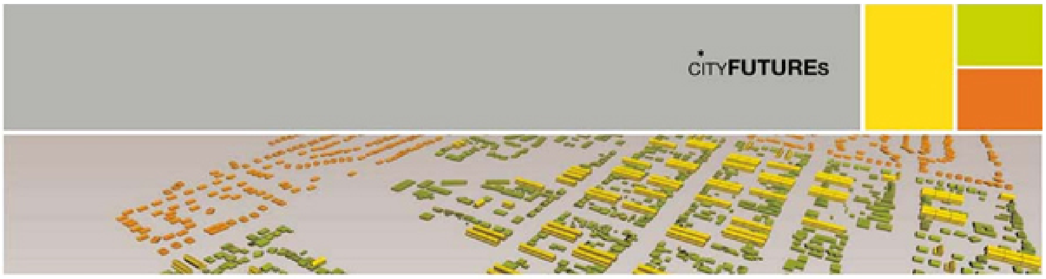

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The Environmental Impacts of Residential Development: Case Studies of 12 Estates in Sydney

Bill Randolph
Darren Holloway
Stephen Pullen
Patrick Troy

City Futures Research Centre
Faculty of the Built Environment
University of New South Wales

Final Report of ARC Linkage Project LP 0348770

Linkage Partner: Landcom

July 2006 (Updated March 2007)

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EXECUTIVE SUMMARY

Objectives and research method

The aim of the research was to make an 'account' of the water and energy consumption of households in different kinds of dwellings in different kinds of developments undertaken by the NSW Landcom since its creation in 1976. The study compared the water and energy consumption of dwellings built on Landcom estates with dwellings built by private developers on comparable estates nearby.

The research therefore allowed an assessment of how far changing building practices over that time have had any discernable effect on household water and energy consumption of those household now living on these estates. This includes the more recent development of larger scale higher density estates on brown-field locations. The research was also undertaken to assess how far new higher density development rated against more traditional and older low density developments in terms of energy and water consumption and overall environmental impacts. There is a considerable literature that argues convincingly that higher residential density delivers better environmental outcomes across a range of factors. This study aimed to assess the validity of such assumptions. Finally, the research allowed some assessment of the role the socio-demographic factors play in influencing observed consumption outcomes of developments characterised by different social profiles. .

The twelve case study areas selected for investigation, including both Landcom and non-Landcom estates, were grouped into five categories reflecting the date of development, ranging from the late 1970s through to more recent developments. Table 1 shows the twelve estates with their locations.

Table 1: List of Landcom and Non-Landcom Case Study Areas

Date of development	Landcom Estate	Comparison Non-Landcom Estate	LGA
Late 1970s	St Clair	Cambridge Gardens	Penrith
Early 1980s	St Andrews	Raby	Campbelltown
Late 1980s/ early 1990s	Glenhaven	West Pennant Hills	Baulkham Hills
Late 1990s	Narellan Vale	Harrington Park	Camden
High density, post 1990	Kings Bay	Liberty Grove Abbotsford Cabarita	Canada Bay Canada Bay Canada Bay

Research Method

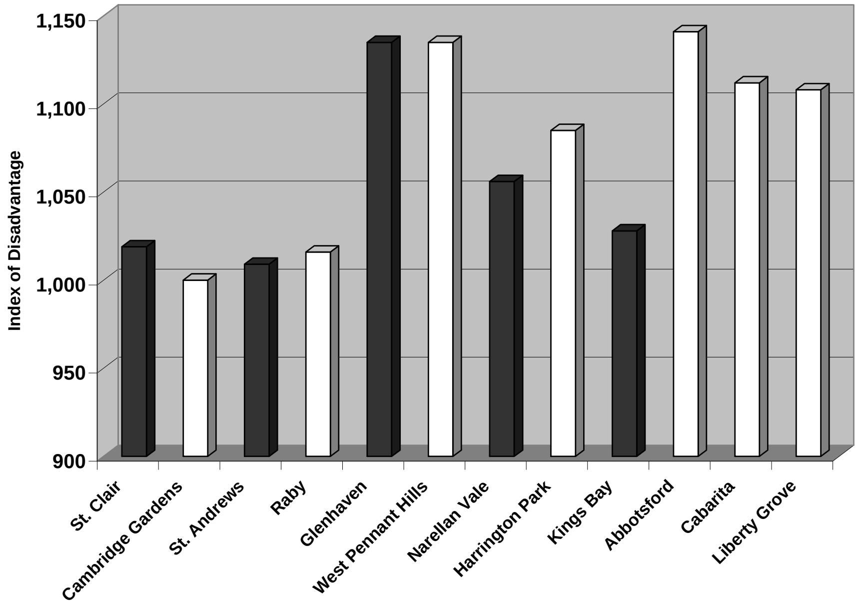
The basic research approach has been to establish the water and energy 'accounts' in terms of kilolitres (kl) of water and gigajoules (GJ) of energy for the dwellings in Landcom estates compared with other developments, both on a household and per capita basis. Energy consumption was measured in two forms. The first, operational energy, comprises the energy (electricity and gas) used on a day-to-day basis by those living in the property. The second, embodied energy, refers to the energy used in the production of the building materials used in the building’s construction as well as its life-cycle energy consumption profile. Finally, an estimate of the greenhouse gas emissions, measured by annualised CO_2 generation, of each estate was undertaken to make some assessment of their overall environmental impact.

The research was undertaken by identifying a series of five estates which were developed by Landcom over the last quarter of a century. Census Collectors' Districts (CCDs) that contain wholly or predominantly Landcom dwellings were identified for each estate to create a 'Landcom set'. At the same time, seven comparable estates developed at the same time by other developers were also identified to create a 'non-Landcom set'. The properties in each set of CCDs were then listed by address. The lists of properties were then used to extract data from the NSW Department of Lands property record database about the nature of the development, its area (built and site), materials of construction, value, etc. In addition, fieldwork on each estate collected information on the building type and materials for each dwelling.

Address level water and energy consumption data for each dwelling on the case study estates were then obtained from the relevant water and energy supply utilities. Data from the 2001 ABS Census for the estates was derived from the ABS’s CDATA statistical package, from which broad socio-demographic profiles of each estate were built up. The Census data provided a basis by which to explore the socio-demographic correlates with different consumption patterns at the CCD level. A summary of four key indicators of socio-demographic profiles for the 12 estates is shown in Figures 1 to 4.

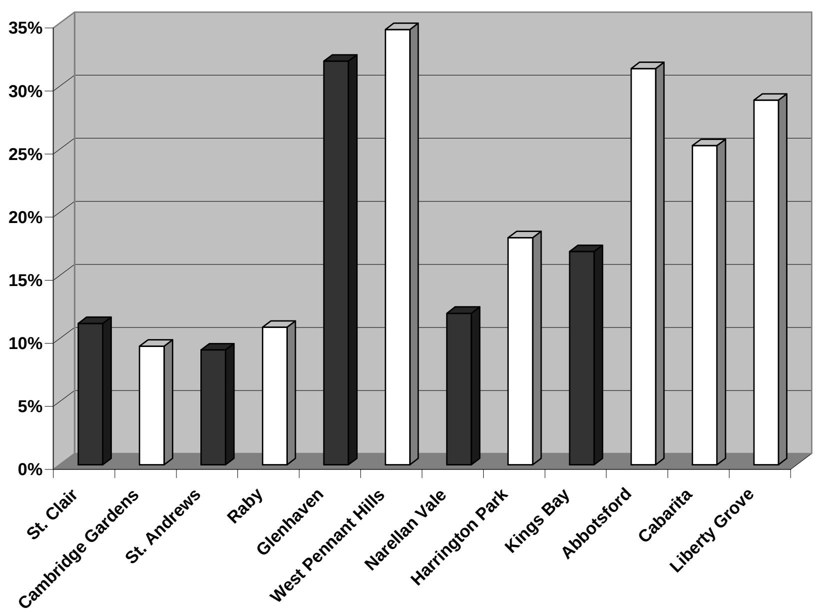
Data on dwelling level water consumption and water infrastructure was provided by Sydney Water and dwelling level electricity and gas data by Energy Australia, Integral Energy and AGL. Data from the NSW Department of Lands property record database was matched for each address to provide a basic property file for all the dwellings in the sampled estates including information on plot area, land value and tenure. Floor area data for selected properties was provided by the local councils in which the case study areas were located. Road information was obtained from the local councils where available, or was deduced from aerial photographs. The research team also conducted a ‘drive by’ survey of all properties in the case study areas to identify the dwelling type of each property and note details of materials and construction method.

Figure 1: Index of Disadvantage, case study estates (2001)



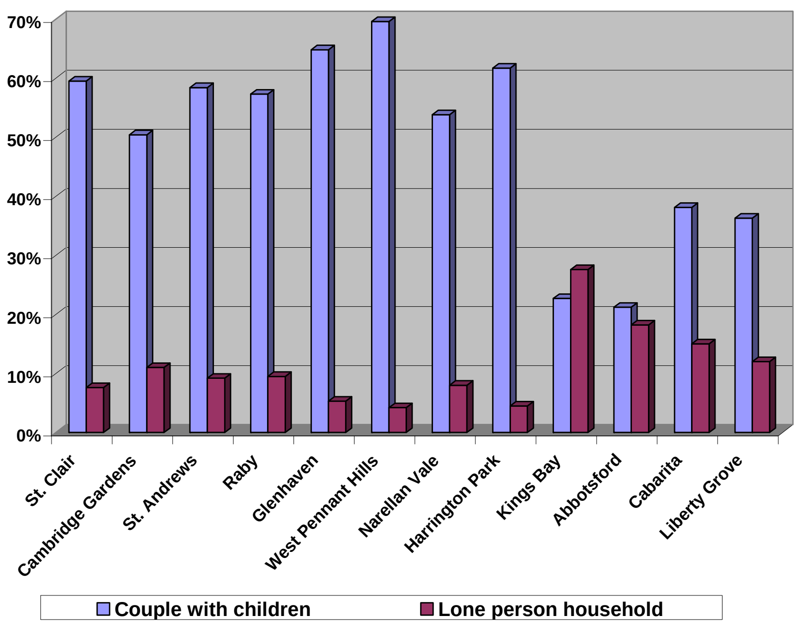
Source: ABS Census 2001 CDATA

Figure 2: Percentage of households with weekly incomes of over $2,000, case study estates (2001)



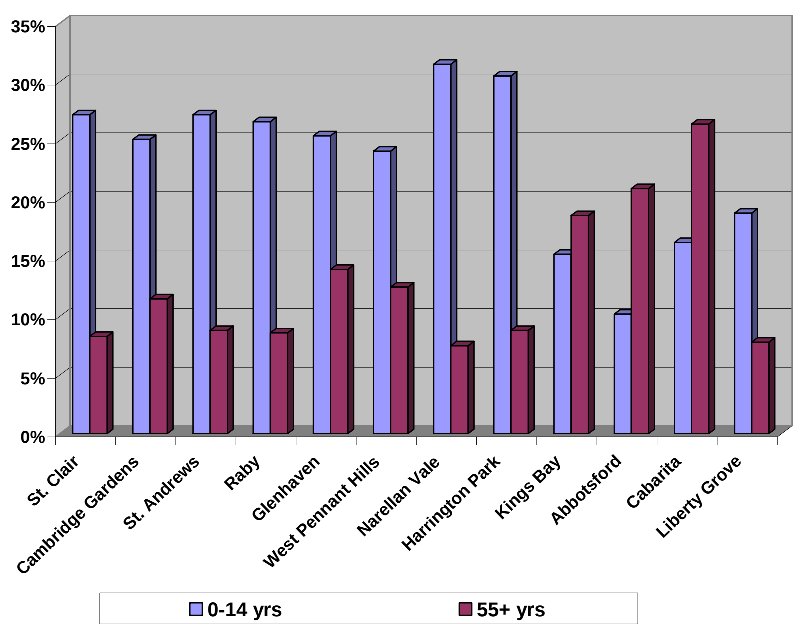
Source: ABS Census 2001 CDATA

Figure 3: Percentage of households in key household types, case study estates (2001)



Source: ABS Census 2001 CDATA

Figure 4: Percentage of individuals in key age cohorts, case study estates (2001)



Source: ABS Census 2001 CDATA

MAJOR FINDINGS

Water Consumption

In 2003 the highest consumers of water, measured in kilolitres per year (kl), across the case study areas were households in Glenhaven and West Pennant Hills, while the lowest consuming households were in Kings Bay and Abbotsford. The predominantly higher density areas (Kings Bay, Abbotsford, Cabarita and Liberty Grove) tended to have lower household consumption than those households in detached housing areas. In general, the higher density estates recorded lower per capital water consumption than the detached house estates, although the differences were not large. Across the twelve case study areas the per capita water consumption averaged 102kl per year, comparable to the results presented by other researchers for this period (Troy et al 2005, ABS 2004). Note that these data refer to the period just before the current water restrictions were introduced in 2004. Current water usage levels are likely to be lower than these especially for properties with gardens. Sydney Water figures indicate that overall weekly water consumption in 2006 for the Greater Sydney region was some 12.9% lower than pre-2004 ten year average.[1]

The main socio-economic factor influencing water consumption appeared to be the income profile of the estate, with the higher income and older age profile estates of Glenhaven and West Pennant Hills both recoding by far the highest household and per capita water consumption (133kl and 121 kl per year respectively). Average consumption across the other six low density estates was broadly comparable, with the two oldest estates recording somewhat higher levels of water use, possibly a reflection of the more mature garden areas on these estates.

Overall, the case study areas predominantly developed by Landcom outperformed their nearby comparator estates in terms of water consumption, except for Glenhaven. which had the highest water consumption of all the case study areas. The predominantly higher density Landcom development of Kings Bay had lower consumption than two of the three comparator high density estates. The Landcom developments of Narellan Vale and St Andrews generally had lower rates of water consumption than the nearby comparator estates of Harrington Park and Raby, while Landcom's oldest development at St Clair had higher levels of household water consumption than its comparator of Cambridge Gardens, but once household size was taken into account, the difference was negligible.

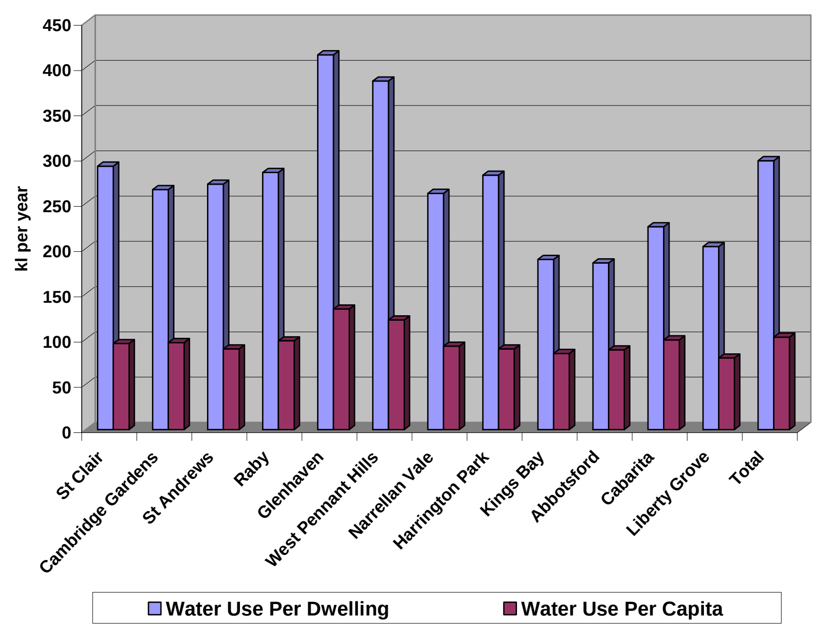
[1] *Mandatory Water Restrictions: Water consumption since the introduction of water restrictions*, http://www.sydneywater.com.au/Publications/FactSheets/WeeklyWaterUsageAndTargets.pdf#Page=1, Downloaded 25 February 2007.

Table 2: Summary of average annual water consumption for case study areas

	Average Water Consumption per Dwelling 2003 (kl)	Average Water Consumption per House 2003 (kl)	Average Water Consumption per Multi-Unit Dwelling 2003 (kl)	Average Water Consumption per Capita 2001 (kl)
Low Density Estates				
Late 1970s				
St Clair	**291**	**291**	**NA[1]**	**95**
Cambridge Gardens	265	264	NA[1]	96
Early 1980s				
St Andrews	**271**	**271**	**NA[1]**	**89**
Raby	284	286	195	98
Early 1990s				
Glenhaven	**414**	**415**	**NA[1]**	**133**
West Pennant Hills	385	387	243	121
Late 1990s				
Narrellan Vale	**261**	**263**	**173**	**92**
Harrington Park	281	281	NA[1]	89
High Density Estates				
Kings Bay	**188**	**NA[1]**	**180**	**84**
Abbotsford	184	NA[1]	183	88
Cabarita	224	248	194	99
Liberty Grove	202	NA[1]	200	79
Total	**297**	**305**	**191**	**102**

1. Note that estimates deleted due to small number of dwellings

Figure 5: Average annual water consumption per dwelling and per capita for case study areas (Kl per year)



Energy Consumption: Operational Energy

Electricity Consumption

Electricity consumption, measure don kilowatt hours (kwt) in 2004 also varied by the socio-demographic status of the estates, and once again, the highest consumption levels were recorded in Glenhaven and West Pennant Hills (Table 3). These two areas had household electricity consumption rates that were significantly higher than the rest of the case study areas. But the key finding here was that variations in energy consumption between the case study estates were not related to dwelling densities. While the lowest household level energy consumption figures were recorded for the high density estates of Kings Bay and Liberty Grove, the other two high density estates of Abbotsford and Cabarita recorded energy consumption rates as high as, if not higher than, the other detached housing estates. On a per capita basis, high density Abbotsford had the highest rate of electricity consumption, followed by Glenhaven and West Pennant Hills. The lowest per capita consumers were low density Narrellan Vale and high density Kings Bay.

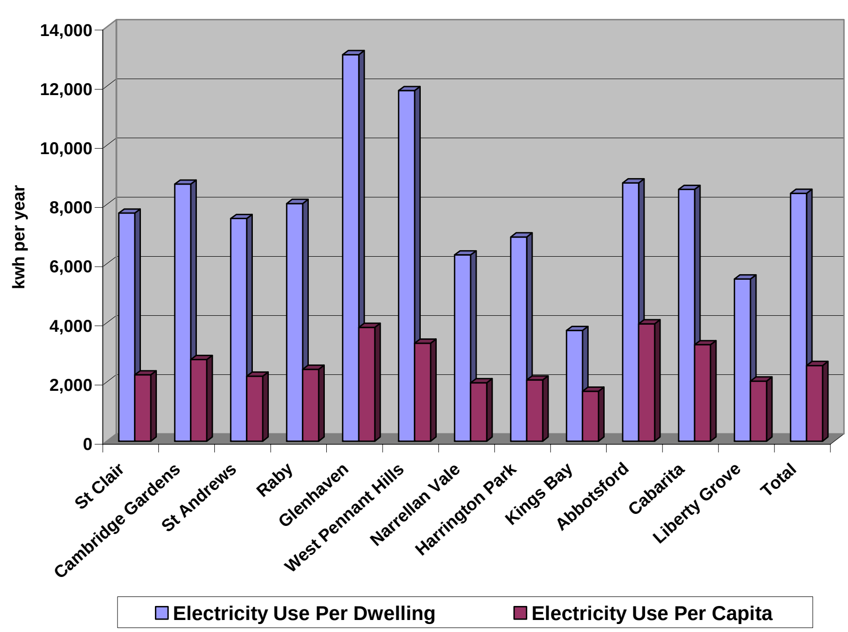
Again, as with the findings for water consumption, the Landcom developments generally had lower rates of household electricity consumption than their nearby comparator estates with the exception of Glenhaven. Landcom's Kings Bay development recorded the lowest electricity consumption levels of all the case study areas and Landcom's developments of Narellan Vale, St Clair and St Andrews generally had lower rates of electricity consumption than the nearby estates of Harrington Park, Cambridge Gardens and Raby. The results presented here, in terms of average consumption figures, are comparable with those found by IPART (2004c) for Sydney as a whole.

