia's Electricity Nuclear Issues Briefing Paper 37*, October, Uranium Information Centre Ltd, Melbourne, available at: www.uic.com.au/nip37.htm (accessed 10 January 2005), .

About the authors

Sara J. Wilkinson is a Lecturer in Construction and Building Surveying, in the Faculty of Architecture, Building and Planning, University of Melbourne, Melbourne, Victoria, Australia.

Richard G. Reed is a Senior Lecturer in Property, in the Faculty of Architecture, Building and Planning, University of Melbourne, Melbourne, Victoria, Australia. He is the corresponding author and can be contacted at: rgreed@unimelb.edu.au