Multi Unit Residential Buildings Energy & Peak Demand Study

Prepared by:

Paul Myors

EnergyAustralia

&

Rachel O'Leary & Rob Helstroom

NSW Department of Infrastructure, Planning & Natural Resources

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1 BACKGROUND

While considerable information is publicly available on energy use in detached residential houses, the same is not true for multi-unit dwellings such as apartment blocks, villas and townhouses. Given that much of the growth in the residential sector in Sydney will be comprised of these higher density housing forms, it is important to improve our understanding of their energy use and their likely impacts on peak energy demand. This is the aim of the Multi Unit Residential Buildings Energy & Peak Demand Study.

In 2003, the NSW Department of Infrastructure, Planning and Natural Resources (now the NSW Department of Planning, or DOP) partnered with EnergyAustralia, Integral Energy and Agility to deliver a study on the energy consumption of multi-unit developments. This project was funded under the $10M Demand Management & Planning Project (DM&P), with project management and technical support provided in-kind by EnergyAustralia and DOP. Other project contributors included Agility, Integral Energy and Sydney Water.

To date, the energy results from the study have been used to inform the development of the multi-unit version of the Building Sustainability Index (BASIX), as well as providing information about peak demand to assist in the planning of electricity networks.

Given the limited number of buildings in this study, the results are not statistically representative of Sydney multi-unit residential buildings and hence, should be interpreted with some care. While they go some way towards describing average energy use in high-rise apartment blocks, the results point to general trends and also instances of great variability in multi-residential buildings. They have the most value in underlining the energy intensiveness of many common area and centralised systems that are often installed in high-density housing forms. When expressed as annual greenhouse emissions per occupant, these results reflect that people living in apartment buildings produce more greenhouse gas emissions than people living in detached houses. This is a result of energy consumption in common areas as well as lower occupancy rates of apartments compared to detached houses. Townhouses and villas appear to be the most efficient dwelling form on a per capita greenhouse gas basis. It must be noted that these multi-unit dwellings were only assessed on stationary energy consumption, and that there are other advantages to high density housing well located near public transport, such as lower transport emissions. These should be investigated in future studies.

2 METHODOLOGY

The section below outlines the methodology for both components of the study, the energy-use investigation and the peak demand research.

2.1 Selection of sample sites

Approximately 100 multi-unit residential buildings in the Sydney metropolitan region, spanning an area from the eastern coastline to Chatswood in the north, Rockdale in the south and extending inland to Westmead were the subject of the study. The forms of these buildings (ie, high-rise, villa, etc) were selected to ensure a relatively equal representation in each of the five building categories described in Table 1 (overleaf). Inclusion of a representative cross section of building ages, building storeys and climate zones was an important consideration in the selection process.

Table 1: Multi-Unit Building Categories

Category	Description
High Rise	Residential apartment buildings **9 or more storeys** high
Mid Rise	Residential apartment buildings **4-8 storeys** high
Low Rise	Residential apartment buildings **up to 3 storeys** high
Townhouses	2 or more **attached** dwellings with common or shared facilities (eg car-parking)
Villa	2 or more **detached** dwellings with common or shared facilities (eg car-parking)

A total of 52 sites, including 4,043 apartments, were involved in the overall study. Permissions to carry out walk-through energy audits were obtained through contact with body corporates, strata managers or building owners. As an incentive, each body corporate was offered an energy report at the close of the project outlining various energy saving opportunities that had been identified in carrying out the audit of their building. Ultimately, 45 sites (comprising 3,854 apartments) underwent the energy audit, and data from this set of dwellings forms the core of the greenhouse results. The composition of the greenhouse study is outlined in Table 2.

Table 2: Summary of dwelling types and number in greenhouse gas component of study

Building types	No. of buildings	No. of dwellings
High rise	17	2952
Mid rise	12	458
Low rise	10	261
Townhouse	3	114
Villa	3	69
TOTAL	45	3854

Due to the small sample size and the similarity of the housing forms, the results from the townhouse and villa audits were combined for the purpose of analysis.

For the peak demand component of the study, 24 sites (comprising 1,787 apartments) were subject to "whole of building" power consumption monitoring. Here, instantaneous power demands were recorded at five minute intervals over a one month period for later analysis. A summary of the sites included in the peak demand study is made in Table 3.

Table 3: Summary of dwelling types and number in the peak demand component of study

Building types	No. of buildings	No. of dwellings
High rise	8	1,365
Mid rise	4	189
Low rise	5	116
Townhouse	4	61
Villa	3	56
TOTAL	24	1,787

2.2 Installation of power loggers

Power loggers were installed at 25 of the sample sites to record the summer peak whole-of-building load profile for the month of February 2004. The loggers were three-phase and recorded five-minute average interval data including volts, amps, kW, kVA, kVAr and power factor.

One logger failed during the monitoring period, reducing the logged sample size to 24.

2.3 Energy audits

An energy auditing company was contracted to conduct walk-through energy audits of the sites, collecting information on all energy-consuming building services and equipment. These audits focussed on the building common areas and included such items as lifts, pools/gyms, as well as central cooling and ventilation systems. However, some general information was also obtained from the audit concerning the individual apartments such as type of cooking and individual hot water systems.

2.4 Energy analysis

The information gathered from the energy audits was used to prepare estimates of the energy consumption of key end-use categories such as hot water, heating/cooling, ventilation, lighting and lifts. These estimates were correlated, as accurately as possible, to energy billing data obtained from EnergyAustralia's customer information system.

The energy analysis results were used to inform the development of the multi-unit version of the NSW Building Sustainability Index (BASIX), which is outlined in more detail in Section 3.3.

3 RESULTS – ENERGY ANALYSIS

3.1 Energy audit of high-rise apartment buildings

Examples of the total annual building energy consumption for two different high-rise apartments, together with the energy saving initiatives recommended as an outcome of the audits, are presented below.