Table 3: Summary of average annual electricity consumption

	Electricity Consumption per Dwelling 2004 (kwh)	Electricity Consumption per House 2004 (kwh)	Electricity Consumption per Multi-Unit Dwelling 2004 (kwh)	Electricity Consumption per Capita 2004[1] (kwh)
Low Density Estates				
Late 1970s				
St Clair	7,708	7,708	NA[2]	2,241
Cambridge Gardens	8,686	8,686	NA[2]	2,757
Early 1980s				
St Andrews	7,523	7,522	NA[2]	2,193
Raby	8,032	8,100	6,873	2,426
Early 1990s				
Glenhaven	13,061	13,062	NA[2]	3,842
West Pennant Hills	11,848	11,907	10,438	3,309
Late 1990s				
Narrellan Vale	6,293	6,295	6,214	1,973
Harrington Park	6.9	6,900	NA[2]	2,066
High Density Estates				
Kings Bay	3,740	7,540	3,152	1,685
Abbotsford	8,724	NA[2]	8,688	3,966
Cabarita	8,505	8,445	8,610	3,259
Liberty Grove	5,480	NA[2]	5,392	2,030
Total	**8,375**	**8,524**	**6,679**	**2,553**

1. Electricity consumption is for 2004 with household size obtained from the 2001 Census
2. Note that estimates for these cells have been suppressed due to the small number of dwellings

Figure 6: Average annual electricity consumption per dwelling and per capita for case study areas (Kwh)



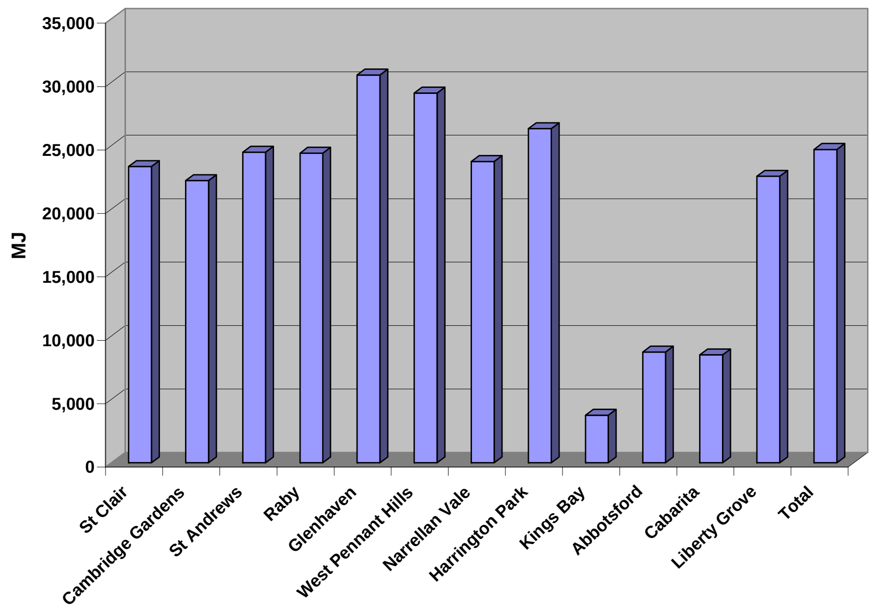
Gas Consumption

Overall, gas consumption levels, as measured in mega joules (MJ), were comparable across the paired estates, with, once more, the high income estates recording highest use. Average annual gas consumption for dwellings with a gas supply was highest in Glenhaven and West Pennant Hills, followed by Harrington Park. As far as Landcom developments were concerned, Narellan Vale had lower average levels of gas consumption than nearby Harrington Park, while St Clair had higher levels of gas consumption than its comparator estate of Cambridge Gardens. The Landcom development of Kings Bay also had lower levels of gas consumption than similar, nearby higher density developments, although there were few households with gas in these areas. Landcom's St Andrews development had similar average levels of gas consumption to nearby Raby. The results presented here are comparable, although slightly higher, than those found by IPART (2004c) for Sydney as a whole. It was not feasible to estimate per capita use for this aspect of the study due to the impossibility of matching gas users with household numbers (both water and electricity services were used by all households in the case study areas, while gas was not). It should also be noted that use of gas was less common in higher density case study areas, which means some of the result for these estates suffer from relatively few case numbers.

Table 4: Average annual gas consumption

	Gas Consumption per Dwelling 2004 (MJ)
Low Density Estates	
Late 1970s	
St Clair	23,350
Cambridge Gardens	22,238
Early 1980s	
St Andrews	24,475
Raby	24,403
Early 1990s	
Glenhaven	30,562
West Pennant Hills	29,141
Late 1990s	
Narrellan Vale	23,745
Harrington Park	26,338
High Density Estates	
Kings Bay	3,740
Abbotsford	8,724
Cabarita	8,505
Liberty Grove	22,576
Total	**24,693**

Figure 7: Average annual gas consumption per dwelling for case study areas (MJ)



Energy Consumption: Embodied Energy

The analysis of embodied energy undertaken in this study provides a comparison between case study areas at a level of detail not previously attempted in analysis of this form of energy use. The approach adopted here has been to construct a life cycle estimate of the energy consumption in different dwelling configurations for the estates.

The total embodied energy per dwelling, measured in giga joules (GJ) in the case study areas was highest in the higher income detached housing areas of West Pennant Hills and Glenhaven, while total embodied energy was lowest in the higher density case study areas, particularly Kings Bay (Table 5). This difference is enhanced when infrastructure such as roads and water systems are taken into account.

The main findings with respect to embodies energy are twofold. Firstly, the embodied energy used in the materials for construction (i.e. the ‘as-built’ embodied energy) is significantly higher in high density developments in Abbotsford and Cabarita. This is mainly due to the extra reinforced concrete used in the construction of basement car parks and reinforcing required for development on these complex and sloping sites.

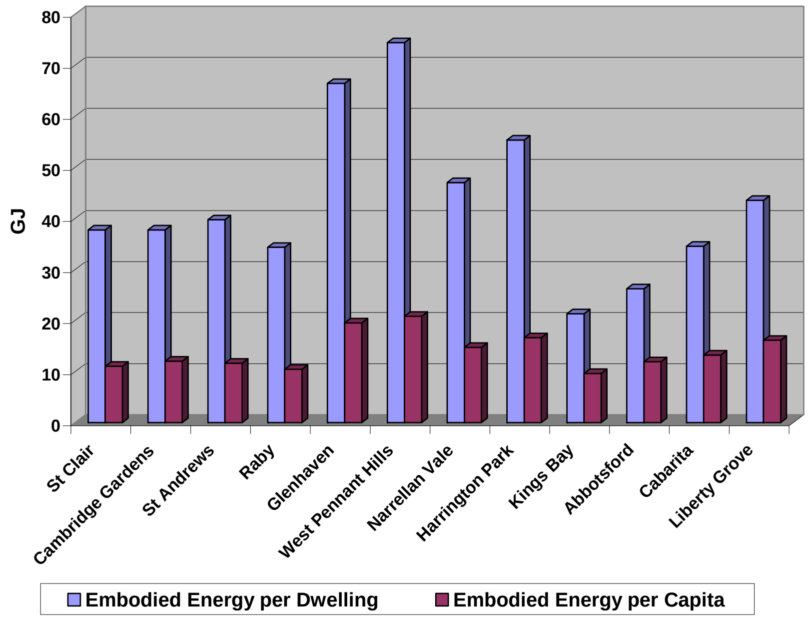
Secondly, once the household size of the dwellings in the case study areas is taken into account, again, density of development is not a predictor of embodied energy patterns. While Glenhaven and West Pennant Hills still have the highest total embodied energy per capita of the case study areas, largely due to the large size of houses in these areas, the high density areas of Cabarita, Abbotsford and Liberty Grove have total embodied energy per capita generally higher than the four oldest low density estates in the study. It appears that more modern building designs and standards have resulted in no benefit in terms of life cycle embodied energy consumption.

Overall, with the exception of St Andrews, all Landcom developments had lower levels of embodied energy than their nearby comparator estates. Again, St Clair and Cambridge Gardens had relatively similar levels of embodied energy. Like the consumption variables presented above, the Landcom development of Kings Bay had the lowest levels of embodied energy of all the case study estates.

Table 5: Summary of embodied energy estimates (GJ)

	Total Embodied Energy per Dwelling (lifetime)	Total Embodied Energy per Capita (lifetime)	Total Embodied Energy per Dwelling (annualised)	Total Embodied Energy per Capita (annualised)
Low Density Estates				
Late 1970s				
St Clair	2420.6	704	37.7	11
Cambridge Gardens	2463.9	782	37.7	12
Early 1980s				
St Andrews	2547.6	743	39.7	11.6
Raby	2212.8	669	34.3	10.4
Early 1990s				
Glenhaven	4421.9	1301	66.4	19.5
West Pennant Hills	4874.8	1362	74.4	20.8
Late 1990s				
Narrellan Vale	3027.7	949	47	14.7
Harrington Park	3540.8	1060	55.3	16.6
High Density Estates				
Kings Bay	1424.2	642	21.3	9.6
Abbotsford	1762.4	801	26.2	11.9
Cabarita	2337.1	895	34.5	13.2
Liberty Grove	2984.9	1106	43.5	16.1

Figure 8: Average total embodied energy per dwelling and per capita for case study areas (GJ)



Carbon Dioxide Equivalent Emissions

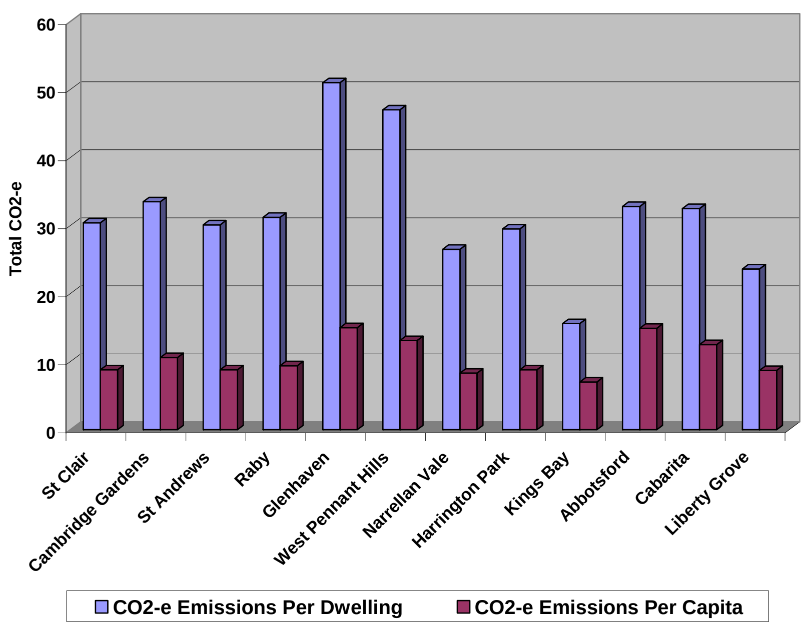
Not surprisingly, the highest carbon dioxide emissions in the case study areas were recorded in Glenhaven and West Pennant Hills (Table 6). The emission intensities recorded in these two areas were also significantly higher than for the other case study areas. Two of the higher density case study areas (Abbotsford and Cabarita) had high carbon dioxide equivalent (CO_2-e) emissions which were similar to most of the detached housing areas. Nevertheless, the Landcom development of Kings Bay had the lowest level of CO_2-e emissions. Except for Glenhaven, all the Landcom developments had lower levels of CO_2-e emissions compared with their nearby comparator estates.

The CO_2-e results presented in this report are comparable with those found by other researchers (Troy et al 2002 and 2003, SSROC 2005) if the figures in Table 6 are adjusted to include transport. While this study excluded transport energy from the calculations due to the complexity of the estimation required (Perkins 2001), previous research has found that transport energy accounts for approximately 40% to 45% of total household energy (Troy et al 2002 and 2003, SSROC 2005). The inclusion of this factor alone would account for the differences between the findings of this report and those of the earlier research quoted above.

Table 6: Estimates of annual carbon dioxide equivalent emissions for case study areas (t CO_2-e)

	Annual CO_2-e emissions - electricity	Annual CO_2-e emissions - gas	Annual CO_2-e emissions - embodied energy	Annual CO_2-e emissions - total (per dwelling)	Annual CO_2-e emissions - total (per capita)
Low Density Estates					
Late 1970s					
St Clair	25.4	1.9	3.1	30.4	8.8
Cambridge Gardens	28.6	1.8	3.1	33.5	10.6
Early 1980s					
St Andrews	24.8	2	3.3	30.1	8.8
Raby	26.4	2	2.8	31.2	9.4
Early 1990s					
Glenhaven	43	2.5	5.5	51	15
West Pennant Hills	39	2.4	5.6	47	13.1
Late 1990s					
Narrellan Vale	20.7	1.9	3.9	26.5	8.3
Harrington Park	22.7	2.2	4.6	29.5	8.8
High Density Estates					
Kings Bay	12.3	1.6	1.7	15.6	7
Abbotsford	28.7	1.9	2.2	32.8	14.9
Cabarita	28	1.7	2.8	32.5	12.5
Liberty Grove	18	1.8	3.8	23.6	8.7

Figure 9: Average annual carbon dioxide equivalent emissions per dwelling and per capita for case study areas (CO_2-e)



Conclusions

Socio-demographic drivers of domestic resource consumption

The results presented here indicate that the levels of energy and water consumption and the broader environmental impacts of residential development appear to be relatively independent of development density or age of the development, especially when allowance is made for occupancy levels. Older estates in this study did not perform significantly worse than more recent estates. Indeed, they consumed less water and energy and their overall greenhouse impacts were lower on a per capita basis than some of the more recent developments. The four higher density estates included in the study, all developed in the last decade, also showed highly variable outcomes in terms of environmental impacts and in many cases performed less well against low rise and older estates. So the assumed environmental bonus from higher density development does not appear to be supported from this evidence.

The study points to the fact that factors beyond the physical aspects of dwelling type are important in determining the environmental ‘stressors’ emanating from domestic property. At its simplest, the general socio-demographic profiles of the various case study estates, especially household size and income levels, appeared to be the most cogent explanation of the main differences in the data. This is especially true of the two higher income estates in the study, Glenhaven and West Pennant Hills, which both consistently recorded water and energy consumption levels significantly higher than the other case study estates and had the highest overall environmental impacts, as measured by estimated greenhouse gas emissions. But at the same time, two of the four higher density developments, Abbotsford and Cabarita, had comparably high greenhouse impacts in terms of their estimated total greenhouse gas emissions. Here, high average household incomes and relatively older population profiles may be the contributing features that might account for some of this variation.

Relevance of the Research to Landcom

This research points to a number of findings that are relevant to the ongoing work by Landcom to achieve high environmental outcomes for its developments:

- Firstly, the methodology employed in this research was developed to show how comparable ongoing monitoring of newly developed estates’ environmental impacts over time could be incorporated into Landcom’s forward planning process. Landcom could apply this method to develop a comprehensive monitoring system to gather comparable data on the environmental implications of all its developments.

- Secondly, the data generated by such a monitoring system could be incorporated into project assessment processes to assess the likely long term environmental impacts of master plan designs for new developments. In particular, it would provide Landcom with a means to review of the efficacy of measures it has taken in the design and development of its estates to reduce their environmental impacts. The study will therefore serve as a benchmarking exercise for future measuring of energy and water consumption profiles on Landcom estates that can be used to monitor trends and assist in the evaluation of the effectiveness of sustainability policies and initiatives.

The methodology developed in this research was reliant on accurate dwelling level data collated from a number of key energy and water utilities and government departments. A number of potential issues with such an approach were encountered and successfully overcome by the research team during the course of the research. These included the very differing data collection facilities employed by each organisation, leading to technical issues in data transfer; very different understandings of what data could be used for, leading to at times lengthy negotiations over access and use; and data protection and confidentiality issues, including commercial in confidence issues, which meant protocols needed to be established to ensure data was used appropriately and in a way that did not compromise data protection legislation; As a major government agency, Landcom would be well placed to negotiate on these issues with other government entities and the utility companies to ensure ongoing assistance and data access.

Finally, water and energy consumption is influenced by the behaviour and attitudes of households which are outside the direct influence of Landcom. However, the profiling method used in this research could be used in conjunction with household interviews within Landcom developments to better understand the complex influences of water and energy consumption and provide input into future residential developments. This type of analysis could be used by Landcom to assist in enhancing planning policies in NSW.

Data Issues

There are a number of issues that need to be addressed in order to make the method used in this project more efficient. First, it was clear from the negotiations with the organisations involved in this research project that the Privacy Act in NSW is ambiguous. Outside of medical and health research the Privacy Act is inadequate for dealing with environmental planning research. Because this has important implications for future research of his kind on environmental sustainability, not least if Landcom were to develop a comparable environmental monitoring approach for its developments, this issue would need to be fully addressed.

Secondly, in the course of assembling the various data streams used in this study, the researchers were faced with a range of significant spatial information issues that need to be addressed at the State level in NSW before such analyses become more routine. There is a lack of consistency in data collected by agencies in NSW, particularly with respect to data standards for street addresses. The lack of data stored centrally in NSW and readily available to researchers is also problematic. Further, data for this project was not collected from some Councils due to third party and licensing restrictions impinged on councils by the providers of spatial information. If urban and environmental modelling of this kind is going to be an important planning tool for the future developments, then spatial information needs to be more readily available at address level and coordinated for better access in a more efficient manner.

Future Research

This research found that water and energy consumption was highest in the case study areas of Glenhaven and West Pennant Hills. Whether this was associated with their higher socio-economic status, a different set of attitudes and behaviour, larger dwelling and household sizes, or a combination of these, could not be directly ascertained from this research. Although the detached housing areas had higher household consumption than multi-unit dwellings, once account was taken of the household size the situation became more complex, with some of the higher socio-economic higher density areas having higher per capita rates of consumption than some detached areas. As noted above, the next step would be to combine research of this kind with information from household surveys within the case study areas to better understand the range of factors that influence water and energy consumption at the household level.

This study has developed a method using data currently held by a number of organisations to examine energy and water consumption and environmental outcomes in different forms of development. This method could be adapted to other cities in Australia and to other developments, including non-residential developments for use as an urban/environmental monitoring tool. Other sources of data such as transport related energy consumption could be included with this method, for example transport consumption, to develop appropriate modelling systems.

1. INTRODUCTION

This report examines the water and energy profiles of domestic dwellings in twelve selected residential housing estates in Sydney, including traditional low density greenfield housing estates and higher density estates in ‘brownfield’ locations. The selected estates include a mix of matched Landcom and non-Landcom estates in order to:

- examine whether Landcom developments are more energy and water efficient than nearby developments, making comparisons in terms of age, geographic location and socio-economic status composition;
- establish and develop a method for the collection of energy efficiency information so that Landcom can continue to monitor the energy and water profiles of their developments as part of their triple bottom line reporting requirements;
- examine the energy and water profiles of different built forms in the Sydney metropolitan area more generally. The methodology developed in this study can also be adapted and applied to other areas in Sydney and other cities in Australia;
- provide data that are convertible to carbon dioxide equivalent (CO_2-e) emissions (i.e. greenhouse gas equivalent emissions) for comparison with other studies on greenhouse gas emissions from the residential sector.

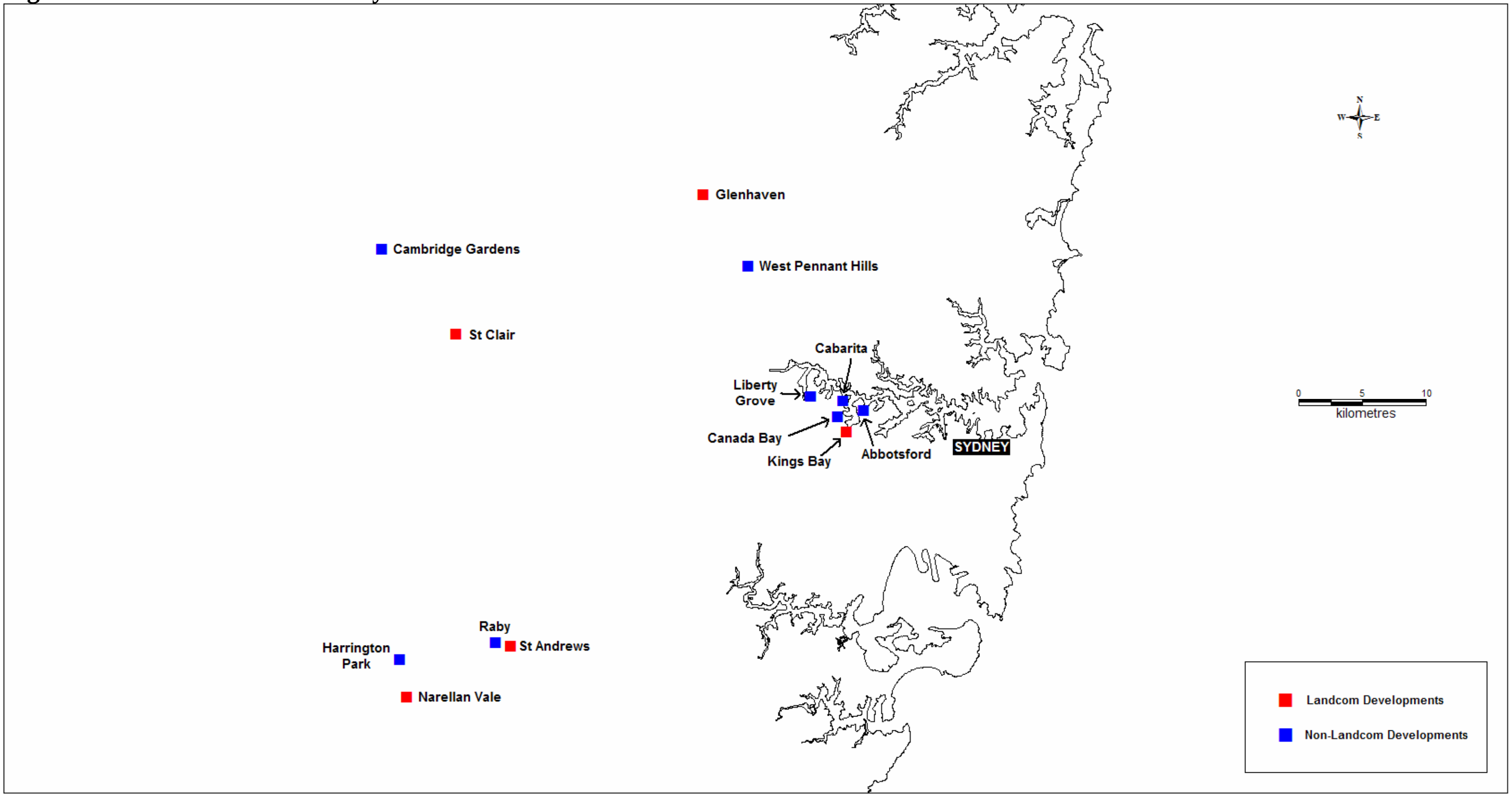
The estates (‘developments’) studied were selected in consultation with Landcom to reflect a range of development periods, from the early days of Landcom in the mid-1970s to more recent estate developments. One of the Landcom developments was also predominantly a higher density redevelopment area. Comparators estates of similar age and located close to Landcom developments were then identified to compare energy and water use. The list of estates selected is presented in Table 1.1 and their locations are shown in Figure 1.1. For the high rise developments, three comparator non-Landcom estates were selected to provide a greater range of properties for effective comparison.

The report continues in Chapter 2 with an overview of recent research into energy and water consumption and embodied energy in Australia and makes some comments on recent Sydney research in order to compare the results obtained in this study. Chapter 3 provides a detailed description of the research method, data and information sources used in this project. Chapter 4 presents the socio-economic characteristics of the selected case study areas in Sydney and their importance in determining levels of energy and water consumption. Chapters 5 through 7 examine the water, electricity and gas consumption in the case study estates while Chapter 8 profiles the energy embodied in the dwellings and infrastructure of the case study areas. Chapter 9 summarises the results of the different water and energy profiles established during the study before going on to examine how the method used during the project can be utilised by Landcom and others in the future.

Table 1.1: List of case study areas indicating dwelling mix and date of development (n.b. Landcom estates are shown in bold)

Case study area	Approximate development date	Average floor area (m^2)	Dwelling type	Council area
Low Density Estates				
St Clair Cambridge Gardens	Late 1970s	**167** 181	Mainly single storey detached dwellings in outer suburbs.	Penrith
St Andrews Raby	Early 1980s	**174** 153	Mainly single storey detached dwellings in outer suburbs.	Campbelltown
Glenhaven West Pennant Hills	Late 1980s/ early 1990s	**313** 333	One and two storey large detached houses.	Baulkham Hills
Narellan Vale Harrington Park	Late 1990s	**201** 237	One and two storey large detached houses in outer suburbs.	Camden
Higher Density Estates				
Kings Bay Liberty Grove Cabarita Abbotsford	All late 1990s All medium to high density developments located at inner suburbs	**192 (Houses)** **50 (Flats)** 245 225 (Houses) 120 (Flats) 107	Two to four storey terraced and three storey walk-ups. Mainly two storey detached houses. Two storey detached houses and five storey apartments. Four storey apartment buildings.	Canada Bay

Figure 1.1: Location of case study areas.



2. BACKGROUND

2.1 Introduction

Levels of water and energy consumption in Australia have been studied in some depth over the past thirty years, with a significant amount of research focusing on Sydney. Some of this research has also been complemented with studies of embodied energy. In order to set the context for the research reported on here, as well as to provide some comparative information on which the results of this research can be benchmarked, this section provides a summary of recent research into both operational energy and water consumption and embodied energy in Australia, with a particular concentration on Sydney. The reviews of literature on water consumption and energy use are presented separately. This distinction will be maintained throughout the following report.

2.2 Water Consumption

The current drought in Sydney has focussed much attention on the issue of water consumption in the city. As dam levels continue to decline and water restrictions are in force, questions are being asked as to how can Sydney manage its demand for water in a more efficient manner. The factors influencing water consumption in Australia have been studied for several decades, notably by the Metropolitan Water Authority (1985), the Department of Water Resources Victoria (1986) and Dandy (1987).

Earlier research on water use was generally limited to metropolitan wide studies, which provides an overview of the situation, but does not allow more detailed understanding of the drivers of consumption at the neighbourhood or household level. More recent studies continued this trend (see eg IPART 2004 a and b). In contrast, the most recent studies have included research into the influence of different built forms on consumption as well as identifying variations in consumption spatially across the metropolitan area (Eardley, et al, 2005; Troy et al. 2005).

These studies have produced a range of findings. In 2003 the Independent Pricing and Regulatory Tribunal (IPART) in NSW surveyed 2,600 households in Sydney as part of a sophisticated exploration of the socio-demographic determinants of water and energy consumption (IPART 2004a, b and c). IPART randomly selected 2,000 households from the metropolitan area for the study, along with an additional sample of 600 households from low income areas. Results from the survey suggested the importance of household size, income, housing tenure, age of dwelling and number of water-consuming services in the dwelling for predicting water consumption. IPART found that on average, households in separate houses consumed most water: 304 kl per year compared with 211kl for those in semi-detached dwellings, 192kl for those in low rise flats (flats in a block of less than four storeys) and 148kl for those households in high rise flats (flats in a block of 4 or more storeys). Once the size of household of the households was taken into account a different picture emerged, however. IPART concluded that, on average, water consumption per capita in Sydney was 92kl per year but that per capita water consumption by those who owned their homes outright was 104kl per person per year. Households purchasing their home used 82kl and 78kl per person per year respectively while private renters in houses used 85kl per person per year compared with 62kl per person per year for private renters in flats. Public housing tenants living in houses recorded the highest consumption of all tenure groups, consuming 106kl per person per year, compared with 92kl per person per year for public tenants in flats. IPART therefore concluded that the type of dwelling was *not* the most important factor in determining water consumption.

The Australian Bureau of Statistics (ABS) found different results again from an audit of water usage in all States and Territories in 2000-01 (ABS 2004). The ABS estimated that in NSW average per capita water consumption was 101kl per annum, a figure slightly higher than that found in Sydney by IPART (92kl). Another recent study conducted in Sydney by Eardley et al. (2005) found yet a different figure, concluding that per capita water consumption was 71kl per year. This is significantly lower than that estimated by the ABS and IPART. The explanations for these differences are not clear.

A recent study by Troy et al. (2005) provides a useful basis for comparison. In 2005, Troy and his colleagues analysed water consumption levels in approximately 25,000 households in a stratified random sample of 140 CDs across Sydney. The areas studied were selected by predominant dwelling type (separate houses, semi-detached dwellings, low rise flats and high rise flats). The types of dwellings were also selected so as to reflect the different geographical locations and socio-economic characteristics of residents of each of these dwelling types across Sydney.

The Troy et al study found that, in 2001, of all dwelling types average water consumption in separate houses was the highest at 310kl per year, followed by semi detached dwellings (235kl per year) and flats (195kl per year). Once the household size of the case study areas was taken into account the picture changed. According to Troy et al. (2005), per capita water consumption for separate houses in 2001 was 103kl per year, closely followed by flats (95kl per year) and semi-detached dwellings (92kl per year). Overall, average per capita consumption in the case study areas selected for the Troy study was 98kl per annum, higher than that found by IPART but lower than the ABS finding.

The results of the study by Troy et al were therefore comparable to those of the IPART study. Both pieces of research concluded that tenants tended to use larger volumes of water than owners and purchasers on a per capita basis. The Troy et al study also concluded that the higher the land value of the dwelling, the higher the water consumption. The study further suggested that between 1987 and 2003 average annual water consumption per square metre of a dwelling varied between 0.37kl and 0.51kl. These findings strongly suggest that there is no straightforward association between dwelling type and water consumption outcomes, an issue the research presented in this report further explores at the local level.

2.3 Energy Consumption

Published studies of energy consumption in Australia, notably those by Poulsen and Forrest (1988), Bartels (1988), and Bartels et al. (1985 and 1995), have tended to focus on demand for electricity rather than gas. As with water research, most of the research on energy consumption has generally been focused on the metropolis as a whole rather than adopting a more disaggregated spatial approach. Only in more recent years has research been directed to better understanding the energy demands of different types of dwellings and different consumption patterns across different geographical areas.

In Sydney, the study most relevant for the project reported on here was that conducted by IPART in 2003 (IPART 2004c). The IPART study indicated that, in 2002-2003, average electricity consumption in the greater Sydney area was 7,539 kilowatt hours (kwh) and average household gas consumption was 21,000 megajoules (MJ). Household size and dwelling type were both important determinants of energy use: higher energy consuming households tended to have more members and to live in houses. However, single person households had the highest per capita consumption, followed by couple-only households, single-parent families and two-parent families. IPART found that households who live in detached houses, semi-detached dwellings and townhouses used 74% more electricity than those in multi-unit dwellings. But once household size was taken into account, IPART found that houses used only 18% more electricity on a per capita basis than did multi-unit dwellings. IPART further contended that renters are more likely than owner-occupiers to use less electricity.

Much is being assumed about the environmental benefits of a shift to higher density dwellings in current metropolitan planning proposals. However, conclusive research to substantiate these claims remains elusive. For example, Myors, *et al*¸ (2005) have shown that *per capita* greenhouse emissions from high rise flats in NSW, at 5.4 tonnes of CO_2 per year, are significantly higher than those for other forms of housing and are substantially higher than the NSW average of 3.1 tonnes per year. While not specifically focusing on dwelling type *per se*, research by Foran (2006) and colleagues at the ANU has show household greenhouse emissions in Canberra and Perth, based upon an assessment of total household energy consumption, is higher in inner city locations compared with suburban locations. This analysis includes both consumed energy for power and transport, but also embodied energy consumption in consumables and the buildings. Foran's analysis suggests strongly that urban density is positively related to total greenhouse gas emissions, with the implication that higher density areas *less* environmentally sustainable. At a broader national scale, Lennox and Turner (2005) found some correlation between total domestic energy use (including stationary and transport energy consumption) and affluence when measured across 80 Australian settlements (including Sydney) although climate was also thought to be important. There was little obvious relationship between settlement size and levels of domestic water consumption. Such broad scale analyses are therefore inconclusive.

Finally, in a review of recent research on the relationship between residential density and non-transport energy use, Wright (2006) summarises the general trends evidenced to date:

- Inner metropolitan medium density housing consumes less operational energy (i.e. energy consumed within the home on an on-going basis), than low density urban fringe development;
- High density, high rise development consumes more operational energy than medium or low rise development;
- Energy use in outer urban and lower density development is lower when measured on a per capita basis.

Therefore the evidence is growing that higher density does not necessarily mean developments are more environmentally sustainable on energy efficiency grounds, although the results of research depend on how the energy consumption is measured and at what scale. The research presented in this report adds further to this body of evidence.

2.4 Embodied Energy

Embodied energy is the total energy expended in the manufacture and fabrication of materials and includes all activities which contribute, both directly and indirectly, to the construction process. Hence, the embodied energy of a building includes all the energy used to manufacture and transport the construction materials and components as well as the on-site construction energy used. For whole-of-life estimates, ‘embodied energy’ also includes the energy embodied in materials used in later maintenance and refurbishment of a building.

Consideration of embodied energy is an important part of a more holistic analysis of energy consumption in the built environment. Whereas the energy consumption of buildings has conventionally focused on annual operational energy, a life cycle approach considers total energy consumption, including the energy embodied in the materials as outlined above. After operational energy, embodied energy is the most significant component of life cycle energy consumption of buildings, although it should be noted that there may be a relationship between high operational energy consumption and low embodied energy and vice versa.

Consideration of the amount of energy embodied in buildings has become more important as a result of concern about high greenhouse gas emissions associated with the manufacture of building materials and their relationship with climate change. Minimising total greenhouse gas emissions therefore requires more comprehensive analysis of energy consumption in the build environment, including embodied energy.

Interest in measuring embodied energy first derived from work carried out by Stein and colleagues several decades ago (Stein, Serber and Hannon, 1976). That team surveyed energy used in the U.S. construction industry using input-output analysis. Since then, research has focused on refining techniques to determine the embodied energy of construction materials and buildings as well as estimating the energy consumption, including embodied energy, of whole areas within towns and cities. In particular, Perkins (2001) has compared two different styles of housing development in Adelaide and considered energy consumption arising from transport use by the occupants of the houses, operational energy consumed in the houses and the embodied energy of the dwellings and local infrastructure such as roads. Troy et al. (2002) also recently carried out a pilot study of six areas in Adelaide and compared their relative water and energy consumption, including embodied energy. From a different perspective, Lenzen et al. (2004) recently analysed the energy requirements including embodied energy of Sydney households using input-output analysis. This study argued that lifestyle, socio-demographic factors and the degree of 'urbanity' all have consequences for total energy use. It found that incorporating both the direct energy consumed by households in the home with indirect uses, such as travel and the energy embodied in the goods and services consumed by households, energy use per capita was higher in the inner and more density developed areas of Sydney compared to the middle and outer areas. These results, together with those of Foran and colleagues noted above, throw further doubt on the notion that there is any simple trade off between urban density, built form and energy efficiency.

3. RESEARCH METHOD

3.1 Selection of Case Study Areas

The project was designed to examine both operational (water and energy) consumption and embodied energy used in twelve matched Landcom and non-Landcom housing estates in Sydney. Census collector districts (CDs) corresponding to these twelve estates were identified from the 2001 Census of Population and Housing in order to provide contextual socio-demographic profiles for each estates. The areas selected were designed to reflect the main periods of estates development since the 1970s and to allow a comparison of the water and energy use of Landcom's estates with that of similar estates developed in the same areas at the same time and for the same socio-demographic group by private developers. Eight of the estates were predominantly comprised of low density house dwellings. A further four case study areas were selected to compare the performance of predominantly higher density housing estates, of which one was developed by Landcom and three by other private sector developers. The latter provided a more rigorous assessment of the performance of higher density estates against which the high density Landcom development could be benchmarked.

The twelve case study areas were chosen and these are listed in Table 1.1. The areas which were composed of detached houses varied in size, but typically contained 1000 – 2000 houses except for St Clair which contained over 5,800 houses. The higher density developments in the Canada Bay council area each contained approximately 300 to 400 dwellings. The older houses in the Penrith and Campbelltown council areas were of modest size on large land lots located in the outer suburbs. More recent developments in the Baulkham Hills and Camden council areas comprised much larger houses with more elaborate external design features particularly in the case study areas of Glenhaven and West Pennant Hills. Case study areas located in the inner suburban council area of Canada Bay are much higher density developments and include detached houses, town houses and apartments. St Clair, St Andrews, Glenhaven, Narellen Vale and Kings Bay are all Landcom developments. Table 1.1 also shows the average floor areas of dwellings in the various case study areas as determined from samples of the limited property records available from local government councils.

A list of the Census CDs comprising the areas is provided in Appendix 1. The number of dwellings in the case study areas is presented for 2001 in Table 1.2 (in this table, as following tables, row data referring to the five Landcom estates are shaded). The table illustrates the difficulty in establishing actual dwelling counts for the estates. Data derived from the Census relates to mid-2001 and does not include properties for which Census records are missing or data was not collected on Census night. The Sydney Water data relate to mid-2003 and is based on all properties to which a water supply is connected. It is therefore likely to be more reliable and was taken as the dwelling basis of aggregated computations of total consumption in each area. However, in the case of multi-unit dwellings, Sydney Water often only records one billing address, rather than all units within the building. Hence the much lower counts of multi-unit dwellings in the latter data set. We have therefore estimated average water consumption for multi-unit dwellings by dividing total consumption per

CD by the number of multi-unit dwellings identified in the Census. While this may be less than completely accurate, it is by far the most accurate estimate possible. This problem does not arise for energy as individual dwellings are separately billed. It is also apparent from Table 3.1 that counts in some cases are very low, especially for multi-unit dwellings in the eight low density estates. The results for these cases have been suppressed in the tables presented in the report.

Table 3.1: Number of dwellings by type in case study areas as found in the Sydney Water Database and by the 2001 Census

	Sydney Water Database 2003		Census of Population and Housing 2001	
	Single Dwellings	**Multi-Unit Dwellings**	**Separate Houses**	**Multi-Unit Dwellings**
Low Density Estates				
Late 1970s				
St Clair	5,883	7	5,856	31
Cambridge Gardens	689	6	683	6
Early 1980s				
St Andrews	1,537	4	1,530	56
Raby	1,842	36	1,788	114
Early 1990s				
Glenhaven	1,276	6	1,288	77
West Pennant Hills	2,404	44	1,229	107
Late 1990s				
Narrellan Vale	2,177	55	2,047	127
Harrington Park	1,028	0	899	3
High Density Estates				
Kings Bay	55	259	55	253
Abbotsford	2	385	3	427
Cabarita	206	0	218	224
Liberty Grove	19	8	18	186
Total	**37**	**319**	**55**	**334**

3.2 Data Collection Methods

The list of CDs comprising the case study areas was provided to Sydney Water who then identified all the properties in each CD from their property address database. These addresses were then matched to the individual water consumption data for each dwelling. Energy Australia and AGL then added the electricity and gas consumption measures to the record for each property. A list of addresses was also supplied to Integral Energy, who unfortunately could provide data only at the CD and not at the address level. Addresses in the CDs served by Integral Energy were therefore assigned a CD level average for their electricity consumption for the purposes of the analysis. This was adequate for the aggregate analysis but did not permit the same detailed comparisons as for households using Energy Australia and AGL services.

Local councils and Sydney Water provided information on the buildings and infrastructure in the case study areas to enable estimation of the energy embodied in the developments in each CD (for further details see Chapter 8 below). Cadastral maps and road polygon layers for direct input into a GIS system were obtained from Baulkham Hills, Penrith and Campbelltown Councils. Road polygon layers from Canada Bay and Camden Council areas were digitised from aerial photographs (except in Abbotsford where this was not possible), as GIS layers were not available. Sydney Water provided water and sewer pipe information from their GIS system.

Councils also provided access to development application data so that floor area information could be obtained. In each of the case study areas, except Penrith, a sample of properties was used to gauge floor area information for the entire case study area (see Chapter 8 for more detail on this). In Penrith, all development applications in each of the case study areas were provided for this purpose.

3.3 'Drive-by' Surveys

To assess the nature of construction techniques and building materials used in the case study estates, a 'drive-by-survey' was conducted for each of the twelve case study estates. Further information on the construction methods and materials used in the four higher density developments was obtained from physical documentations for each development held by Canada Bay Council and Landcom.

The drive-by survey also allowed the research team to resolve ambiguities in the classification of dwellings types between that used by Sydney Water and that employed by the Census. This related to the definition of detached and semi-detached housing, which were not differentiated in the Sydney Water database.

3.4 Data Analysis and Interpretation

Data used in this project was obtained from a number of sources. The databases used had been developed by the relevant organisations for different purposes which meant that the date and length of record available varied accordingly but were the best that could be obtained. The water consumption data obtained from Sydney Water covered the period 1987 to 2003 for all properties except that properties registering usage of less than 25 kl of water consumption per year were excluded as they were considered to be unoccupied. Energy data collected from Energy Australia was for 2003-04 for electricity consumption and 2002-03 to 2003-04 for gas. Integral Energy provided electricity consumption data at the CD level from 2000 to 2004. AGL provided gas consumption data from the first quarter 2004 to the first quarter of 2005. Floor area data provided by the local Councils was correct at mid-2005 and water and sewer pipe information as well as construction data (e.g. wall, roof and floor materials) were also correct at mid-2005.

3.5 Conversion of Results to Greenhouse Gas Emissions

A major advantage of the method developed in this research to measure the energy usage profiles of different types of dwelling is that energy related emissions, including gas and electricity use as well as embodied energy estimates, can be converted to greenhouse gas equivalent emissions (CO_2-e). To make the conversions, the data was divided into either 'delivered' or 'primary' energy. 'Delivered' energy refers to energy delivered directly to the household (see Troy et al. 2003), i.e. the kilowatt hours (kH) of electricity or megajoules (MJ) of gas that a household uses or consumes and for which it pays. 'Primary' energy, on the other hand, refers to the full cost of providing energy to a household as it includes both the 'delivered' component itself and the energy used in the manufacture and transmission of the 'delivered' energy. Thus, 'delivered' electricity is consumed directly by households, but the production of this electricity may be hundreds of kilometres away and leads to significant energy costs because of the need for transmission, making the cost of the production of energy significantly higher than that of the energy 'delivered' energy for consumption.