The energy audits highlighted the challenge of accurately predicting energy consumption from a walk through audit. The consultant's electricity estimates for Site A and Site B were 86% and 101% of the actual electricity meter readings from EnergyAustralia. For all sites, the electricity audit estimates ranged from 31% to 202% of the actual consumption, with the average accuracy being 90%. These discrepancies could have been a result of missing loads, under- or over-estimation of usage hours, miscalculations, errors in utility billing data etc. Due to the range of these results, the audit data were not used in developing multi-unit BASIX. Actual utility consumption data formed the core of the analysis.

. Based on electricity and gas billing data for the most recent available 12 month billing period, the total energy consumption was accurately broken down into common areas and apartments.

Common area end uses comprised of:

- Lighting (building exterior, lobbies, fire stairs, access stairs, hallways, carparks)
- Lifts
- Hot water supply, including circulation pumps (where centralised system)
- Heating and cooling for individual apartments (where centralised system)

- Carpark ventilation
- Common exhaust fans
- Pool and spa (including water heating, pumps, heating, ventilation and air-conditioning (HVAC) systems and lighting of pool area)
- Saunas
- Cooling tower pumps and fans

Further breakdown into these specific areas of energy end-use has been based on data from the walk-through audits, and it should therefore be borne in mind that this particular data has not been substantiated with actual metered consumption data.

Individual apartment end uses comprised of:

- Hot water heating
- Individual apartment space cooling and heating
- Interior lighting
- Cooking (electric only)
- Internal exhaust fans
- Refrigerators
- Washing machines
- Clothes dryers
- Dishwashers
- All other domestic use such as computers, TV, small appliances, etc
- Standby power etc.

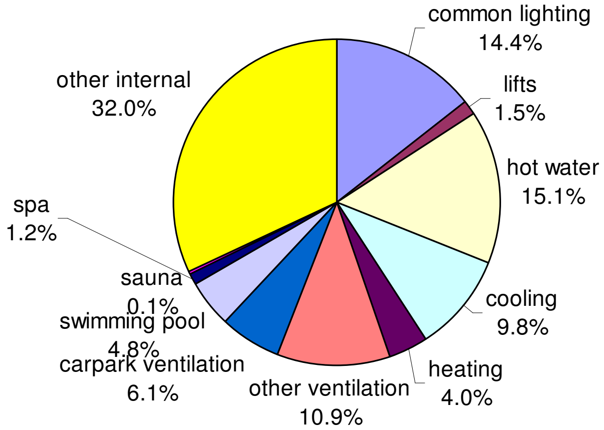
Not all of these end-uses were able to be audited for the individual apartments. They are collectively reported as “other internal” in the building audit breakdowns.

Table 4: Comparison of annual energy consumption and annual per capita greenhouse gas emissions for two high-rise apartment sites, Sydney.

Site	Building type	Number of dwellings	Annual site total energy consumption (MJ/year)	Annual per capita greenhouse gas (tonnes CO_2 /person.year)
Site A	High-rise	~ 175	11,215,214	6.5
Site B	High-rise	~ 158	5,853,856	3.5

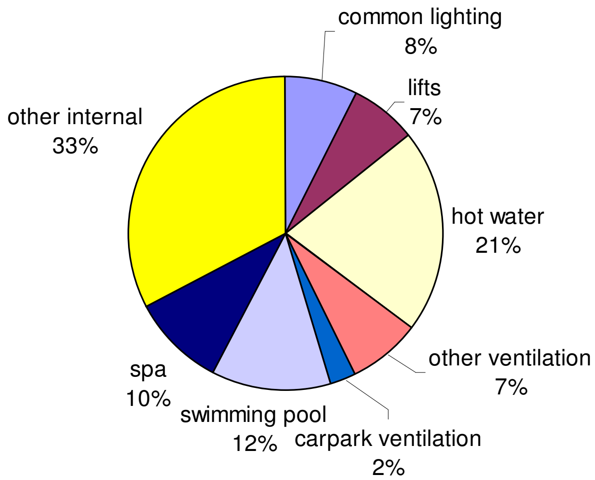
As evidenced in Table 4, total energy amounting to 11,215,214 MJ/year was consumed by Site A which results in the production of 6.5 tonnes CO_2/person.year. In contrast, Site B consumed a total of 5,853,856 MJ of energy in the year which led to the generation of 3.51 tonnes CO_2/dwelling.year. The greenhouse breakdown for both sites is displayed below.

Site A: Estimated greenhouse source breakdown.



Site A - Here, the largest greenhouse gas sources have been identified as 'other internal' (including the refrigerator and clothes dryer) (32%), followed by the centralised gas hot water system (15%), common area lighting (14%), water loop cooled space cooling and space heating (14%) and other ventilation (11%). Other greenhouse sources include the 75,000 litre, gas-heated swimming pool and spa (6%), the electric resistance sauna – (0.1%), car park ventilation (6%) and lifts (2%).

Site B: Estimated greenhouse source breakdown.



Figures 1 & 2: Comparison of greenhouse gas breakdown for two high-rise apartments Site A & B, Sydney

Site B - In this building, the largest greenhouse emissions are associated with 'other internal' (33%), which include the apartment refrigerator, lighting and clothes dryer loads. The second largest greenhouse emissions came from the 48,000 litre, electrically heated swimming pool & spa (22%). Lower emissions are associated with the central gas instantaneous hot water system (21%), common area lighting (8%), other ventilation (7%), lifts (7%), and car park ventilation (2%).

It is interesting to note that, although Table 4 indicates that the per capita greenhouse emissions of Site A and Site B are very different, the breakdown between common area energy usage and apartment energy usage is not that dissimilar. A key difference in the greenhouse breakdown is that Site B does not have a central heating/cooling system, has electrically heated swimming pool and spa, lower common area lighting loads and carpark ventilation requirements.

It must be noted that for both Sites A & B (Figures 1 & 2) the gas cooking energy is not represented in the % greenhouse gas breakdown. These graphs are best estimates only from the walk through energy audits.

A number of energy saving initiatives were identified by the consultants for both sites. These included the installation of:

- pool area ventilation and heating control;
- pool pump control;
- conversion of electric resistance pool heating to electric heat pump (Site B);
- lighting controls for common areas (eg. carpark, hallways, firestairs, lobby, external);
- variable speed drives for the cooling tower fan & condenser water pump (Site A).

Faced with common area energy costs of $15,000/month at Site A, it is expected that these efficiency measures will return significant savings to building managers and body corporates.

3.2 Summary of characteristic energy end-uses in high-rise apartments

There are several important general observations which can be drawn from an overview of the audit results across high-rise apartment buildings. These concern:

- *Hot water* - Approximately 71% of high-rise sites were supplied by central gas storage system, 6% with a central gas instantaneous system and the remaining 23% with individual electric hot water systems.

- *Heating & Cooling* – Centralised heating/cooling systems were identified in 65% of the audited high-rise sites. All of these sites were serviced by centralised water loop systems. Greenhouse gas emissions of approximately 1.3 tonnes of CO_2 per person per annum can be attributed to the heated and cooled dwellings.

- *Swimming pools* - Pools were commonplace amongst high rise developments, with 88% having one or more common area pools for their inhabitants. In contrast, only 17% of mid rise and 10% of low rise housing developments included pools. The average swimming pool size for a high-rise development was 111,000 litres in volume. A total of 83% of the pools were located indoors and 17% outdoors, of which 87% were freshwater and 13% salt water. No pool covers were found at any of the pools, however 73% of pools used pump timers. Most pools were heated, with 60% heated by gas, 33% with electric resistance heating and 7% were not heated.

- *Lighting* - A thorough lighting audit was conducted of each common area of each site. Analysis of the audit findings (Figure 3 overleaf) shows that the main end-uses of lighting energy consumption changed with each different dwelling type. Across high-rise sites, the majority of common area lighting energy consumption originated in the hallways (45%) followed by the car park (33%); firestairs (12%), lobby (8%) and external areas (2%). In contrast, the average low-rise in the study used most energy for lighting carparks (35%), then for hallways (22%), lobby (3%), fire/access stairs (19%) and notably a greater percentage of total common area lighting energy than high-rise for external lighting (21%).

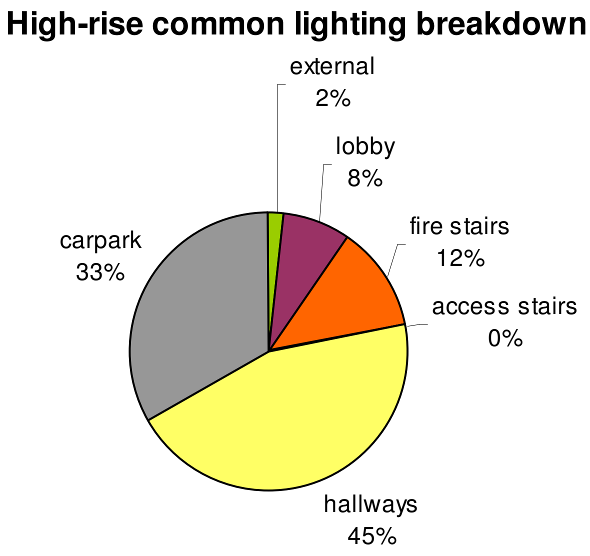


Figure 3: High-rise average common area energy / greenhouse lighting breakdown

4 RESULTS – GREENHOUSE ANALYSIS

4.1 Energy consumption for different housing types

Variation in per capita greenhouse emissions across the housing spectrum from single, detached dwellings to high-density, multi-unit apartment blocks is of considerable importance in establishing the practicality of applying energy benchmarks in the multi-unit BASIX tool.

In seeking to determine housing type dependencies, the analysis initially considered all 45 sites that received energy audits in the greenhouse gas component of the study. Some sites were then eliminated from the study where their total, per-dwelling energy use was greater than 1.5 standard deviations from the sample mean. This elimination of strongly atypical data decreased the sample size from 45 to 41, and reduced the number of apartments from 3,854 to 3,670. A summary of the energy and greenhouse characteristics of this selected sub-sample are presented in Table 5.

Table 5: Total annual energy use and resulting greenhouse gas emissions by dwelling type.

Building type	**Annual energy (elec. + gas) per dwelling MJ/dwelling.year**	**Annual greenhouse gas emissions per dwelling tonnes CO_2/dwelling.year**	**Annual greenhouse gas emissions per person tonnes CO_2/person.year**
High Rise	49,063	10.4	5.4
Mid Rise	30,594	7.3	3.8
Low Rise	27,158	6.5	3.4
Townhouse + Villas	25,547	5.1	2.1
Detached	39,974	9.0	2.9
AVERAGE	**36,309**	**8.0**	**4.1**

Table 5 shows the average annual energy consumption of the sample to be 36,309 MJ/dwelling.year for all the audited multi-dwelling buildings. This includes a shared assignment of common area energy consumptions as well as the internal dwelling consumption. As a basis for comparison, the table also includes the average annual energy consumption (of approximately 39,974 MJ/dwelling.year) for a detached dwelling in east Sydney.

Comparing across dwelling types, both the greenhouse and energy findings in Table 5 clearly show that the surveyed high-rise buildings, consuming on average 49,063 MJ/dwelling.year and generating 5.4 tonnes of greenhouse emissions per year, represented the least efficient housing form. With more modest common area energy demands, mid-rise apartments (30,594 MJ/dwelling.year) and low-rise apartments (27,158 MJ/dwelling.year) represented both lower per-capita energy consumption and greenhouse emissions. Not surprisingly, those dwellings falling within the Townhouse + Villas classification had, at 25,547 MJ/dwelling.year, the lowest average energy demand of all building types.