4. A SOCIAL PROFILE OF CASE STUDY AREAS

4.1 Introduction

This section uses a range of variables derived from the 2001 Census of Population and Housing and data supplied by the energy and water utilities in Sydney to present a brief socio-demographic profile of the twelve case study estates[2]. The discussion reveals the different social characteristics of the case study areas which assist in understanding the differential social context in which the analysis of water and energy consumption can be placed. Summary profile data for the twelve case study estates are present in Figures 4.1 to 4.9. While we do not explicitly attempt to correlate the outcomes of the water and energy analysis with these socio-demographic variables in the following analysis (it was not considered appropriate given the limited number of case study areas and the problems of ecological fallacy using aggregate spatial data of this kind), the different social profiles of the estates groupings will be drawn on to inform the interpretation of the results.

Overall, the estates reflect a range of socio-economic characteristics, as summarised by the scores on the ABS Index of Socio-economic Disadvantage (Figure 4.1), although none fall below the average score of 1000. A more detailed description of the data is presented in Appendix 2, together with detailed tabulations from which the figures presented here are derived. The analysis indicates how closely matched in socio-demographic terms the pairings of low rise estates area. However the greater housing market variations in the four higher density estates are associated with a much greater variety in the socio-demographic structure.

4.2 The Low Density Estates

Late 1970s

- ***St Clair (Landcom): 5,960 households***
- ***Cambridge Gardens: 692 households***

These case study areas are the oldest in the study and are located in Penrith, a generally lower value outer suburban area. They are characterised by families with children and younger adults, but also couple only households and lone parents. Moderate to lower incomes predominate. Half the properties are being purchased with a relatively low proportion of renters. The employment profile of adult workers shows lower proportions of managers, administrators and professionals, and higher proportions of lower skilled, trade people and manual sector workers compared to the other casse study estates. Unemployment rates are among the highest of the twelve estates.

The population is predominantly Australian born and the levels of mobility are relatively low. The ABS Index of Disadvantage is around the Australian average, but among the lowest of the twelve estates in this study. The housing markets in these two estates are dominated by house properties and home ownership, with around three in ten being outright owners and just under half home buyers.

[2] Dwelling numbers here are therefore based on Census data, rather than Sydney Water dwelling numbers (see Table 3.2 and Chapter 2 for a discussion on this).

Early 1980s

- ***St Andrews (Landcom): 1,605 households***
- ***Raby: 1,930 households***

Located in Campbelltown, also a generally low value suburban local government area, these two estates were built in the early 1980s and share many of the social characteristics of St Clair and Cambridge Gardens. Households are marginally less likely to be outright owners than for St Clair and Cambridge Gardens, as would be expected in a slightly younger estate, and the proportion of renters is slightly higher. Again, the suburbs are overwhelmingly comprised of house properties with a tenure structure very similar to that of the late 1970s low rise estates, although rental and semi-detached housing account for a marginally higher proportion of the housing than for the earlier two suburbs.

Early 1990s

- ***Glenhaven: 1,383 households***
- ***West Pennant Hills: 1.343 households***

Located in Baulkham Hills, these two very similar sized estates represent a much higher income socio-demographic than the previous four estates. Their main defining feature is the proportion of households with incomes over $2,000 per week, which exceeds 30% in both cases, by far the highest of all eight low density estates in the study, and the highest Index of Disadvantage scores (both over 1,100). The occupational structure of adults bears this out, with the highest proportions of individuals employed in managerial, administrative and professional work of all the eight low density case study areas, exceeding 50%.

Households are also predominantly couples with children, emphasising the family orientation of these estates. However, the age structure shows a much larger proportion in the mature 35 to 54 age range compared to all the other case study areas. There are noticeably few people in the 25 to 34 age range, a reflection of the more mature family structure. The proportion of older people is also the highest among the low density estates.

The high income and more mature profile of the population is reflected in the higher proportion of outright owners which is again, by far the highest among the low rise estates at around 50% of al households. The corollary is that few households rent.

Late 1990s

- ***Narellan Vale: 2,199 households***
- ***Harrington Park: 915 households***

The most recently constructed estates before the 2001 census, these two estates, both located in Camden occupy a middle ground between the social profiles of the four moderate income lower density estates in Penrith and Campbelltown and that of the higher income Baulkham Hills case study estates. This intermediate social position is evidenced by the Index of Disadvantage at around 1,050, and income profiles with a much greater proportion of households in the middle income categories. In contrast to the other low density estates, the household structure indicates a predominance of younger families with the proportion of the population aged under 15 exceeding 30% in both estates, the highest of all twelve case study areas, and low percentages of older people. Economic activity rates are high, with relatively high proportions of working adults employed in managerial, professional work, as well as in trades and advanced clerical/service work, compared to the Campbelltown and Penrith case study estates.

By far the largest proportion of households are buying their homes (60%), the highest of all twelves case study estates, again emphasising the young family profile, but also reflecting the more recent development of the estates.

4.3 The High Density Estates

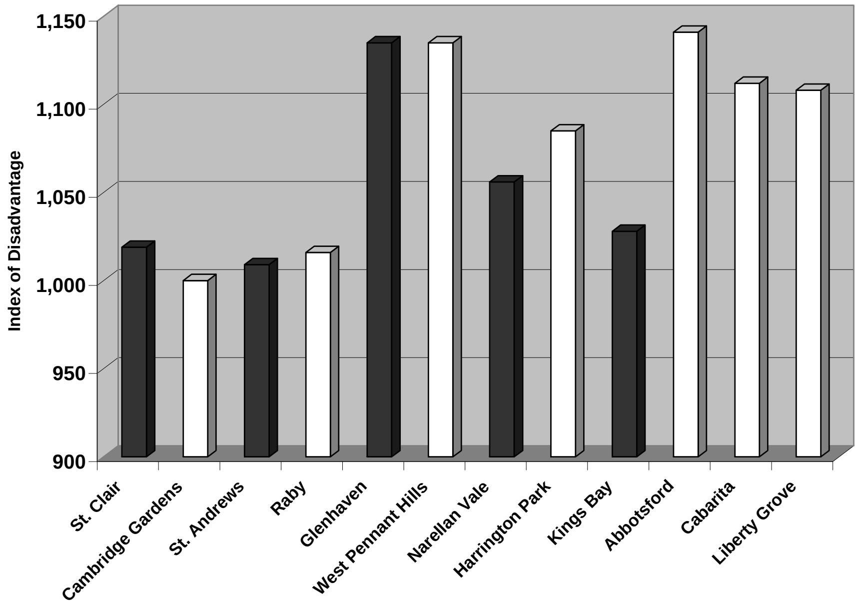
The four higher density case study areas show a rather divers setoff social profiles, which reflects more varied housing markets structures. Only Kings Bay and Abbotsford are predominantly comprised of flats. Semi-detached housing is the predominant build form in Liberty Grove while there is a mix of housing types in the Cabarita case study area.

Housing tenure is also much more mixed, with high proportions of rentals in Liberty Grove and Kings Bay, but ownership predominating in Abbotsford and Cabarita, the latter with very high proportions of outright owners compared to the other estates, suggesting a more mature ‘empty nester’ population. The result is a more varies socio-demographic outcome across these estates.

While the Abbotsford, Cabarita and Liberty Grove have among the highest proportions of household incomes in the highest categories compared to the other case study estates. But they also have among the highest proportions of households on lowest incomes. The latter may reflect the higher proportions of single person households, rather than low incomes *per se* (indeed, the Index of Disadvantage scores are uniformally high for these estates).

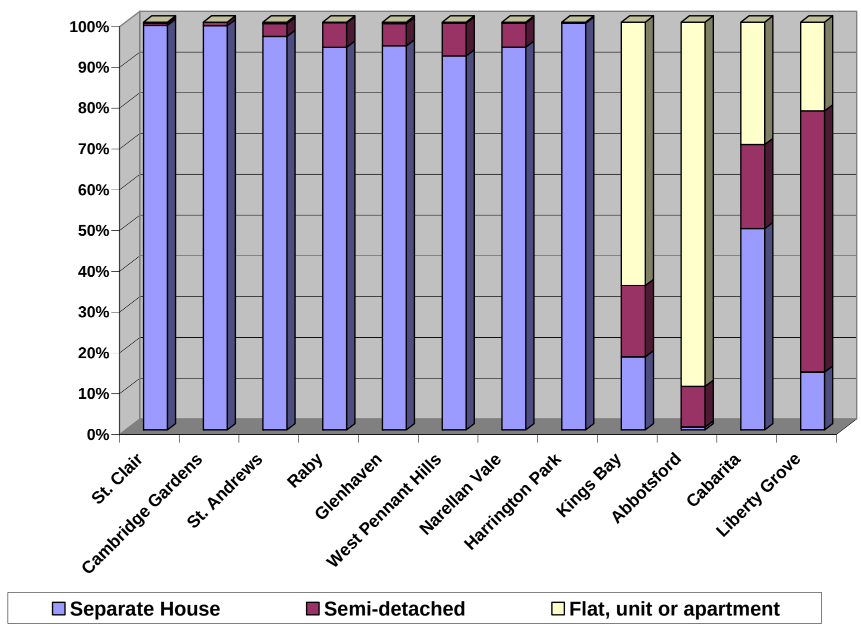
In contrast to the low density estates, couples with children are in the minority and as a result, children comprise a relatively small proportion of total population on all the estates. High proportions of older people indicate a strong empty nester component to the populations of these estates, although Liberty Grove is an exception with a more family orientated profile compared with the others, possibly a reflection of the high overseas born population on the estate. In line with the higher proportions of higher income households, all four estates record high percentages of working adults in professional, administrative and managerial occupations (ranging from 56% to 65% of the total).

Figure 4.1: Index of Disadvantage, case study estates (2001)



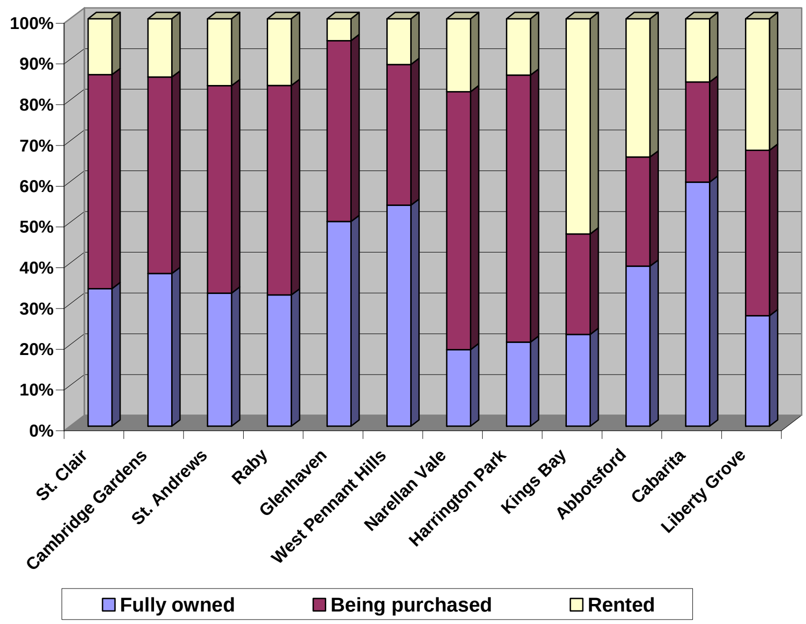
Source: ABS Census 2001 CDATA

Figure 4.2: Dwelling type profile, case study estates (2001)



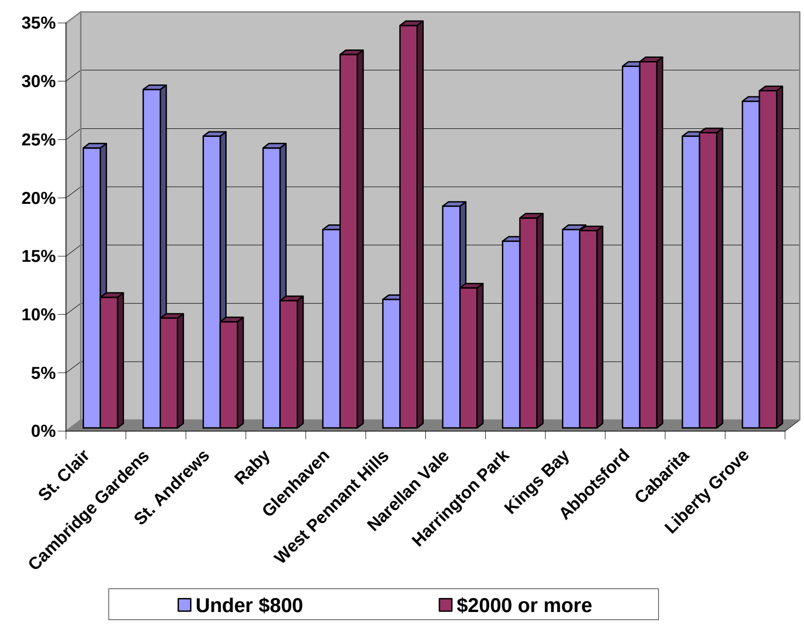
Source: ABS Census 2001 CDATA

Figure 4.3: Percentage of households by main tenure categories, case study estates (2001)



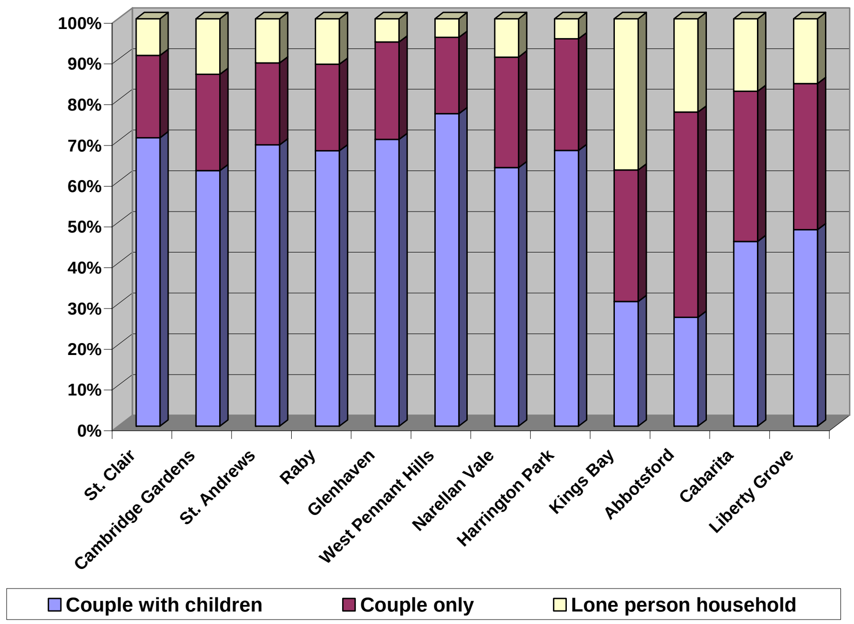
Source: ABS Census 2001 CDATA

Figure 4.4: Percentage of households with weekly incomes of over $2,000 or under $800, case study estates (2001)



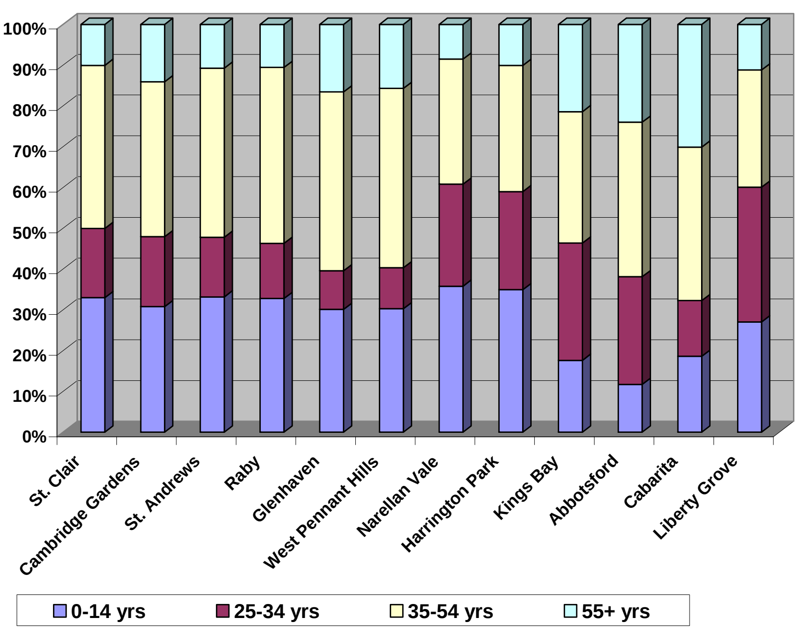
Source: ABS Census 2001 CDATA

Figure 4.5: Percentage of households in key household types, case study estates (2001)



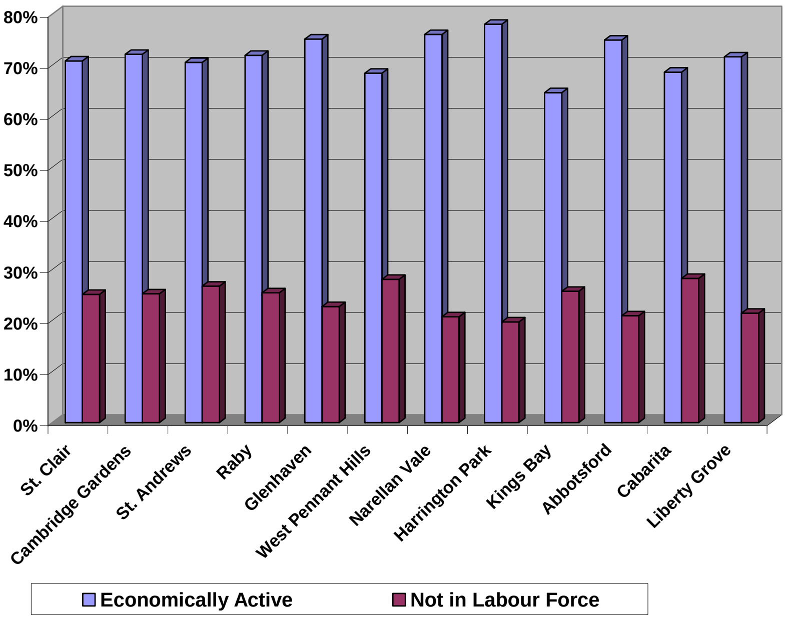
Source: ABS Census 2001 CDATA

Figure 4.6: Percentage of individuals in key age cohorts, case study estates (2001)



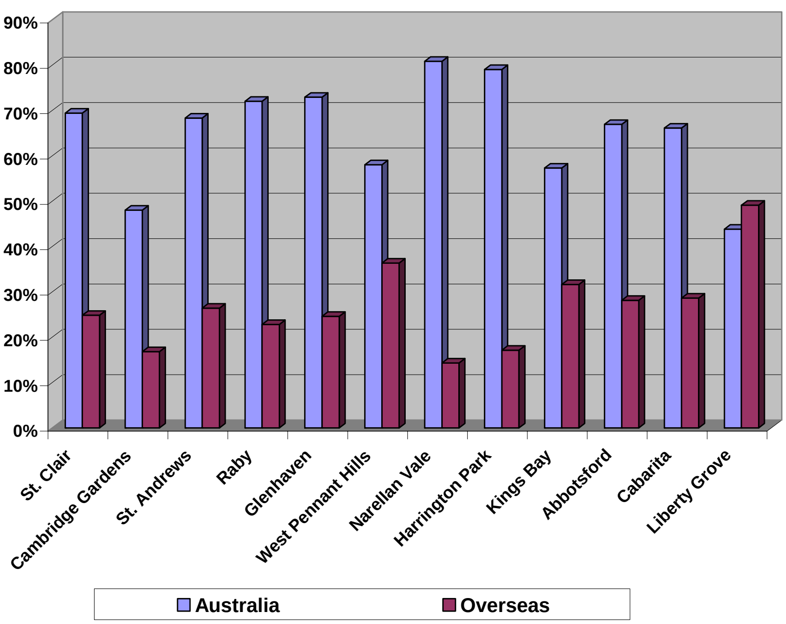
Source: ABS Census 2001 CDATA

Figure 4.7: Percentage of individuals economically active or not in the labour force, case study estates (2001)



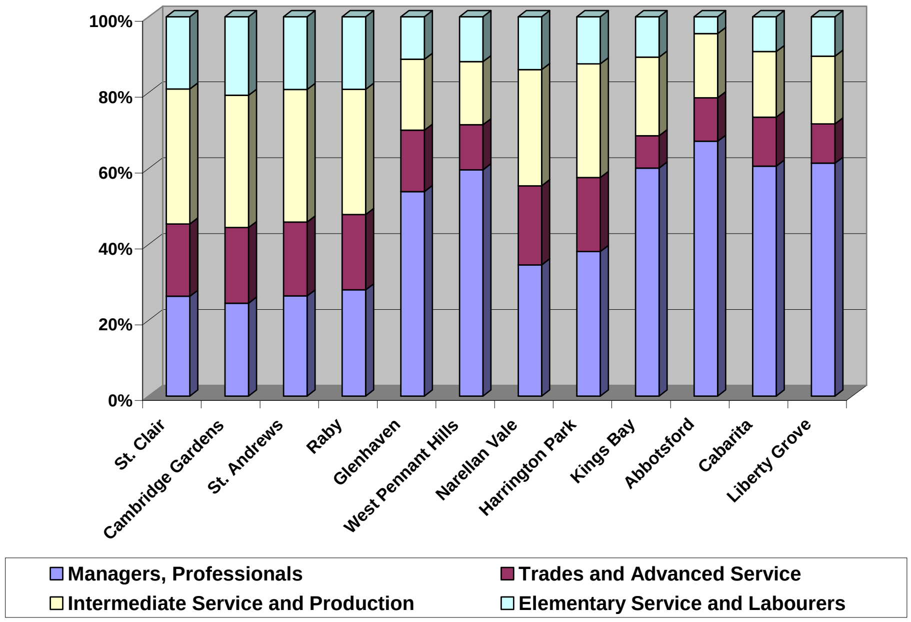
Source: ABS Census 2001 CDATA

Figure 4.8: Percentage of individuals born in Australia or overseas, case study estates (2001)



Source: ABS Census 2001 CDATA

Figure 4.9: Percentage of individuals by occupational category, case study estates (2001)



Source: ABS Census 2001 CDATA

5. WATER CONSUMPTION

5.1 Introduction

This chapter presents data on water consumption levels for the twelve case study estates and by dwelling type for the period 1987 to 2003. Consumption by size of property area is also analysed, to explore the relationship between plot size and consumption. In addition, consumption is analysed on a per household and a per capita basis. The data show significant variation between the estates but there main finding is that household size is a key determinant of overall water consumption, but there is relatively little variation in consumption on a per capita basis. In addition, there is also variation which can be associated with income level. Comparisons between the five Landcom and seven non-Landcom estates are also made.

5.2 Overall Water Consumption

Between 1987 and 2003 average annual water consumption per dwelling decreased from 339 kl to 297 kl across the case study areas as a whole (Table 5.1) and also decreased in nine of the estates. The exceptions were Glenhaven, West Pennant Hills and Harrington Park (Figure 5.1 and Table 5.1). All these three estates were developing during this period, and these outcomes may reflect the type of new stock being added to the estates over this time. But it is also possible to show an association with higher income levels, especially in respect to the first two of these estates. Having said that, all low density estates recorded a downturn in average dwelling consumption levels in the 2001 to 2003 period. As this occurred before the current water restrictions were introduced, this result may reflect rainfall changes rather than behavioural changes among consumers towards lower consumption. Generally, water consumption reached its highest level in 1991 and its lowest level in 1995, reflecting peaks and troughs of annual rainfall patterns, especially summer rainfall, over this time[3], although this varied across the estates.

For the low density estates, the association with higher income is clearly evident in Figures 5.1 and 5.2, with Glenhaven and West Pennant Hills averaging well over 400kl in 2003 and the other six low density estates recording broadly similar consumption levels bunched in the range 293kl to 328kl. The data do not show nay trend towards lower consumption levels for the newest estates of Narellan Vale and Harrington Park which suggests that changing design and building standards in developments up to this time had little impact on overall water consumption compared to estates built in earlier periods. Note that the development of these estates pre-dated the introduction of BASIX standards in 2004.

Water consumption in the higher density estates generally recorded the lowest consumption levels on a per dwelling basis over this period (ranging from 187kl to 257kl in 2003), but as at least two of these areas were only developed from the later 1990s, trends were less conclusive. Indeed, water consumption per dwelling in

[3] See Troy, T., Holloway, D. and Randolph, B. (2005) *Water Use and the Built Environment: Patterns of Water Consumption in Sydney*, Research Paper No. 1, City Futures Research Centre, Faculty of the Built Environment, University of New South Wales.

Abbotsford and Liberty Grove increased between 1998 and 2003 during the development period and stock numbers increased.

Of all the case study areas, Glenhaven had the highest consumption in 2003 (414 kl) whereas Abbotsford had the lowest (184 kl). Only two case study areas – Glenhaven and West Pennant Hills – consumed more than 300 kl per year, while two areas – Kings Bay and Abbotsford – consumed less than 200 kl per year.

Two of the four predominantly separate house Landcom estates (Narellan Vale and St Andrews) consumed less water than nearby comparator estates. On the other hand, the Landcom estates of Glenhaven and St Clair had higher rates of consumption than did nearby comparator estates. In recent years, water consumption in the Landcom estate of Kings Bay has been lower than in the other three higher density case study areas of Cabarita, Abbotsford and Liberty Grove.

Figure 5.1: Annual average water consumption per dwelling for case study areas, 1987-2003

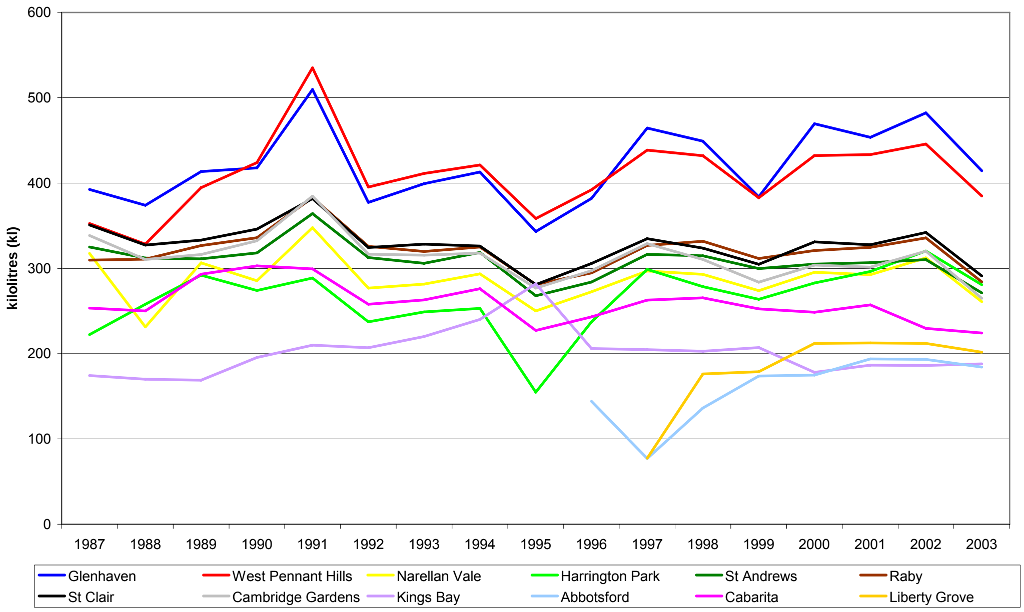


Figure 5.2: Average annual water consumption per dwelling by estate, 2003

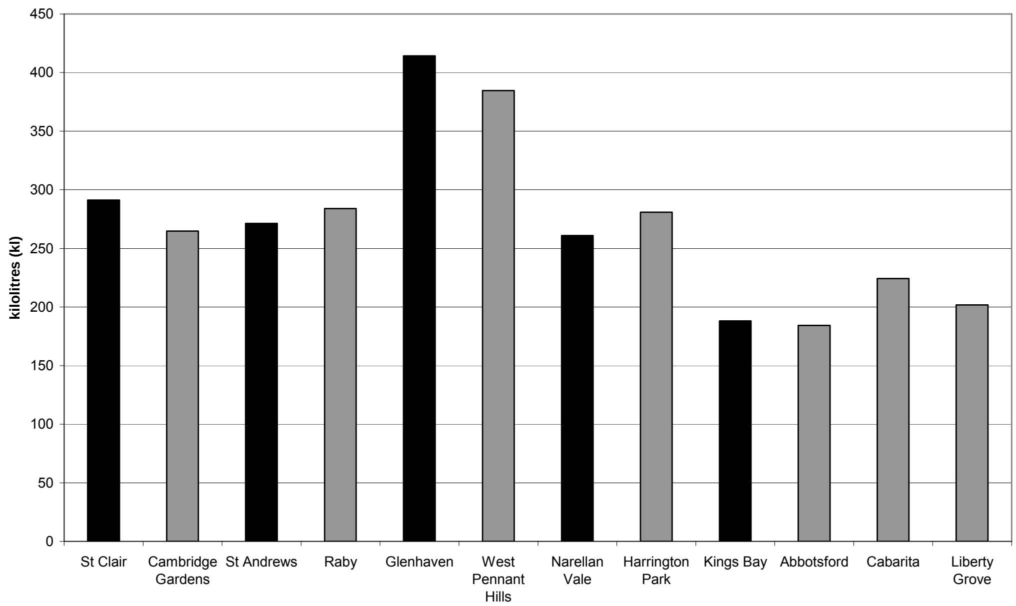


Table 5.1: Annual average water consumption per dwelling for case study areas, 1987 to 2003 (kl)

Area			1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Low Density Estates																			
Late 1970s	St Clair	Dwellings	5,225	5,345	5,409	5,524	5,585	5,655	5,684	5,737	5,785	5,809	5,829	5,856	5,873	5,885	5,890	5,899	5,899
		Consumption per Dwelling	**351**	**327**	**333**	**346**	**382**	**324**	**328**	**326**	**281**	**306**	**335**	**324**	**305**		**328**	**342**	**291**
	Cambridge Gardens	Dwellings	667	671	671	673	674	693	694	694	696	698	695	697	696	695	695	694	693
		Consumption per Dwelling	**339**	**310**	**316**	**332**	**385**	**316**	**316**	**318**	**277**	**297**	**329**	**310**	**284**	**304**	**301**	**320**	**265**
Early 1980s	St Andrews	Dwellings	1,287	1,357	1,411	1,446	1,453	1,456	1,460	1,460	1,467	1,472	1,476	1,486	1,518	1,534	1,541	1,545	1,543
		Consumption per Dwelling	**325**	**312**	**311**	**318**	**364**	**313**	**306**	**319**	**268**	**284**	**316**	**315**	**300**	**305**	**307**	**310**	**271**
	Raby	Dwellings	1,374	1,591	1,653	1,687	1,737	1,758	1,769	1,821	1,841	1,853	1,861	1,866	1,870	1,874	1,878	1,875	1,879
		Consumption per Dwelling	**310**	**311**	**327**	**336**	**383**	**326**	**320**	**325**	**281**	**295**	**327**	**332**	**311**	**321**	**325**	**336**	**284**
Late 1980s	Glenhaven	Dwellings	581	692	776	829	890	958	1,011	1,056	1,105	1,146	1,178	1,220	1,250	1,272	1,282	1,296	1,300
		Consumption per Dwelling	**393**	**374**	**413**	**418**	**509**	**377**	**399**	**413**	**343**	**382**	**464**	**449**	**384**	**470**	**453**	**482**	**414**
	West Pennant Hills	Dwellings	398	732	1,029	1,245	1,387	1,524	1,668	1,745	1,849	1,955	2,101	2,234	2,317	2,404	2,448	2,511	2,558
		Consumption per Dwelling	**353**	**328**	**395**	**424**	**535**	**395**	**411**	**421**	**358**	**392**	**438**	**432**	**383**	**432**	**433**	**446**	**385**
Late 1990s	Narellan Vale	Dwellings	12	52	157	252	335	458	640	864	1,081	1,263	1,493	1,735	1,940	2,084	2,232	2,306	2,318
		Consumption per Dwelling	**317**	**231**	**306**	**285**	**348**	**277**	**281**	**294**	**250**	**273**	**297**	**293**	**274**	**295**	**293**	**312**	**261**
	Harrington Park	Dwellings	21	20	22	22	22	22	22	22	109	193	270	414	564	798	1,028	1,187	1,283

		Consumption per Dwelling	**222**	**258**	**292**	**274**	**289**	**237**	**249**	**253**	**155**	**237**	**299**	**278**	**264**	**283**	**296**	**320**	**281**

Area		**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
High Density Estates																		
Kings Bay																		71,28 3
	Dwellings	140	139	138	140	141	141	141	145	143	145	145	145	146	215	314	380	379
	Consumption per Dwelling	**174**	**170**	**169**	**195**	**210**	**207**	**220**	**240**	**282**	**206**	**205**	**203**	**207**	**178**	**187**	**186**	**188**
Abbotsford																		
	Dwellings	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	52	136	246	376	387	387	387
	Consumption per Dwelling	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**144**	**77**	**136**	**174**	**175**	**194**	**193**	**184**
Cabarita																		
	Dwellings	203	202	204	205	205	207	208	205	205	206	205	203	213	312	340	424	459
	Consumption per Dwelling	**253**	**250**	**293**	**303**	**299**	**258**	**263**	**276**	**227**	**243**	**263**	**266**	**252**	**249**	**257**	**230**	**224**
Liberty Grove																		
	Dwellings	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	30	85	216	340	356	357	358
	Consumption per Dwelling	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**77**	**176**	**179**	**212**	**213**	**212**	**202**
Total																		
	Consumption per Dwelling	**339**	**321**	**336**	**350**	**402**	**331**	**335**	**340**	**290**	**313**	**348**	**339**	**311**	**335**	**334**	**345**	**297**

5.3 Water Consumption in Houses

The next two section disaggregate the trends by dwelling type, looking at single house dwellings first. Water consumption for houses closely matches that for all dwelling types, particularly in areas were houses predominate (Table 5.2). Aggregate trends over the 1987-2003 period show some variation, peaking in 1991, but remaining generally within the 300-350kl band (Figure 5.3). The 1991 peak was most pronounced in Glenhaven and West Pennant Hills (Figure 5.4). Looking at variations between estates, in 2003, houses in Glenhaven recorded the highest consumption per house dwelling (415 kl) while houses in Liberty Grove had the lowest consumption of all the case study areas (221 kl) (Figure 5.4).

Overall, the water consumption per house in the case study areas in 2003 was 305 kl. This figure is consistent with the studies conducted by IPART (2004a and b) and Troy et al. (2005) for studies of Sydney as a whole. IPART suggests that houses consumed an average of 304 kl per annum in 2003 compared with Troy et al's figure of average house consumption of 310 kl per annum in 2001. Only two of the case study areas (Glenhaven and West Pennant Hills) had rates of consumption over this amount.

Glenhaven had the highest consumption per single dwelling in the study period, with the small number of houses in Kings Bay generally consuming least over the period. Between 1998 and 2003, houses in Liberty Grove consumed least of all houses in the case study areas. Note that case numbers of house dwellings in the Abbotsford estate were very low, so the figures for this case study are not reliable.

Figure 5.3: Aggregate average annual water consumption per dwelling for separate houses, all estates, 1987-2003

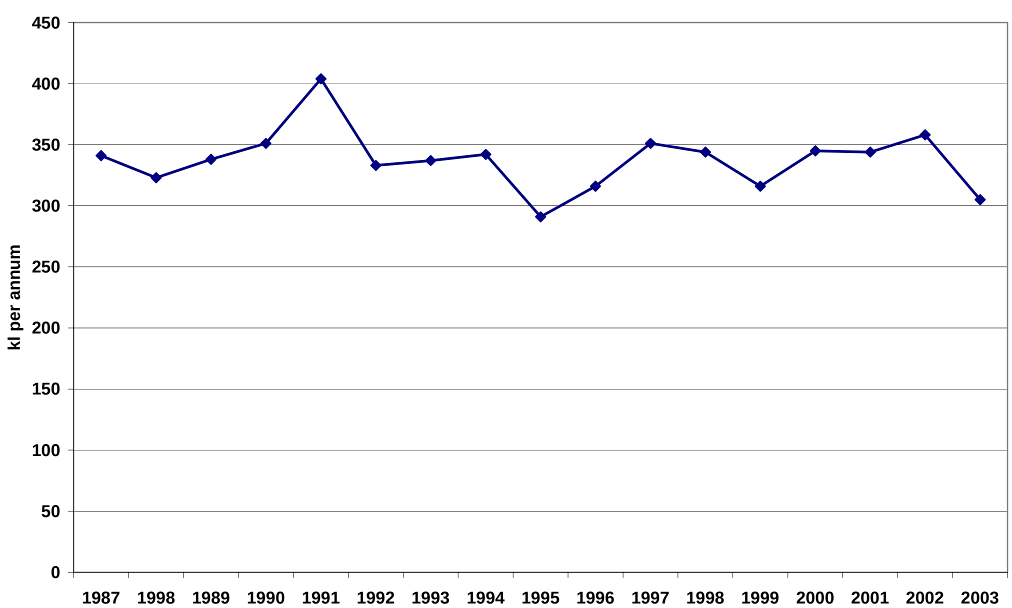


Figure 5.4: Water Consumption per dwelling for separate houses, 1987-2003

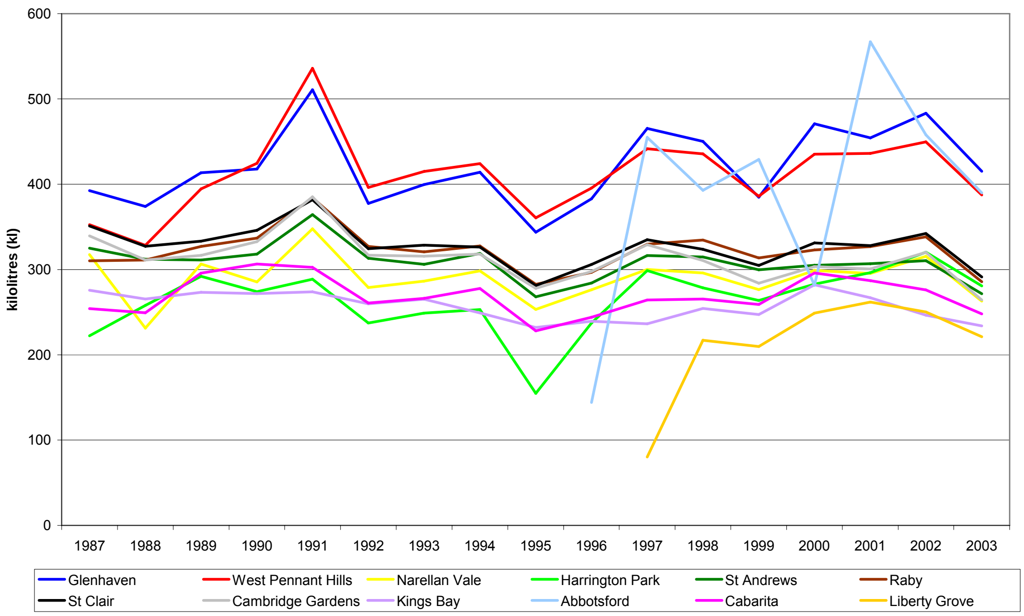


Figure 5.5: Water Consumption for separate houses, 2003

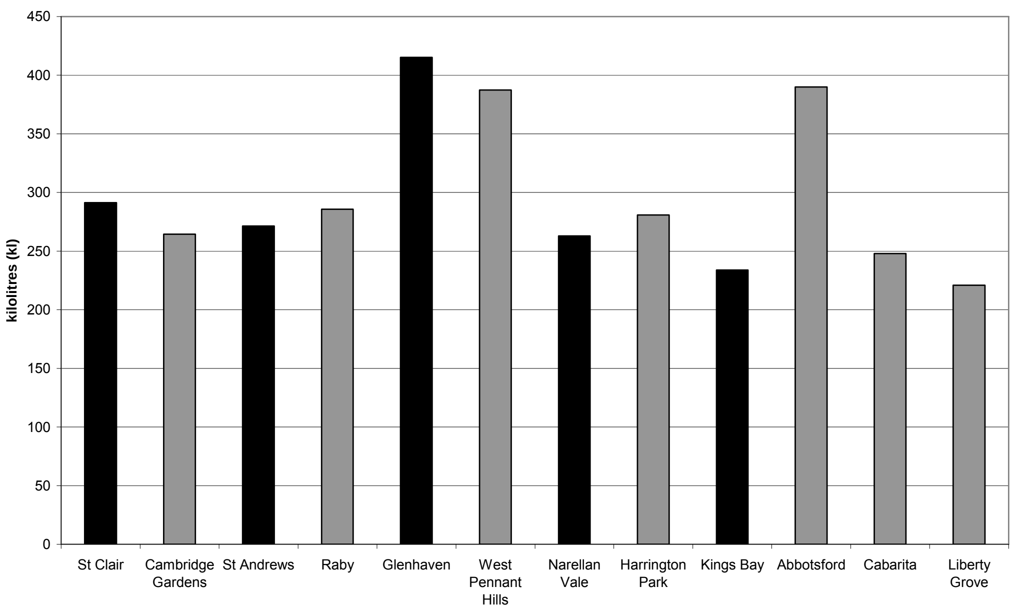


Table 5.2: Average annual water consumption per separate house, 1987 to 2003 (kl)