Total energy is, in the form presented and discussed above, a poor metric upon which to base energy efficiency and greenhouse assessments. Comparing electrical energy to gas consumption does not take into account the quantity of primary fuel that has been consumed where the energy is first generated eg.at the power station. Analysis of total energy consumptions can nonetheless furnish useful information about the performance of generic technologies in various applications. Electrical energy supply, as well as total greenhouse, are the primary considerations of this study and therefore analysis of total energy is not taken further in the present report.

4.2 Total greenhouse gas emissions for different housing types

Total greenhouse gas emissions (tonnes CO_2/dwelling.year) are presented in Figure 4 below for each housing type.

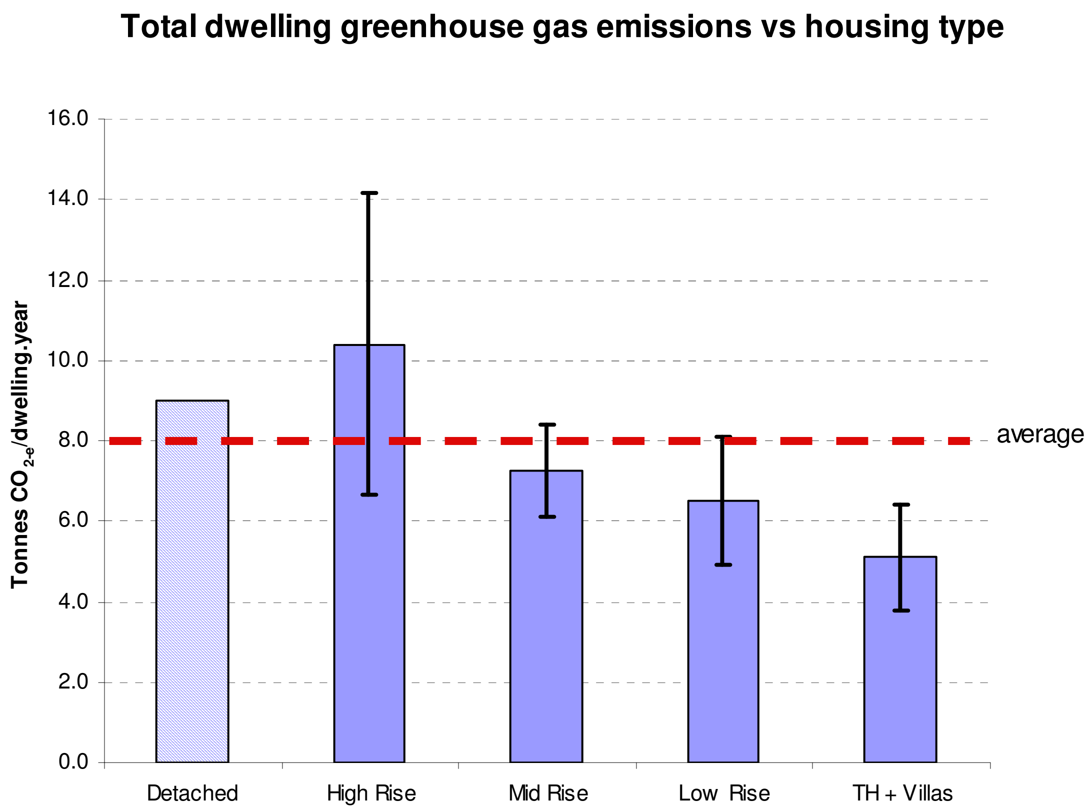


Figure 4: Total dwelling greenhouse gas emissions (tonnes CO_2 / dwelling.year) for each dwelling type

This representation of the Table 5 summary graphically highlights the general fall in greenhouse emissions as multi-dwelling buildings become increasingly free of common area amenities. Such a trend is however clearly inapplicable to the detached building form where the average annual greenhouse gas consumption for detached dwellings in eastern Sydney is 9 tonnes CO_2/dwelling.year (data supplied by EnergyAustralia for BASIX, 2004). Ignoring any differences in occupancy rates, such higher emissions for detached dwellings could arise as a consequence of greater floor area.

4.3 Per capita greenhouse gas emissions for different housing types

When the results are analysed on a per capita basis (ie by dividing the per-dwelling emissions by the appropriate occupancy rates for each housing type), the differences between dwelling types becomes more pronounced. The occupancy rates used to derive the per occupant greenhouse emissions are outlined in Table 6 below.

Table 6: Sydney occupancy rates and proportion of the population living in each housing form

Dwelling type	**Proportion of population living in the housing form (%)**	**Average occupancy rate (people / dwelling)**
Detached dwellings / separate houses	72.8%	3.05
Semi-detached, townhouse, villa	9.9%	2.37
Low-rise apartments	10.3%	1.92
Mid-rise apartments	3.8%	1.92
High-rise apartments	2.0%	1.92

Source: ABS census data, 2001

These data, showing that detached dwellings have the highest occupancy rates (3.05 people per dwelling) followed by semi-detached dwellings (2.37) and finally by apartments (1.92 people per dwelling), has a large influence on the per capita greenhouse emissions findings.

Greenhouse emissions reduction per capita data are presented in Figure 5 overleaf. Here, the generally lower occupancy rates (1.92 persons per dwelling) of high-rise, mid-rise and low-rise apartments leads to per capita greenhouse emissions that exceed those of detached dwellings (3.05 persons per dwelling). Indeed, when viewed on a per-occupant basis, only townhouse and villa housing forms are seen to be less greenhouse intensive than detached. The limitations of not having actual per capita data for the study dwellings is outlined in more detail in Section 6.1.