Area		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
St Clair	Dwellings	5,223	5,343	5,405	5,520	5,581	5,651	5,680	5,731	5,779	5,802	5,822	5,849	5,866	5,878	5,883	5,892	5,892
	Consumption per Dwelling	**351**	**327**	**333**	**346**	**382**	**325**	**328**	**326**	**281**	**306**	**335**	**324**	**305**	**331**	**328**	**342**	**291**
Cambridge Gardens	Dwellings	663	667	667	669	670	689	690	690	690	692	689	691	690	689	689	688	687
	Consumption per Dwelling	**339**	**311**	**317**	**333**	**385**	**317**	**316**	**318**	**278**	**298**	**329**	**311**	**284**	**304**	**301**	**320**	**264**
St Andrews	Dwellings	1,285	1,355	1,409	1,444	1,451	1,452	1,456	1,456	1,463	1,468	1,472	1,482	1,514	1,530	1,537	1,541	1,539
	Consumption per Dwelling	**325**	**312**	**311**	**318**	**364**	**313**	**306**	**319**	**268**	**284**	**316**	**315**	**300**	**305**	**307**	**310**	**271**
Raby	Dwellings	1,372	1,587	1,649	1,679	1,729	1,746	1,757	1,790	1,809	1,821	1,825	1,830	1,834	1,838	1,842	1,839	1,843
	Consumption per Dwelling	**310**	**311**	**327**	**337**	**384**	**327**	**321**	**328**	**283**	**297**	**330**	**334**	**313**	**323**	**327**	**338**	**286**
Glenhaven	Dwellings	581	692	776	829	886	954	1,007	1,050	1,099	1,140	1,172	1,214	1,244	1,266	1,276	1,290	1,294
	Consumption per Dwelling	**393**	**374**	**413**	**418**	**511**	**378**	**399**	**414**	**344**	**383**	**465**	**450**	**385**	**471**	**454**	**483**	**415**
West Pennant Hills	Dwellings	398	732	1,029	1,243	1,385	1,518	1,640	1,716	1,820	1,917	2,061	2,192	2,271	2,360	2,404	2,463	2,510
	Consumption per Dwelling	**353**	**328**	**395**	**424**	**536**	**396**	**415**	**424**	**361**	**396**	**442**	**436**	**386**	**435**	**436**	**450**	**387**

Area		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Narellan Vale	Dwellings	12	52	157	252	335	454	616	834	1,048	1,228	1,458	1,696	1,900	2,029	2,177	2,251	2,265
	Consumption per Dwelling	**317**	**231**	**306**	**285**	**348**	**279**	**286**	**298**	**253**	**276**	**300**	**296**	**276**	**299**	**295**	**315**	**263**
Harrington Park	Dwellings	21	20	22	22	22	22	22	22	109	193	270	414	564	798	1,028	1,187	1,283
	Consumption per Dwelling	**222**	**258**	**292**	**274**	**289**	**237**	**249**	**253**	**155**	**237**	**299**	**278**	**264**	**283**	**296**	**320**	**281**
Kings Bay	Dwellings	49	48	47	49	50	50	50	53	51	53	53	53	54	54	55	55	54
	Consumption per Dwelling	**276**	**266**	**273**	**272**	**274**	**260**	**265**	**249**	**232**	**239**	**236**	**254**	**247**	**282**	**267**	**246**	**234**
Abbotsford	Dwellings	0	0	0	0	0	0	0	0	0	1	1	1	1	2	2	2	2
	Consumption per Dwelling	0	0	0	0	0	0	0	0	0	**144**	**455**	**393**	**429**	**282**	**567**	**458**	**390**
Cabarita	Dwellings	199	198	200	201	201	203	204	203	203	204	203	203	204	201	206	227	256
	Consumption per Dwelling	**254**	**249**	**296**	**306**	**302**	**261**	**266**	**278**	**228**	**244**	**264**	**266**	**259**	**296**	**287**	**276**	**248**
Liberty Grove	Dwellings	0	0	0	0	0	0	0	0	0	0	14	19	33	37	37	37	37
	Consumption per Dwelling	0	0	0	0	0	0	0	0	0	0	**80**	**217**	**210**	**249**	**262**	**250**	**221**
Total	Dwellings	9,818	10,709	11,377	11,925	12,327	12,756	13,140	13,564	14,090	14,538	15,059	15,663	16,193	16,701	17,156	17,491	17,681
	Consumption per Dwelling	**341**	**323**	**338**	**351**	**404**	**333**	**337**	**342**	**291**	**316**	**351**	**344**	**316**	**345**	**344**	**358**	**305**

5.4 Water Consumption in Multi-Unit Dwellings

Between 1987 and 2003 the water consumption of households living in multi-unit dwellings showed much greater variation than those living in houses. For most low density estates, this was a result of very low counts of multi-unit dwellings (Table 5.3). The aggregate trends for multi-unit dwellings averaged over the eight lower density areas is shown in Figure 5.6. In contrast to the trends for separate houses shown above, this shows a steady rise in average consumption levels over the period, from 166kl to 201kl, although the trend had been falling in the final years of the period from a peak of 228kl in 2001.

The individual trends for high density areas is more disjointed, reflecting the dates the sites were developed (Figure 5.7). Only the Kings Bay area had any number of dwellings before the mid-1990s. In 2003, Kings Bay recorded the lowest average dwelling consumption (180 kl), followed by Abbotsford (183 kl), Cabarita (194 kl) and Liberty Grove (200 kl). The results for the latter two areas may be a reflection of the higher proportions of separate and semi-detached houses in these developments. Nevertheless, they are all relatively closely bunched in the 180 – 200 kl per annum range.

These results match those of Troy et al. (2005), who found that multi-unit dwellings consumed 200 kl per annum in 2001 for Sydney as a whole. This compares with consumption per multi-unit dwelling across the twelve case study areas in this study in 2001 of 198 kl.

Figure 5.6: Aggregate average annual water consumption per dwelling for multi-unit dwellings in low density estates, 1987-2003

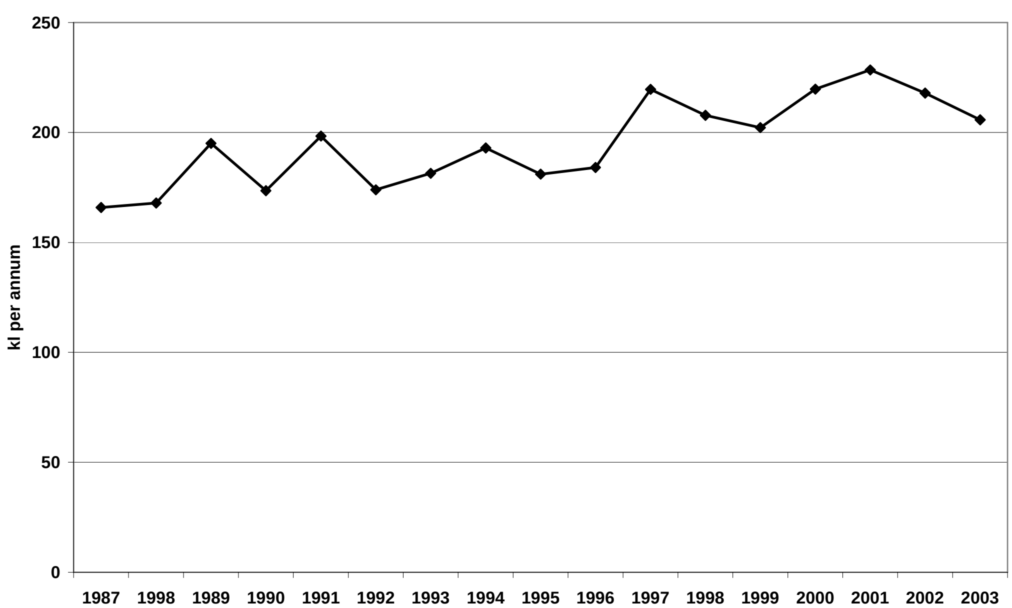


Figure 5.7: Average annual water consumption per dwelling for multi-unit dwellings in high density estates, 1987-2003

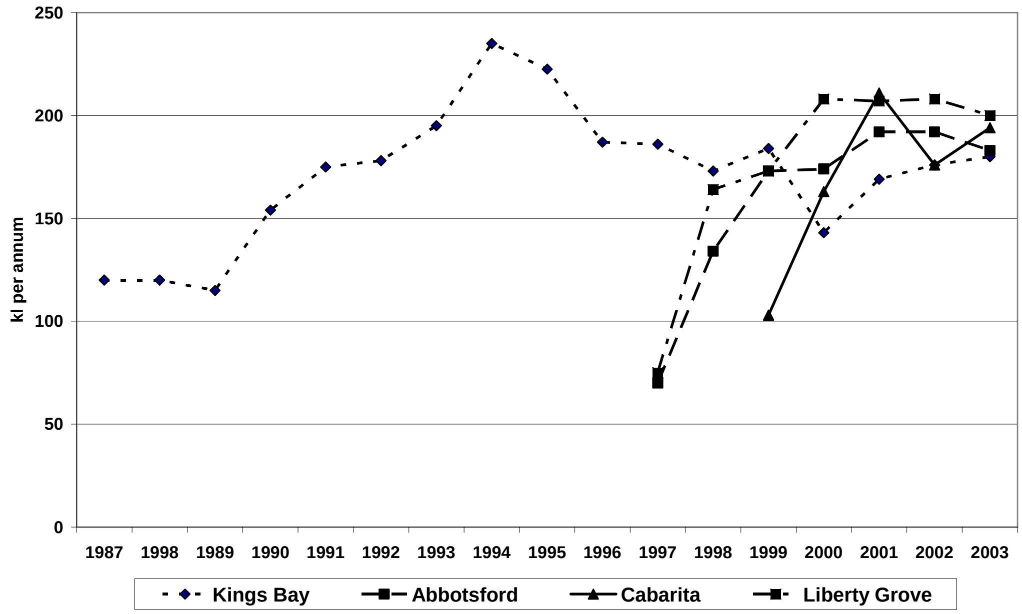


Table 5.3: Average annual water consumption for multi-unit dwellings, 1987 to 2003 (kl)

Area		1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
All Low Density Estates	Dwellings	10	12	14	20	24	38	80	110	116	128	134	140	145	158	158	162	160
	Consumption per Dwelling	166	168	195	174	198	174	181	193	181	184	220	208	202	220	228	218	206
Kings Bay	Dwellings	91	91	91	91	91	91	91	92	92	92	92	92	92	161	259	325	325
	Consumption per Dwelling	120	120	115	154	175	178	195	235	223	187	186	173	184	143	169	176	180
Abbotsford	Dwellings	0	0	0	0	0	0	0	0	0	0	51	135	245	374	385	385	385
	Consumption per Dwelling	0	0	0	0	0	0	0	0	0	0	70	134	173	174	192	192	183
Cabarita [1]	Dwellings	4	4	4	4	4	4	4	2	2	2	2	0	9	111	134	197	203
	Consumption per Dwelling	0	0	0	0	0	0	0	0	0	0	0	0	0	163	211	176	194
Liberty Grove	Dwellings	0	0	0	0	0	0	0	0	0	0	16	66	183	303	319	320	321
	Consumption per Dwelling	0	0	0	0	0	0	0	0	0	0	75	164	173	208	207	208	200
Total [2] All Estates	Dwellings	105	107	109	115	119	133	175	204	210	230	303	441	682	1,115	1,263	1,397	1,394
	Consumption per Dwelling	128	131	127	157	178	175	187	211	199	181	175	172	180	185	198	193	191

Notes
1. Data for the eight low density estates have been aggregated to avoid confidentiality issues and to provide more viable averages.
2. Average consumption data for Cabarita have been suppressed where case numbers fall below 10.

5.5 Water Consumption Per Capita

The previous section focused on water consumption on a per dwelling basis. This section analyses annual consumption data on a per capita basis. As Troy, *et al* (2005) demonstrated for Sydney, per capita consumption variations between dwelling types was much less significant than for households. In other words, individual water use was similar regardless of the size of household or dwelling occupied. The present study confirms this is largely true in the twelve case study estates, although variations are not insignificant, and tend to reflect socio-economic differences. The figures for per capita consumption were estimated for 2001 only by aggregating the total annual water consumption for each estate in 2001 and divided this figure by the numbers of people recorded as resident on the estate at the time of the 2001 Census.

Overall, in 2001, annual per capita consumption varied between 133kl in Glenhaven and 79kl in Liberty Grove (Table 5.4 and Figure 5.8). However, as Figure 5.7 illustrates, in eight of the twelve case study areas per capita water consumption clustered in a range between 88kl and 99kl. The main outliers were Glenhaven and West Pennant Hills, the two high income low density estates in the study, where per capita use exceeded 120kl per annum. There was no necessary variation between high and low density areas, although the two lowest per capita figures were for two of these, Kings bay and Liberty Grove. Similarly, there was no systematic relationship between outcomes in the groups of paired Landcom and non-Landcom estates.

Figure 5.8: Annual average per capita water consumption in case study areas, 2001

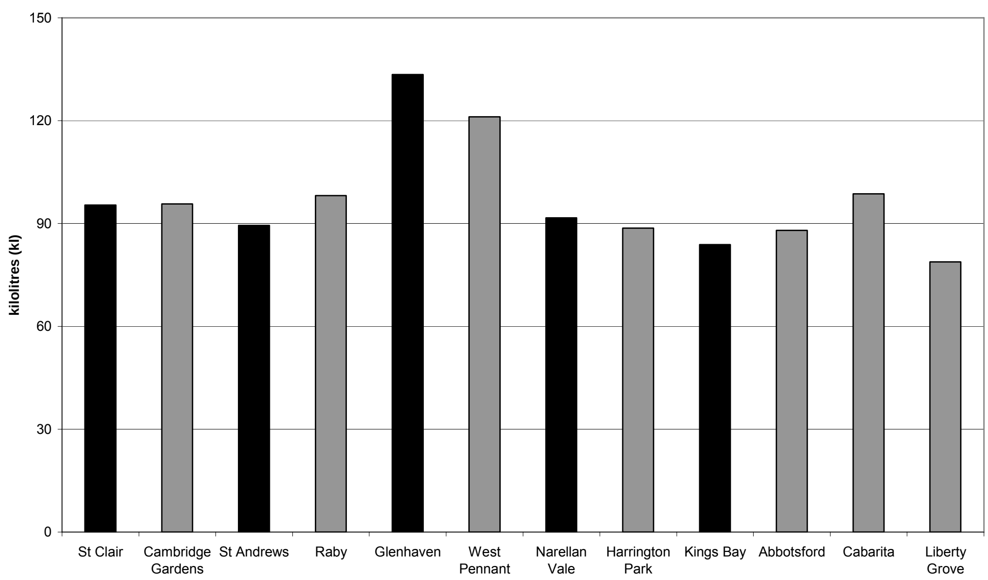


Table 5.4 also shows that the outcomes for houses and multi-unit dwellings were broadly comparable across the case study areas, with the exception of the two high income estates. Overall, the per capita consumption figure for all houses in the twelve estates averaged 101 kl, similar to that found by Troy et al. for houses across Sydney (98 kl) but slightly above that found by IPART (92 kl). For multi-unit dwellings, per capita consumption averaged 83kl per annum in 2001across the twelve case study areas, below that recorded by Troy, *et al* for Sydney as a whole (91 kl).

Table 5.4: Annual average per capita water consumption for case study areas, 2001

Area			Houses	Multi-Unit Dwellings	Total
Low Density Estates					
Late 1970s	St Clair	Consumption per Dwelling (kl)	328	NA	328
		Persons per Household	3.44	NA	3.44
		Consumption per Capita (kl)	**95**	**NA**	**95**
	Cambridge Gardens	Consumption per Dwelling (kl)	301	NA	301
		Persons per Household	3.17	NA	3.15
		Consumption per Capita (kl)	**95**	**NA**	**96**
Early 1980s	St Andrews	Consumption per Dwelling (kl)	307	NA	307
		Persons per Household	3.47	NA	3.43
		Consumption per Capita (kl)	**88**	**NA**	**89**
	Raby	Consumption per Dwelling (kl)	327	218	325
		Persons per Household	3.37	2.24	3.31
		Consumption per Capita (kl)	**97**	**97**	**98**
Late 1980s	Glenhaven	Consumption per Dwelling (kl)	454	NA	453
		Persons per Household	3.46	NA	3.4
		Consumption per Capita (kl)	**131**	**NA**	**133**
	West Pennant Hills	Consumption per Dwelling (kl)	436	273	433
		Persons per Household	3.63	2.98	3.58
		Consumption per Capita (kl)	**120**	**92**	**121**
Late 1990s	Narellan Vale	Consumption per Dwelling (kl)	295	182	293
		Persons per Household	3.24	2.5	3.19
		Consumption per Capita (kl)	**91**	**73**	**92**
	Harrington Park	Consumption per Dwelling (kl)	296	NA	296
		Persons per Household	3.34	NA	3.34
		Consumption per Capita (kl)	**89**	**NA**	**89**
High Density Estates					
	Kings Bay	Consumption per Dwelling (kl)	267	169	187
		Persons per Household	2.73	2.1	2.22
		Consumption per Capita (kl)	**98**	**81**	**84**
	Abbotsford	Consumption per Dwelling (kl)	NA	192	194
		Persons per Household	NA	2.21	2.2
		Consumption per Capita (kl)	**NA**	**87**	**88**
	Cabarita	Consumption per Dwelling (kl)	287	211	257
		Persons per Household	2.85	2.38	2.61
		Consumption per Capita (kl)	**101**	**89**	**99**
	Liberty Grove	Consumption per Dwelling (kl)	262	207	213
		Persons per Household	3	2.65	2.7
		Consumption per Capita (kl)	**87**	**78**	**79**
	Total	Consumption per Dwelling (kl)	344	198	334
		Persons per Household	3.4	2.4	3.28
		Consumption per Capita (kl)	**101**	**83**	**102**

NB. Results for data where case numbers fell below 10 have been suppressed. There were no multi-unit dwellings recorded in Harrington Park.

6 OPERATIONAL ENERGY: ELECTRICITY

6.1 Introduction

From this section onwards, the report turns to a consideration of the outcomes on each of the twelve estates of their energy consumption patterns. In this chapter the patterns of operational energy are analysed, followed by gas in chapter 7. Chapter 8 then tackles the embodied energy profiles of the estates, making an overall ‘life-cycle’ estimate of energy consumption incorporating both operational and energy use and the associated greenhouse gas emission.

In this chapter, the trends in electricity consumption of case study areas over the period 2003 to 2004 are presented. It is important to note that while the analysis presented here is for ‘2004’ the two data sets obtained for this analysis are for slightly different periods. The Energy Australia database obtained for this project is for the 2003-2004 financial year (Kings Bay, Abbotsford, Cabarita, Liberty Grove) while the Integral Energy dataset is for the 2004 calendar year (Glenhaven, West Pennant Hills, St Clair, Cambridge Gardens, Narellan Vale, Harrington Park, St Andrews, Raby). As most of the electricity data used in this section is from Integral Energy, the analysis presented below will be termed ‘2004’. It is not expected that the slight difference in period has significant effects on the findings.

6.2 Electricity consumption in the case study areas: all dwellings

In 2004, average electricity consumption across all twelve case study areas was 8,375 kilowatt hours (kwh) (Table 6.1 and Figure 6.1). This is slightly higher than that found by IPART (7,539 kwh). Glenhaven had the highest electricity consumption in the case study areas (13,061 kwh), closely followed by West Pennant Hills with 11,848 kwh. The lowest consuming households in 2004 were in Kings Bays (3,740 kwh) and Liberty Grove (5,480 kwh). Glenhaven was the only Landcom case study area which had higher electricity consumption than its nearby comparator estate (West Pennant Hills). Kings Bay had substantially lower electricity use than an of the other case study areas, while two of the other higher density estates recorded electricity use above five of the low density estates. In other words, there was no clear-cut difference between the high and low density estates.

Figure 6.1: Electricity Consumption in the Case Study Areas, 2004 (kwh)

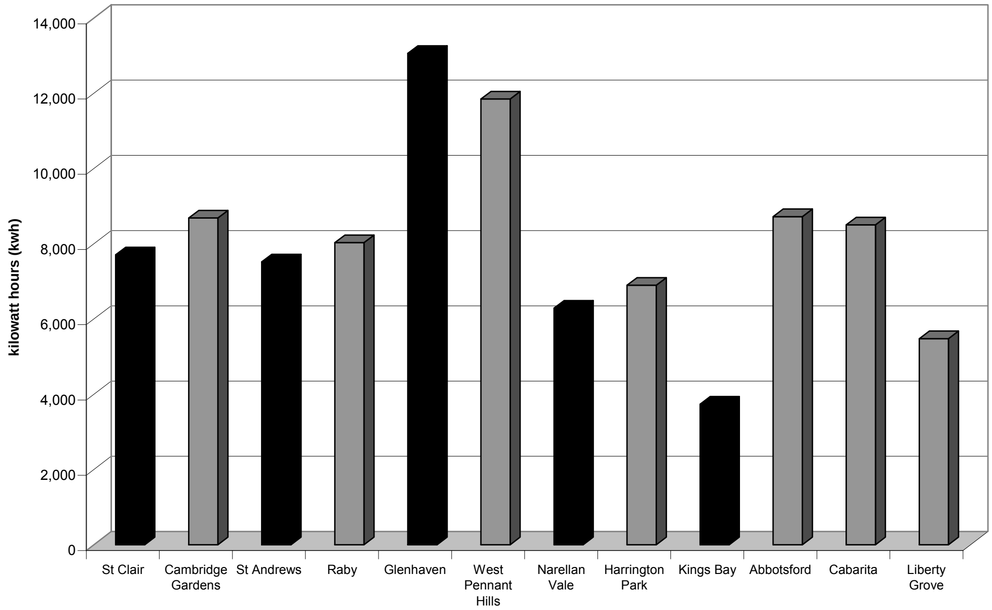


Table 6.1: Electricity Consumption for Case Study Areas 2004 (kwh)

	Houses	Multi-Unit Dwellings	Total
Low Density Estates			
Late 1970s			
St Clair	7,708	NA	7,708
Cambridge Gardens	8,686	NA	8,686
Early 1980s			
St Andrews	7,522	NA	7,523
Raby	8,100	NA	8.023
Early 1990s			
Glenhaven	13,062	NA	13,061
West Pennant Hills	11,907	NA	11,848
Late 1990s			
Narrellan Vale	6,295	NA	6,293
Harrington Park	6,900	NA	6,900
High Density Estates			
Kings Bay	7,540	3,152	3,740
Abbotsford	NA	8,688	8,724
Cabarita	8,445	8,610	8,505
Liberty Grove	6,215	5,392	5,480
Total	8,375	6,679	8,375
Dwellings	17,192	1,512	18,704

NB. Results for data where case numbers fell below 10 have been suppressed. In addition, due to the lack of case level data in estates supplied by Integral Energy, results for the remaining multi-unit dwellings the low density estates have also been suppressed. There were no houses recorded in Abbotsford.

6.3 Electricity consumption: houses

In all case study areas, houses consumed on average 8,524 kwh of electricity per annum (Table 6.1). This figure is slightly higher than that found by IPART (7,834 kwh). Houses in Glenhaven had the highest electricity consumption across all the case study areas, 13,062 kwh, with West Pennant Hills next (11,907 kwh). The lowest average electricity users were houses in Liberty Grove and Narellan Vale (6,215 kwh and 6,295 kwh, respectively).

As far as Landcom estates were concerned, houses in three – Narellan Vale, St Andrews and St Clair – had electricity consumption levels lower than those of the nearby comparator estate.

6.4 Electricity Consumption: Multi-Unit Dwellings

Only in the case of the predominantly higher density estates in Concord supplied by Energy Australia – Kings Bay, Abbotsford, Cabarita and Liberty Grove – were address level data available. Together with the very low numbers of higher density housing in most of the low density case study areas, only the results for the four high density estates have been presented here (Table 6.1).

Of these four areas, Kings Bay had the lowest electricity consumption (3,152 kwh), followed by Liberty Grove (5,392 kwh). Multi-unit dwellings in Abbotsford and Cabarita had significantly higher electricity consumption at 8,688 kwh and 8,610 kwh, respectively. Overall, the average electricity consumption per annum in these four areas was 6,129 kwh, a figure significantly higher than the 4,494 kwh found by IPART for Sydney as a whole (IPART 2004c) and higher than five of the low density estates. This is likely to reflect the generally higher income profile of these four estates compared to much of the flat sector across Sydney (Bunker, *et al*, 2005).

6.5 Electricity consumption per capita

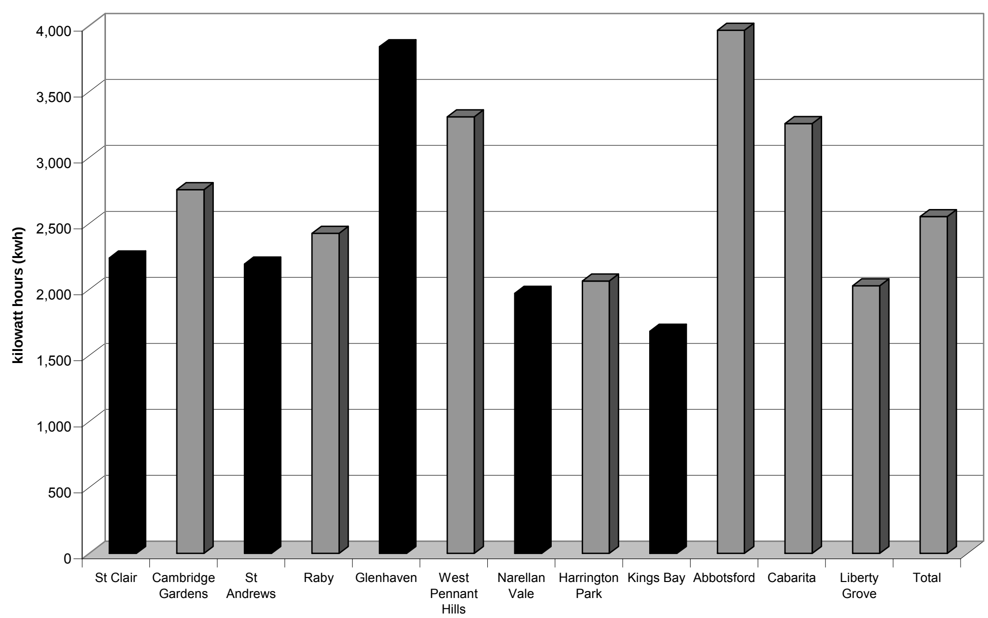
An estimate of per capita electricity consumption was made by using the figures derived from the above analysis (for 2004) and dividing them by the population of each estate at the time of the 2001 census. While the estimates should therefore be treated with some caution as the effect of using 2001 census counts will have the effect of overstating per capita consumption in some of the most recently developed estates, in the absence of contemporary population counts this represents a 'best fit' approach. The issue of how far gas use effects electricity consumption is dealt with in section 7.5 below.

In 2004, estimated average electricity consumption per capita across the case study areas was 2,553 kwh (Table 6.2). Per capita electricity consumption for houses was 2,507 kwh while multi-units consumed 2,783 kwh per person in 2004. The highest consuming area on a per capita basis in 2004 was the higher density area of Abbotsford with 3,966 kwh per person (Figure 6.2). This was followed by the detached housing case study areas of Glenhaven (3,842 kwh) and West Pennant Hills (3,309 kwh), with the higher density Cabarita also recording a high average per capita electricity use. So the four highest per capita figures were evenly split between two low and two high density estates. Their common characteristic was the relatively higher income profile of the residents.

Among the eight low density estates, there was some indication that the most recent estates, Harrington Park and Narellan Vale, had lowest per capita results. This may reflect higher building design standards on these estates or the larger household size due to the number of children on these estates, although more detailed research would be needed to either of these hypotheses.

Of the five Landcom areas only Glenhaven had a higher per capita consumption than its nearby comparator estate of West Pennant Hills. The other four Landcom areas (Narellan Vale, St Andrews, St Clair and Kings Bay) all had lower per capita rates of electricity consumption than their nearby comparator developments.

Figure 6.2: Electricity consumption per capita for the case study areas, 2004



Results for multi-unit dwellings suggest a higher electricity per capita usage than houses. This is likely to reflect the lower level of connectivity to gas, resulting in greater reliance on electricity for flat dwellers and perhaps the presence of communal facilities. The Landcom high density estate, Kings Bay, had the lowest overall per capita electricity consumption in 2004 (1,501 kwh).

Table 6.2: Electricity consumption per capita in the case study areas, 2004 (kwh)

	Houses	Multi-Unit Dwellings	Total
Low Density Estates			
Late 1970s			
St Clair	2,241	NA	2,241
Cambridge Gardens	2,740	NA	2,757
Early 1980s			
St Andrews	2,168	NA	2,193
Raby	2,404	3,068	2,426
Early 1990s			
Glenhaven	3,775	NA	3,842
West Pennant Hills	3,280	3,503	3,309
Late 1990s			
Narrellan Vale	1,943	2,485	1,973
Harrington Park	2,066	NA	2,066
High Density Estates			
Kings Bay	2,762	1,501	1,685
Abbotsford	NA	3,931	3,966
Cabarita	2,963	3,618	3,259
Liberty Grove	2,072	2,035	2,030
Total	2,507	2,783	2,553

NB. Results for data where case numbers fell below 10 have been suppressed.

6.6 Greenhouse Gas Equivalents for Electricity Consumption

One of the advantages of using the method developed in this study is that the energy consumption (both electricity and gas) can be converted to carbon dioxide equivalent emissions (tonnes CO_2-e), that is, estimates of greenhouse gas emissions. Greenhouse gas equivalents can be generated using factors which account for the process of producing the energy (referred to as primary energy consumption) and converting the energy to a CO_2-e estimate. The conversion factors used in this report are those used by Troy et al (2002) in their study of Adelaide. Table 6.3 below presents the CO_2-e estimates for electricity consumption.

Annual estimated greenhouse gas emissions ranged from 13.8 tonnes CO2-e in Glenhaven to just 3.4 tonnes CO_2-e in Kings Bay. This a substantial variation, and emphasises the environmental impact of larger higher income suburban housing of the kind found at Glenhaven.

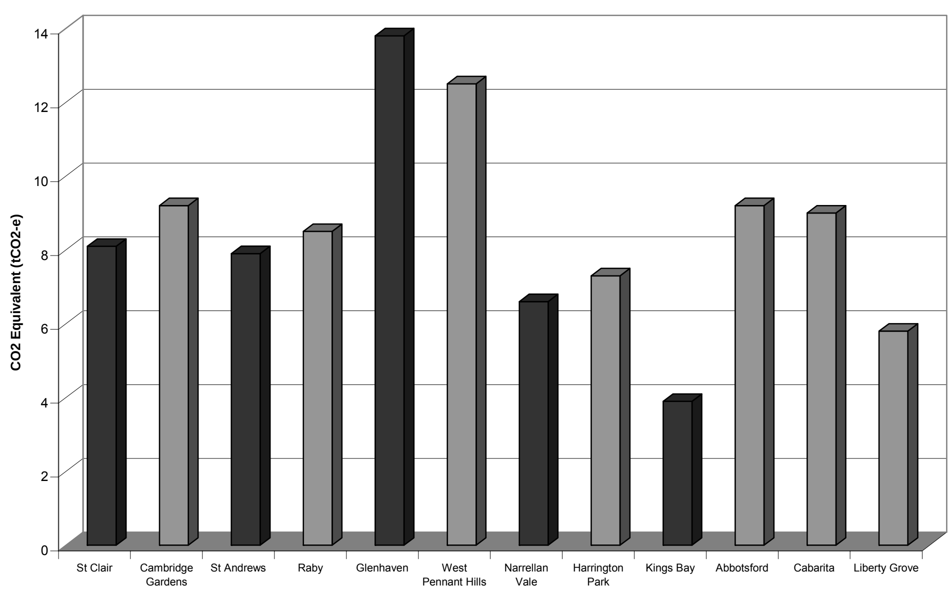
Table 6.3: Estimated Primary Electricity Consumption and Carbon Dioxide Equivalent Intensities (CO_2-e), 2004

	Total Electricity Consumption per dwelling (kwh)	Estimated Total Primary Electricity Consumption per dwelling (GJ)	Estimated Carbon Dioxide Equivalent Intensity (t CO2-e)
Low Density Estates			
Late 1970s			
St Clair	7,708	86.6	8.1
Cambridge Gardens	8,686	97.6	9.2
Early 1980s			
St Andrews	7,523	84.5	7.9
Raby	8,032	90.2	8.5
Early 1990s			
Glenhaven	13,061	146.7	13.8
West Pennant Hills	11,848	133.1	12.5
Late 1990s			
Narrellan Vale	6,293	70.7	6.6
Harrington Park	6,900	77.5	7.3
High Density Estates			
Kings Bay	3,740	42	3.9
Abbotsford	8,724	98	9.2
Cabarita	8,505	95.5	9
Liberty Grove	5,480	61.6	5.8

Notes:

- 1 GJ delivered electricity equals 3.12 GJ primary electricity
- 1 kwh= 3.6 MJ = 0.0036 GJ.
- 293 kt/PJ for delivered energy

Figure 6.3: Estimated Carbon Dioxide Equivalent Intensities (CO_2-e), 2004



7. OPERATIONAL ENERGY: GAS

7.1 Introduction

This section presents an examination of gas consumption in 2004 for the case study areas. The gas consumption analysis presented below is confined to dwellings which are supplied by AGL which is the major gas retailer in the Sydney region.

7.2 Gas consumption in the case study areas

In 2004 average gas consumption in the case study areas was 24,693 megajoules (MJ) (Table 7.1 and Figure 7.1). Glenhaven had the highest gas consumption per annum (30,562 MJ), followed by West Pennant Hills (29,141 MJ) and Harrington Park (26,338 MJ). These results were significantly higher than those found by IPART for the overall Sydney average (21,000 MJ). With the exception of these three, the rest of the case study areas, including the higher density areas, were broadly in the 20,000 to 24,000 MJ range, with the higher density estates recording usage in the lower half of that range. The lowest gas consumption in 2004 was recorded in Kings Bay (19,693 MJ) and Cabarita (20,233 MJ). The Lancom estates showed a typically inconsistent performance compared to non-Landcom estates.

Figure 7.1: Gas Consumption in Case Study Areas, 2004 (MJ)

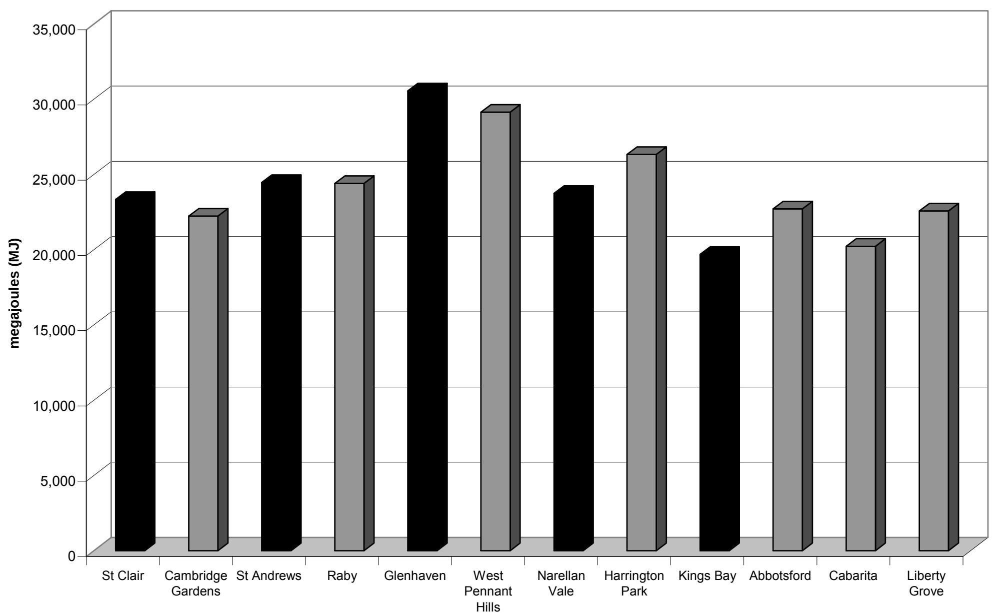


Table 7.1: Gas Consumption for Case Study Areas 2004 (MJ)

	Houses	Semi-detached Dwellings	Total
Low Density Estates			
Late 1970s			
St Clair	23,368	NA	23,350
Cambridge Gardens	22,391	NA	22,238
Early 1980s			
St Andrews	24,577	NA	24,475
Raby	25,454	NA	24,403
Early 1990s			
Glenhaven	30,952	NA	30,562
West Pennant Hills	29,323	22,789	29,141
Late 1990s			
Narrellan Vale	23,818	21,148	23,745
Harrington Park	26,338	NA	26,338
High Density Estates			
Kings Bay	18,392	23,362	19,693
Abbotsford	NA	22,533	22,714
Cabarita	20,260	20,163	20,233
Liberty Grove	20,618	22,911	22,576
Total	24,889	19,804	24,693

7.3 Gas consumption in houses, 2004

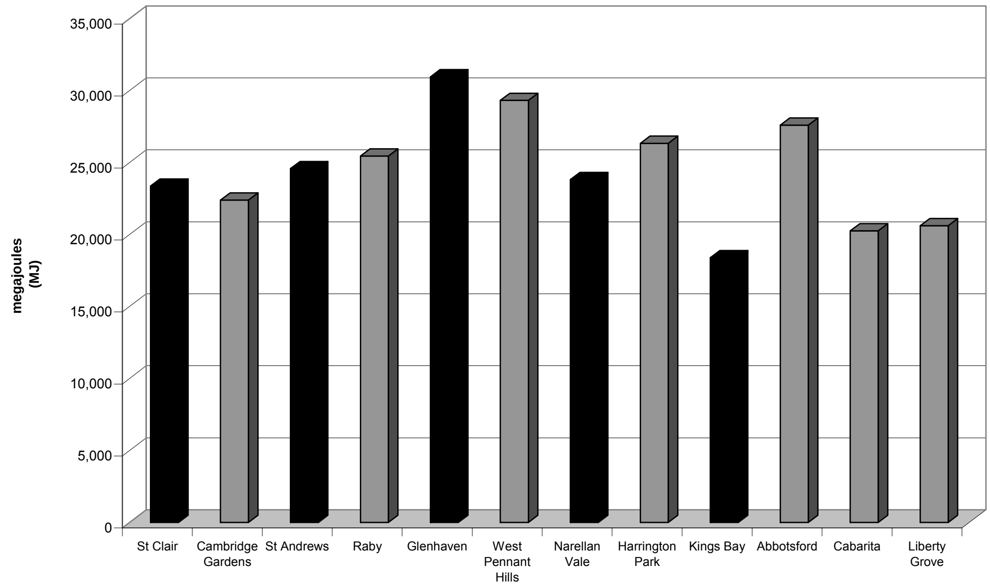
In 2004, average estimated gas consumption in houses in the case study areas was 24,889 MJ (Table 7.1 and Figure 7.2). Following the previous water and electricity analyses, the area with the highest gas consumption was Glenhaven (30,952 MJ), followed by West Pennant Hills (29,323 MJ). Houses in the Kings Bay area had the lowest gas consumption of all the case study areas (18,392 MJ) those in Cabarita (20,260 MJ) and Liberty Grove (20,618 MJ) had the next lowest levels of gas consumption.

7.4 Gas consumption in semi detached dwellings, 2004

Few multi-unit developments that had access to the gas network. Consequently, they have been ignored for the purpose of this analysis. On the other hand, some 271 semi detached dwellings in the case study areas were connected to the gas supply, the majority of which were in the five higher density estates. The case numbers were too small to analyse for six of the estates, so data are only identified for those where case numbers warranted separate analysis.

Overall, gas consumption for semi-detached houses averaged 19,804 MJ. The estimate for gas consumption in semi detached dwellings in Kings Bay was the highest of all the case study areas (23,362 MJ), followed by Abbotsford (22,533 MJ) and Liberty Grove (22,911 MJ).

Figure 7.2: Gas Consumption in Houses in the Case Study Areas, 2004 (MJ)



7.5 An Examination of Electricity and Gas Consumption

Several studies have concluded that households that are connected to the reticulated gas network use less electricity than households without networked gas (IPART 2004a, Troy et al 2003). Is this the case for the twelve case study areas. The analysis is limited to houses because of the small number of records for multi-unit dwellings and is therefore only indicative. For this section the data is limited to those houses supplied electricity by Energy Australia and are supplied gas by AGL. It is important to note that electricity data from Integral Energy could not be linked with gas data from AGL and the electricity data was for the 2003-2004 financial year while the data for gas is for the period March 2004 to March 2005.

Table 7.2 confirms the results of other studies which show that, overall, houses which are not connected to the gas network use more electricity than those houses that are connected. Overall, houses with no gas connected consumed 8,768 kwh of electricity per annum, while houses connected to the gas network consumed 8,072 kwh per annum. This indicates that houses with gas connection consume approximately 8% less electricity per annum than those without gas. However, this varied between estates: in Glenhaven, Liberty Grove, St Clair, Cambridge Gardens and Raby electricity consumption was actually lower in houses that did not have gas connected.

7.6 Greenhouse Gas Equivalents for Gas Consumption

Households with the highest carbon dioxide equivalent emissions (CO_2-e) for gas in the case study areas were in Glenhaven and West Pennant Hills (2.0 t CO_2-e). Dwellings in Kings Bay had the lowest CO_2-e for gas with 1.3t, although the difference between the highest and lowest ranking case study areas was minimal. Landcom and non-Landcom case study areas had similar levels of CO_2-e for gas (Table 7.3 and Figure 7.3).