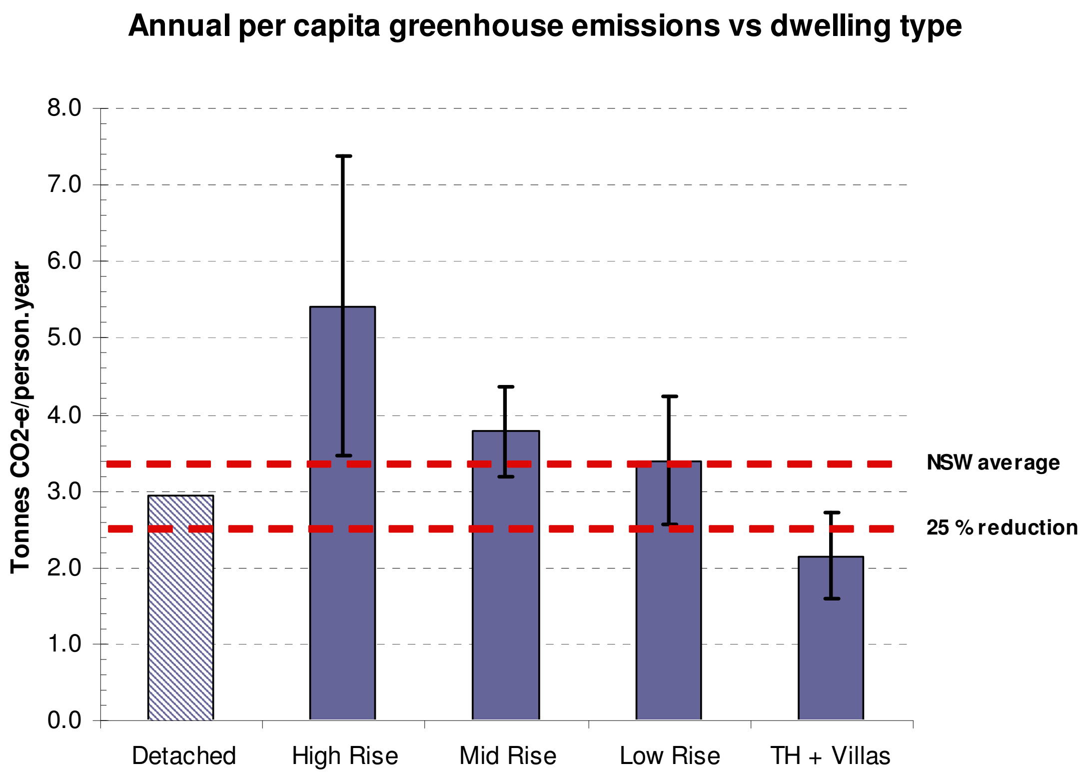


Figure 5: Annual per capita greenhouse gas emissions for each dwelling type

4.4 BASIX greenhouse gas 'benchmarks'

The multi-unit study was conducted in order to provide data on the energy consumption of different residential dwelling types. One approach to devising a greenhouse scoring system that was investigated for the development of BASIX, involved the generation of a different "benchmark" or average greenhouse emission standard for each specific dwelling type (ie, high-rise, mid-rise, etc.). That is, the 25% BASIX greenhouse reduction would apply to each different benchmark, depending on the dwelling type.

This approach was seen to be impractical in the light of the present study where, clearly, there are very large variations in per capita greenhouse emissions between different dwelling types and within each dwelling type. The range of the outcomes from each building form is shown by the variance bars displayed in Figures 4 and 5 from the audit data. Such variability is also reflected in the two case studies outlined in Section 3.1. Substantial greenhouse inefficiencies, such as electrically heated swimming pools and uncontrolled and inefficient lighting and ventilation systems, were commonly identified in the energy audits. With more thoughtful selection of common area technologies, many high-rise buildings could enjoy large energy and greenhouse savings. In fact, as none of the audited buildings boasted energy efficient design, it is likely that even those that are represented by the lower variance markers in Figures 4 and 5 could achieve substantial greenhouse savings with quite modest changes to common plant, systems and apartment design.

Given these findings, and the impracticality of establishing a robust set of data describing the greenhouse emissions of each individual building type across the state, a decision was made to adopt one single average benchmark for all dwelling types as the cornerstone of the BASIX rating system. This benchmark is therefore equivalent to the NSW average residential electricity and gas consumption data collected from all state-wide energy utilities by the Department of Energy, Utilities and Sustainability.

Expressed in terms of greenhouse gas emissions, this formulation yields a 'benchmark' or average greenhouse emissions of 3,292 kg of CO_2 per person per year as the fundamental BASIX reference. At a mandated reduction of 25%, each new dwelling, regardless of type and location, needs to emit no more than 2,469 kg of CO_2 per occupant. This requirement, rewarding good thermal design and energy efficient practices, is seen as an equitable means of significantly reducing the impact of NSW housing on global warming.

A cost-benefit analysis of single detached dwellings and multi-unit dwellings has been conducted to ensure that the target of 25% was not cost-prohibitive. A summary of the cost per dwelling for an example townhouse, mid-rise and high-rise developments is outlined in Table 7.

Table 7: Summary of costs to meet BASIX requirements.

Development	*No. of units*	*Cost per unit ($)a*	*Total cost ($)a*	*Estimated variance (%)*
Townhouse	5	7,570	37,900	4.2
Mid-rise	49	6,770	331,900	3.1
High-rise	190	9,080	1,724,800	3.6
Weighted average cost per unit	n/a	8,590	n/a	n/a

a All costs are exclusive of GST

Source: Direct costs of BASIX compliance for multi-unit dwellings, Centre for International Economics, 2005.

5 RESULTS - PEAK DEMAND ANALYSIS

5.1 General

As noted in Section 2.2 above, 3-phase power loggers were installed at 25 of the audited sites. These instruments recorded the whole-of-building load profiles over February 2004, thereby providing accurate quantification of RMS line voltage, current, kW, kVA, kVAr and power factor over an important summer peak period.

In most cases the demand profile had the expected characteristic shape with peak demand occurring between 5-9pm in the evenings, and a smaller morning peak between 7-9am.

The overall monthly peak demand was identified for each site. Any demand spikes outside of the hours of 12pm to 9pm (generally associated with off-peak hot water systems turning on) were excluded from the analysis. Across all sites, the average summer peak demand was 2.6 kVA per apartment, ranging from 0.4 kVA up to 7.9 kVA per apartment.

5.2 Relationship between demand and building type

No clear relationship between building category and peak demand was able to be discerned in the logged data.

5.3 Demand characteristics for various load types

5.3.1 Air-conditioning

Of the 24 power-monitored sites, 9 were provided with air-conditioning systems. Analysis of the peak load information from the air-conditioned and non air-conditioned site data sets shows a strong relationship exists between the use of air-conditioning systems and building peak demand.

The average peak demand for the 15 sites with no air-conditioning was 1.8 kVA per apartment over the month of February. In contrast, the average peak demand for the remaining 9 sites with air-conditioning was 3.8 kVA per apartment. Attributed to air-conditioning, this 111% increase of 2 kVA more than doubled the average peak demand.

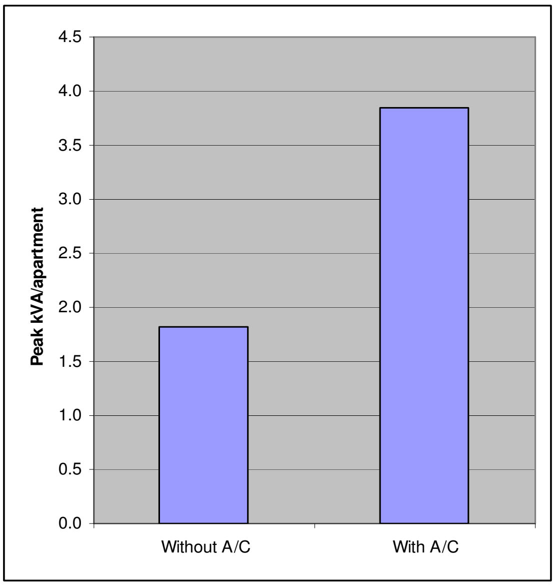


Figure 6: Comparison of average peak demand for buildings with and without air-conditioning

5.3.2 Hot water systems

As would be expected, those sites with off-peak electric hot water systems have a distinctive demand profile with high peaks at the times when these systems are switched on. This is generally around 9am and 10pm each day.

5.4 Demand as a function of ambient temperature

Sydney weather data for the study period was obtained from the Bureau of Meteorology. Four high temperature days with maximum temperatures of greater than 32 ^{o}C were encountered during the logging period (9th, 11th, 21st & 29th February 2004). Not surprisingly, the peak demand at sites with air-conditioners increased significantly as ambient temperature rose towards those peaks.

As an example of the sensitivity of demand to ambient temperature, Figure 7 (overleaf) compares the demand profiles at Site No. 2 (coastal Sydney) for a mild day (23 ^{o}C) and for a hot day (37 ^{o}C). Site 2 is a low-rise luxury development of 34 dwellings. Here, the monitored peak demand is seen to almost double from 79 kVA to 155 kVA (an increase of 76 kVA or over 2.2 kVA per apartment) with the peak occurring about 6.30pm. Obviously the difference in peak demand between these two days is predominantly due to temperature-dependent appliances such as air conditioners and (to a lesser extent) refrigerators/freezers.

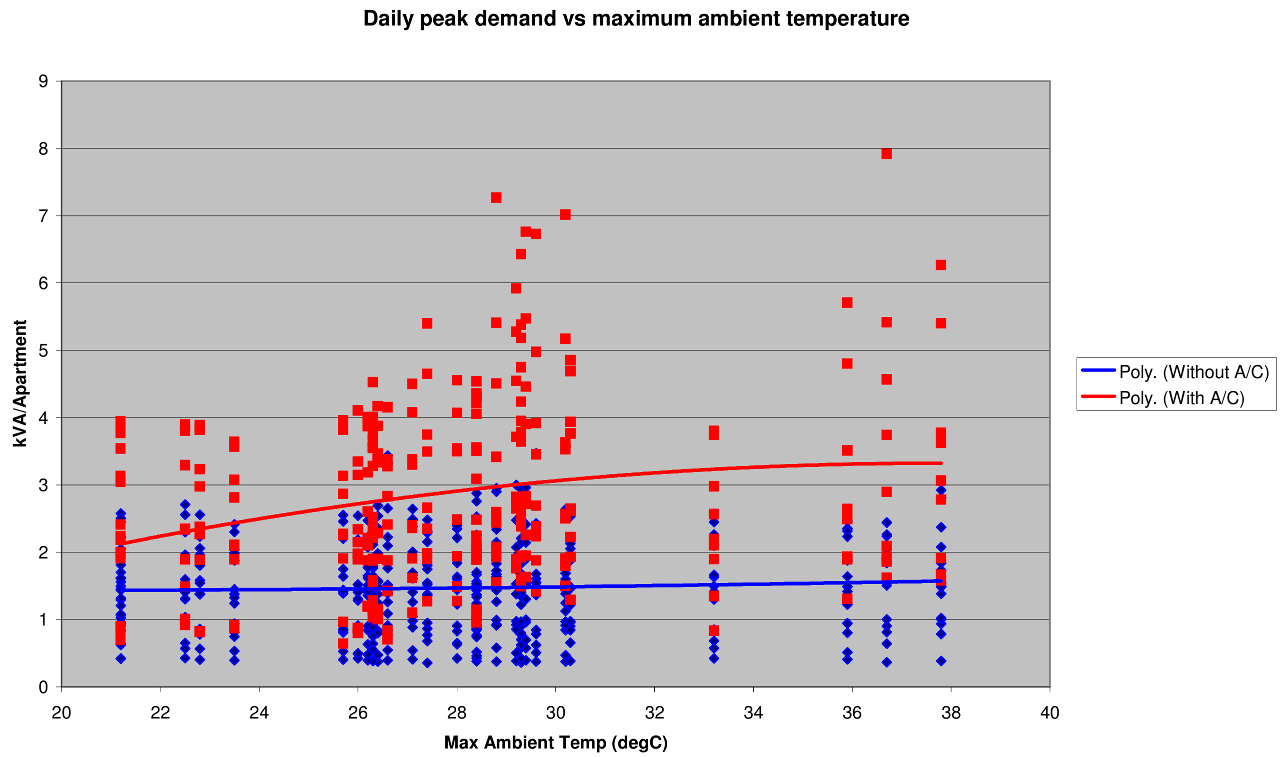


Figure 7: Demand during a hot day and a mild day at Site No. 2 (coastal Sydney)

Daily peak demands, expressed as kVA/apartment have been plotted in Figure 8 (overleaf) against daily maximum ambient temperature for all sites. These results show that, for those sites without air conditioners, the peak demand did not rise significantly with increasing temperature. That is, the average daily peak of about 1.4 kVA/apartment at 21 ^{o}C rises only to 1.6 kVA/apartment at 38 ^{o}C. In contrast, for air conditioned sites, the average daily peak rose to 3.6kVA/apartment at 38 ^{o}C from a level of 2.3 kVA/apartment at 21 ^{o}C.

Air-conditioned sites have a significantly higher average electrical demand even in mild weather when active cooling wouldn't normally be required. One possible explanation for this is that the residents of air-conditioned homes are generally more affluent, and, in addition to air-conditioning, generally have more energy consuming appliances than homes without air-conditioning. Another possibility is that, once air conditioning is installed, occupants will get used to a certain level of comfort and will continue to use this technology, even on relatively mild days.

A further observation that can be made from the demand data is that the rise in demand with temperature for air-conditioned dwellings tends to flatten out at ambient temperatures above 30-32 ^{o}C. This can be seen in Figure 7 with the 2nd order polynomial representing average peak demand of all sites with air conditioning.

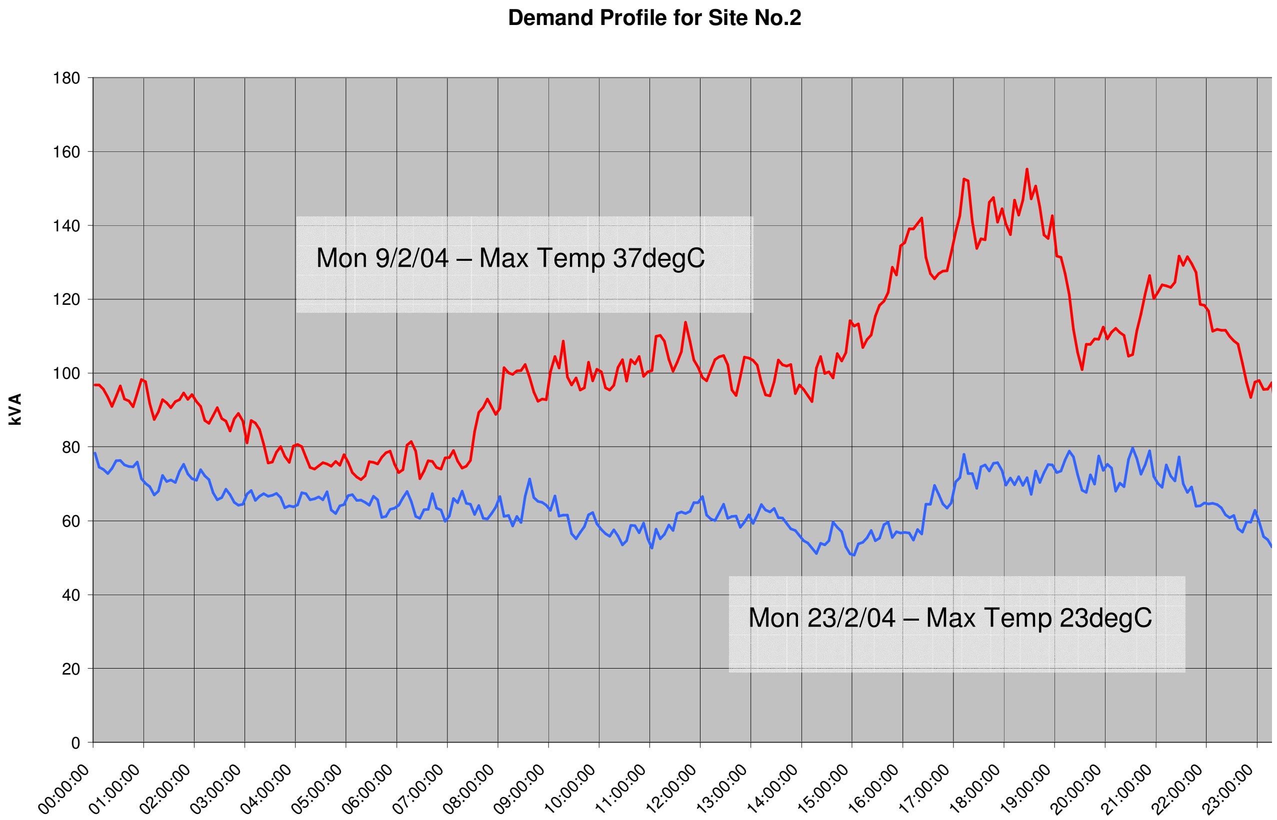


Figure 8: Daily peak demand versus maximum ambient temperature

6 SUMMARY & CONCLUSIONS

6.1 Limitations to study

A number of limitations to this study were identified and are documented below.

6.1.1 Sample size & quality

At the outset of this study, the NSW Department of Infrastructure, Planning and Natural Resources (DOP) selected a range of Sydney suburbs to adequately reflect varying climate zones. DOP then physically inspected representative housing in the suburbs and selected sites to try to get a good cross section of housing luxury level, building age and size. This sample was therefore not randomly selected, and hence unknown skewing of the data and analysis outcomes is to be expected. For example, possible bias towards the more prominent luxury housing estates, might explain why the total annual per capita greenhouse emissions outcome from this study is, at 4.1 tonnes CO_2 per person per year (Table 5), which is higher than the NSW average of 3.3 tonnes CO_2 per person per year.

Future studies should aim to increase the sample size (total number of sites) as well as properly randomise the samples in terms of billing addresses. Furthermore, the number of sites audited in each housing type should reflect the local occupancy rates for each dwelling type. In NSW, 2% of people live in high rise apartments compared to 10.3% of people who live in low rise apartments (ABS Census, 2001). Hence, as is not the case with the present study where the sample size was particularly small for townhouses and villas, the audited low-rise apartments should outnumber their high-rise rise counterparts by approximately five to one.

An under-representation of western Sydney dwellings is also apparent in the present study. This was a largely due to Integral Energy not being contacted early enough to be fully involved with the study. While DOP had originally selected a number of western Sydney locations, EnergyAustralia was unable to gain access to the meter boxes of many of those sites during the peak demand component of the study. In addition, some of the selected western Sydney sites declined to be involved in the study. Once they had been contacted part way through the study to correct this imbalance, Integral Energy were quick to compile a list of western Sydney addresses and to start getting the necessary permissions for energy monitoring and auditing. It was intended to study these sites as Stage 2 of the project, however this stage was unable to be initiated due to the limitations on the project timeframe.

6.1.2 Availability of gas data

Total gas consumption data was provided to the study for the centralised systems, such as central hot water, central pool heating etc. The study did not, however, get access to individual gas consumption records, due to privacy restrictions. In most cases, these individual gas consumptions are likely to be small, eg. cooking and occasionally space heating in comparison to the common area and centralised system demands.

6.1.3 Accuracy of billing data

In some cases, it was difficult to identify all electricity accounts for a given street address. This is because the street address may have been recorded slightly differently in the text field for some of the individual dwelling accounts. This presents a potential source of error in the billing data used in this study.

6.1.4 Challenges of accurately estimating loads without actual logging

It is important to note that, in only 40% of the audited sites, the total energy consumption of the site estimated from the auditor’s reports fell within +/- 20% of the actual billing data recorded by EnergyAustralia. This highlights the difficulty of accurately calculating energy consumption of a building to a reasonable level of accuracy through a simple walk through audit in which plant energy consumption and estimating hours of operation were recorded. It also highlights the need to do more detailed and accurately metered logging of different housing types, to better understand the energy end use in residential buildings.

6.1.5 Calculation of annual greenhouse gas per person emissions

The actual occupancy rates of each building were not assessed in the study, as this would have involved a time- and labour-intensive task of surveying all building inhabitants. Therefore, the annual per capita greenhouse gas emissions were calculated using Sydney average occupancy rates taken from the ABS Census 2001 for each dwelling type rather than the actual occupancy.

6.2 Lessons learned

6.2.1 Recruiting buildings to participate in the study

A total of 100 sites were initially selected to participate in the study. EnergyAustralia contacted either the head of the body corporate or the strata manager, to gain their consent to participate in the study. Permission was sought for access to the site in order to conduct an energy and water audit and also to access the site energy billing data. Great difficulty was experienced in obtaining access permission from several of the building owners, and this consumed much more time and effort than was originally planned for this part of the study.

Some of the challenges faced in gaining the consent included; identifying and making contact with an enthusiastic and responsible site representative; gaining permission from the wider body corporate; and strata managers unwilling to become involved. Offering to return the results of their energy audit back to building owners or representatives in a way that would pinpoint energy saving opportunities, as well as identifying a helpful strata manager that had access to a number of multi-unit sites, were useful strategies for gaining cooperation at many sites.

However, rather than choosing the buildings first and then seeking permission from the owners afterwards, it should be recommended that future studies publicly advertise for participant buildings. By getting building owners who are proactively seeking to be part of the study, this method should ensure that there is an adequate level of co-operation and enthusiasm for the study. However, this method would introduce its own set of sample bias.

6.2.2 On site access to plant rooms and building managers

The consultants involved with the energy audits also found a number of challenges when conducting the audits. These included; difficulty in actually making contact with the identified building contact persons to make appointments; reluctance of some building contacts to participate after initial permission was granted and also the difficulty in accessing locked plant rooms etc. In some instances, a number of site visits had to be made to collect all information. Where it was impossible to access certain areas and equipment, assumptions were made.

Possible solutions for future studies include a greater focus on, and analysis of, billing information only, and a more detailed study (including metering) of a select number of sites that have co-operative building contacts.

6.2.3 Focus on common areas only

The energy consultant’s project brief was originally to focus on the common areas only. This led to some degree of confusion for the consultants, as certain services (such as hot water, cooling and heating systems) can have central, individual, or mixed ownership. Apartment cooling is a good example. Here a water loop cooled system has centralised cooling towers, fans and water circulation pumps, but separate refrigeration compressors in individual apartments. These compressors usually represent the greatest electricity demand and are included in the individual dwelling account bill, however the fan and circulation pump energy can be significant and is billed to a common services account.

The study brief needed to be amended during the project, to include billing data and audit data for individual dwellings. It was, in retrospect, short-sighted not to study the energy consumption of the building as a whole. There is little value in simply comparing the percentage of energy consumed in common areas of different buildings, because each building has its own unique situation, and was often not comparable.

It will be important for future studies to recognise the varying degrees of centralisation and integration of the common area as well as individual apartment services in many buildings and to focus on both the central services and individual apartments’ consumption, to clearly understand the total building energy consumption.

6.2.4 Comparison with other recent energy studies

IPART recently released a study "Residential energy use in Sydney, the Blue Mountains and Illawarra" which looked at the energy consumption of 2000 households. Their comparisons of annual electricity consumption per person showed occupants of apartments consuming less electricity than houses. However this study (which found that common area consumption can be up to 50% of the energy consumption of a building, and impacts occupants through their high body corporate fees) did not attribute common area electricity and gas consumption data to the apartment. It thereby excluded a significant quantity of centralised hot water and HVAC from the individual dwelling energy accounts. It is critical that future studies look at the whole building consumption, including internal apartment consumption and common areas, to fully understand the energy needs of multi-unit dwellings.