Table 7.2: Electricity consumption for houses with and without gas (kwh)

	Without Gas	With Gas	Total
Low Density Estates			
Late 1970s			
St Clair	7,704	7,713	7,708
Cambridge Gardens	8,990	8,020	8,686
Early 1980s			
St Andrews	7,542	7,463	7,522
Raby	8,071	8,171	8,100
Early 1990s			
Glenhaven	13,047	13,164	13,061
West Pennant Hills	11,972	11,792	11,907
Late 1990s			
Narrellan Vale	6,316	6,278	
Harrington Park	6,900	6,901	6,900
High Density Estates			
Kings Bay	8,596	6,880	7,540
Abbotsford	NA	NA	NA
Cabarita	8,598	8,343	8,445
Liberty Grove	6,054	6,495	6,215
Total	8,768	8,072	8,375
Dwellings	10,983	6,754	17,737

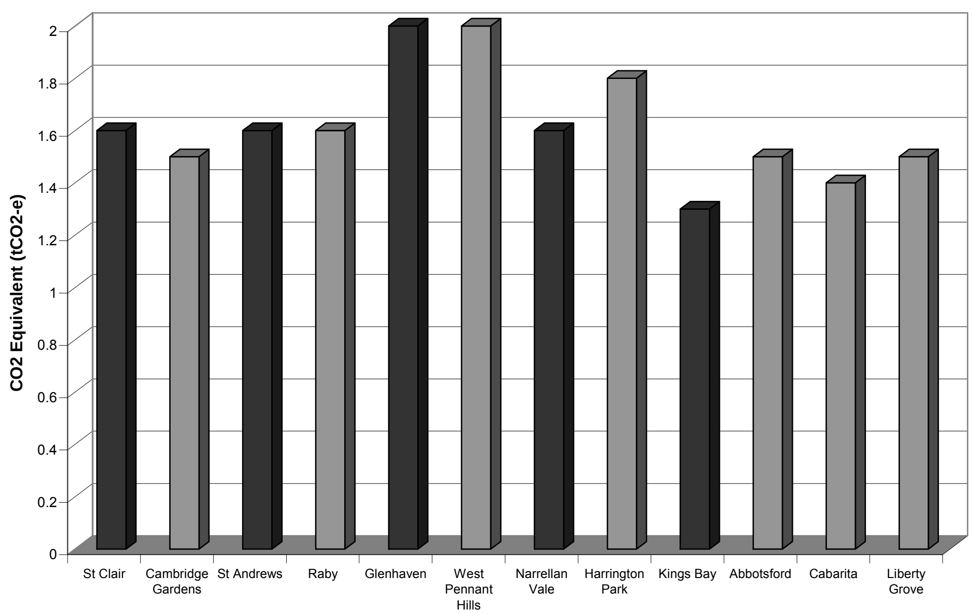
Table 7.3: Estimated Primary Gas Consumption and Carbon Dioxide Equivalent Intensities (CO_2-e) per dwelling, 2004

	Total Electricity consumption (kwh)	Estimated Total Primary Electricity Consumption (GJ)	Estimated Carbon Dioxide Equivalent Intensity (t CO2-e)
Low Density Estates			
Late 1970s			
St Clair	23,350	28.5	1.6
Cambridge Gardens	22,238	27.1	1.5
Early 1980s			
St Andrews	24,475	29.9	1.6
Raby	24,403	29.8	1.6
Early 1990s			
Glenhaven	30,562	37.3	2.0
West Pennant Hills	29,141	35.6	2.0
Late 1990s			
Narrellan Vale	23,745	29	1.6
Harrington Park	26,338	32.1	1.8
High Density Estates			
Kings Bay	19,693	24	1.3
Abbotsford	22,714	27.7	1.5
Cabarita	20,233	24.7	1.4
Liberty Grove	22,576	27.5	1.5

Notes:

- 1 GJ delivery gas equals 1.22 GJ primary gas
- 67 kt/PJ for delivered energy

Figure 7.3: Estimated Carbon Dioxide Equivalent Intensities (CO_2-e), 2004



8. EMBODIED ENERGY

8.1 Introduction

This section of the report describes the estimation of the embodied energy of the twelve case study areas in Sydney. This analysis therefore offers an assessment of the performance of the original building design and materials in terms of the energy used in their construction. As the method for this part of the research is rather more complex than that of the previous sections, a detailed description of the approach and the assumptions used is necessary. This is followed by an analysis of the estimated as-built embodied energy of the estates and an assessment of the annualised life-time energy use including both the embodied energy component and an estimated

8.2 Detailed Research Method

8.2.1 Collection of data

The method used for estimating the embodied energy of the case study areas consisted of a categorization of the dwelling types, collection of construction details and materials, estimation of materials quantities and then the calculations of embodied energy.

a) Survey of case study areas

Each case study area was surveyed to determine the nature of the dwellings and surrounding infrastructure. These surveys were carried out in December 2004. From a 'drive-by survey' of each study area carried out in December 2004, it was possible to determine whether they were relatively homogeneous in terms of the type of dwelling constructed. Where there were different types of dwelling, such as a combination of one storey and two storey houses, it was possible to estimate the relative proportions of each type. Furthermore, the surveys enabled observations to be made of materials used in the dwellings which affect the total embodied energy, for example, the use of timber or aluminum window frames, the roof pitch, the extent of ornate architectural features, etc. Photographs of the different dwelling styles were taken for later reference and these provided confirmation of construction details. Specific addresses which showed typical construction features were noted for further enquiries. A summary of the information obtained during the surveys is given in Appendix 3.

b) Collection of further construction details

As a result of the surveys of the case study areas, further information was required relating to the materials of construction of certain dwelling types as follows.

- The case study areas in the council areas of Campbelltown and Penrith were constructed in the early 1980s through to the early and mid 1990s. Consequently, early dwellings were constructed at the period when there was a transition from double brick to brick veneer external walls and from timber suspended to concrete slab on ground floors.
- West Pennant Hills case study area contained large houses, some of which had double and triple garages in a basement configuration beneath the ground floor requiring additional construction materials.

- The case study areas in the council area of Canada Bay were constructed to a higher density and further information was required to estimate embodied energy. In addition, the case study areas of Cabarita and Liberty Grove had shared swimming pool facilities which also required consideration.
- In most cases confirmation of ceiling heights was also required.

Further information was collected from the offices of Penrith, Baulkham Hills and Canada Bay Councils in February 2005 by examining the relevant development approval files. The information on flooring materials and ceiling heights obtained from Penrith Council was also relevant to houses in the Campbelltown area constructed at the same time. Similarly, ceiling heights from West Pennant Hills houses were relevant to other houses of similar age and size in the Baulkham Hills and Camden Council areas. A summary of this information is shown in Appendix 4.

8.2.2 Estimation of Embodied Energy

Embodied energy is estimated from the sum of the products of the materials quantities (in kilograms, kg) in a building and the corresponding embodied energy coefficients (in megajoules per kilogram, MJ/kg). This equates to:

$$E = m_1e_1 + m_2e_2 + m_3e_2 \ldots$$

where E is the total embodied energy
m_1 is the mass of material 1
e_1 is the embodied energy coefficient of material 1

This gives a total embodied energy for the building (in megajoules or gigajoules, where 1000MJ are equal to 1GJ) which, for the purposes of comparing building type, can be expressed as an embodied energy intensity by dividing by the floor area of the building (in megajoules per square meter, MJ/m^2, or gigajoules per square meter, GJ/m^2). For whole case study areas where the total embodied energy is a large quantity, units of terajoules (TJ) are used where 1000GJ are equal to 1TJ.

The case study areas covered the full range of dwelling types and residential urban developments where, unlike commercial or industrial buildings, it is not normal for Bills of Quantity to be produced by quantity surveyors for the purpose of tendering for the construction contracts. In the case of multi storey apartments, pre-tender estimates based on approximate quantities of materials required are derived but these are normally confidential documents. Hence, the process of determining the types and quantities of materials in buildings for the estimation of embodied energy must be directed to other means. In some cases, information on materials types on buildings on particular land lots can be obtained from the State Property Register (Pullen et al, 2002) or from Local Government Authorities. This was not the case for the case study areas nominated so alternative methods were derived.

In the case of single storey detached housing, a method had been well established based on a spreadsheet technique known as SEED, derived from the 'spreadsheet for estimating the embodied energy of dwellings' (Pullen & Perkins, 1999). Two and three storey houses required a further development of this technique involving the inclusion of multiple floors and party walls. The embodied energy of the apartment blocks at Cabarita and Abbotsford was based on the pre-tender estimates of two similar developments. The following notes give details of the techniques used.

a) Smaller single storey houses

The embodied energy of single storey houses were derived using the SEED spreadsheet technique which conveniently estimates embodied energy from basic dimensions and material specifications of houses (Pullen, 2000a). The spreadsheet can accept embodied energy coefficients for building materials from a variety of sources. For this exercise, the coefficients were derived from input-output analysis using the method previously described by Treloar (1994) in conjunction with the input-output data based on ABS statistics from 1996/97 (Australian Bureau of Statistics 2001). These were combined with process analysis data for the main construction materials to form hybrid embodied energy coefficients which were used throughout this analysis. The carbon dioxide equivalent emissions (CO_2-e) associated with the embodied energy consumption were also estimated using an extension of the spreadsheet technique. For this purpose, carbon dioxide equivalent coefficients were evaluated using a similar technique based on input-output tables.

Appendix 5 shows the estimation of the embodied energy intensity of a typical single storey house in Raby. It uses an original spreadsheet for a post 1971 house based on a typical 170m^2 floor area as precise floor plans for Raby were not available. Hence, relative relationships between the dimensions of building elements are maintained and the embodied energy intensity (per m^2) can be evaluated. The spreadsheet in Appendix 5 also reflects the proportions of different types of floors and roof tiles according to the observations made and summarised in Appendix 3 and further information obtained from council records and summarised in Appendix 4.

Similar spreadsheets were compiled for the case study areas of St Andrews, Cambridge Gardens and St Clair which are all predominantly single storey residential areas constructed between the early 1980s and the early 1990s.

b) Larger single storey houses

The single storey houses in Harrington Park and Narellan Vale in the Camden Council area and Glenhaven and West Pennant Hills in the Baulkham Hills Council area are characterised by larger footprints, higher ceiling heights, use of gable ends and half gable ends in the roof design, some houses with a 30º roof pitch and more elaborate window frames manufactured from powder coated aluminium. Appendix 5 shows the estimation of the embodied energy intensity for a typical single storey Harrington Park house. Similar spreadsheets were compiled for the larger single storey houses from the other case study areas incorporating all observations and details from council records.

c) Two storey houses

The spreadsheet for estimating the embodied energy of two storey houses is based on an extended SEED design incorporating upper floor components and staircases and has been configured to represent a typical late 1990s dwelling. The data relating to floor, wall and window areas as well as types of materials for the building components, both in the house and in external features were derived from a detailed study of six two storey houses constructed at the Mawson Lakes residential development just north of Adelaide (Pullen, 2000b). These houses were relatively large (average floor area of 280m^2) and were constructed with various elaborate external features including porches and balconies. The average dimensions for the six houses and typical construction materials were taken so that typical relative relationships could be established between the principal construction components.

The two storey house spreadsheet was then used to estimate the embodied energy of typical two storey houses in the case study areas of Harrington Park, Narellan Vale, Glenhaven and West Pennant Hills. Adjustments were made to the spreadsheet where appropriate, based on observations made in the case study areas and these included higher ceiling heights, use of gable ends and half gable ends in the roof design, some houses with a 30º roof pitch and more elaborate window frames manufactured from powder coated aluminium. The final estimate for the embodied energy of houses in these case study areas was proportionally taken from both the single storey and two storey spreadsheets. A similar process was undertaken for two storey houses at Liberty Grove and Cabarita in the Canada Bay Council areas. Significant differences at Cabarita included the use of painted timber cladding and large tiled areas in living rooms.

A further complexity arose from the case study area of West Pennant Hills where two and three car garages were constructed under the ground floor of approximately half of the houses making use of the sloping sites in that location. The additional embodied energy was estimated by the detailed examination of the construction drawings lodged with the Council of two particular houses constructed in this way. The final embodied energy of such houses was estimated based on the additional basement contribution and with timber suspended flooring on both the ground and first floors.

d) Apartment buildings

The residential developments in the Canada Bay Council area of Cabarita and Abbotsford consisted partly or wholly of apartment buildings for which bills of quantity were not available. Hence, the method adopted was to utilize an average embodied energy intensity derived from the analysis of two similar apartment buildings where detailed bills of quantity or pre-tender estimates were available. Adjustments were then made for particular features of the Cabarita and Abbotsford apartment blocks. For example, the Abbotsford site was sloping and one side of the basement parking structure for most apartment buildings was visible and consisted of decorative concrete blocks. This represented a significant difference and was taken into account during the embodied energy estimation.

The apartments in Cabarita and Abbotsford were compared to similar developments at Garden East in the north eastern corner of the central business district in Adelaide and the Holdfast Marina at Glenelg, South Australia, where previous research has been conducted. Minor modifications were made for the apartments in Cabarita and Abbotsford to reflect differences from the developments in Adelaide.

In calculating the embodied energy and carbon dioxide equivalent intensities (ie per square metre floor area), the area for one car park was also included as part of the apartment area. This was consistent with the approach taken with detached houses where the car garage area was added to the floor area for living.

e) Kings Bay development (lower rise dwellings)

This case study area required special analysis when estimating the embodied energy of the dwellings. This is a medium density development consisting of 1, 2 and 3 bedroom apartments and 2 and 3 bedroom townhouses in blocks ranging from 2 to 6 storeys but with a significant proportion of 2 and 3 floor residences. Most of the parking is underground with some of this provided by reusing the basement of a carpet factory previously occupying the site. The embodied energy of the existing basement structure was considered in the estimation, even though it could be argued that this energy was expended during the construction of the carpet factory and not the Kings Bay development.

For the purpose of the analysis, two storey townhouses and three storey walk-ups were studied. The spreadsheet method was employed using actual dimensions for the principal construction components which were gleaned from construction drawing files inspected at Canada Bay Council offices. Additional entries for party walls, floor materials such as Ultrafloor and stairwells required modifications to the spreadsheet. The embodied energy of the basement car parks was taken from that part of the estimates for the Glenelg and Garden East apartment blocks referred to previously. A similar proportion of two and three storey buildings were taken as representing this development.

In calculating the embodied energy and carbon dioxide equivalent intensities (ie per square metre floor area), the area for one car park was also included as part of the apartment area.

8.2.3 Integration with property files

In order to evaluate the embodied energy of a typical dwelling in each case study area, an average floor area was required. In the case of the older outer suburban case studies, the floor areas were obtained from a sample of property records obtained from the relevant council (see Chapter 3). Listed properties with floor areas below $100m^2$ or above $1000m^2$ were not considered as the small entries probably represented home extensions, outhouses or pergolas and large entries were probably data entry errors. For the inner suburban case study areas which were all in the Canada Bay Council area, the average floor areas were obtained by examining typical floor plans of the dwellings. These data are summarised in Table 8.1.

8.2.4 Infrastructure

a) Roads

The embodied energy of roads was evaluated from the information on the road surface area and the embodied energy intensities for residential and collector roads. These intensities were derived from typical road construction specifications of $625kg/m^2$ dolomite base and $72kg/m^2$ asphalt for residential, and $736kg/m^2$ dolomite base and $96kg/m^2$ asphalt for collector roads, respectively, as confirmed by Roads and Traffic Authority of NSW. It should be noted that energy expended during the construction of roads was not considered in this analysis nor was any additional embodied energy for road repairs.

Table 8.1: Summary of the Number of Property Records

	Sample Number	Average Floor Area (m^2)
Low Density Estates		
Late 1970s		
St Clair	6517	167
Cambridge Gardens	733	181.1
Early 1980s		
St Andrews	49	172.7
Raby	50	153.4
Early 1990s		
Glenhaven	202	312.5
West Pennant Hills	206	332.5
Late 1990s		
Narrellan Vale	245	201.3
Harrington Park	237	236.6
High Density Estates		
Kings Bay	Typical designs	Townhouse 192.0 Walkup 50.0
Abbotsford	Typical designs	107.3
Cabarita	Typical designs	House 225.0 Apartment 120.0
Liberty Grove	Typical designs	245

b) Water supply

The lengths of different types and diameters of pipes in each case study area were obtained from GIS data and amounted to over 4000 records in total. A range of pipe types were used including cast iron concrete lined (CICL), ductile iron concrete lined (CICl), steel concrete lined (SCL), unplasticized polyvinylchloride (uPVC), glass fibre reinforced plastic (GRP), copper and polyethylene (PE), in sizes from 100mm to 1200mm diameter. The wall thickness of the different pipes was obtained from Australian Standards and manufacturers specifications. This enabled the embodied energy per meter length of each pipe type to be estimated. Hence, the embodied energy of the water supply system in each case study area was then calculated.

c) Sewer system

A similar method to the water supply system was also applied to the sewer system where the types of pipes used included cast iron concrete lined, ductile iron concrete lined, mild steel concrete lined, reinforced concrete (MSCL), glass fibre reinforced plastic, polyvinylchloride and vitreous clay in a similar range of sizes.

d) Storm water system

No data was obtained on the storm water system in each case study area. An estimate on the embodied energy of a residential storm water system had previously been carried out for a suburb on the outskirts of Adelaide (Pullen et al 1998). This data was updated with the recently developed hybrid embodied energy coefficients and a value for the embodied energy per dwelling calculated. This value was used to estimate the embodied energy of the storm water system in each Sydney case study area.

For all three pipe systems, the total embodied energy was increased by 22% to account for the energy expended during the pipe laying process. This estimate of on-site energy consumption was calculated during earlier research work (Pullen et al, 1998) based on information obtained from pipe laying contractors. No additional embodied energy was included for maintenance during the life of the pipe systems.

e) Other infrastructure
The estimation of the embodied energy of other infrastructure such as gas supply, electricity reticulation and communications was not attempted.

8.3 Results

8.3.1 Embodied energy intensities

Both the embodied energy intensities and the carbon dioxide equivalent intensities arising from associated emissions are given in Table 8.2 for the dwellings in the case study areas. The first column of figures shows the embodied energy intensity for the materials in the dwellings at the beginning of the life cycle or 'as-built'.

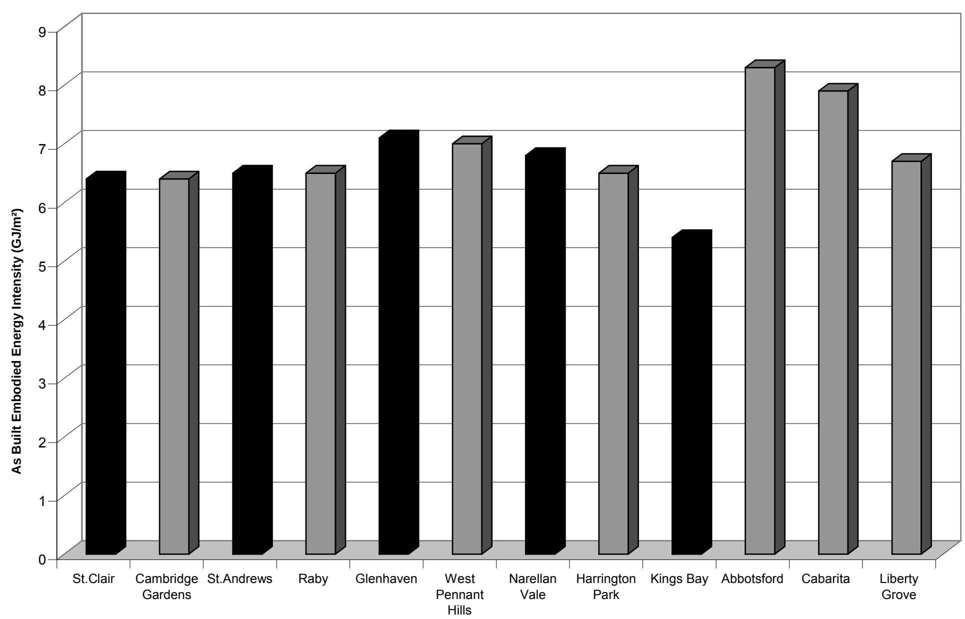
Table 8.2: Embodied energy (EE) and carbon dioxide equivalent intensities

	EE Intensity (GJ/m^2)			Carbon Dioxide Equivalent Intensity ($kgCO2\text{-}e/m^2$)		
	Materials		Materials & Construction	Materials		Materials & Construction
	As- built	With replacements		As-built	With replacements	
Low Density Estates						
Late 1970s						
St Clair	6.4	10.3	11.0	530	848	907
Cambridge Gardens	6.4	10.2	10.9	528	845	904
Early 1980s						
St Andrews	6.5	10.3	11.1	533	853	912
Raby	6.5	10.4	11.2	542	867	928
Early 1990s						
Glenhaven	7.1	11.4	12.2	592	947	1014
West Pennant Hills	7.0	11.1	11.9	511	818	875
Late 1990s						
Narrellan Vale	6.8	10.8	11.6	561	898	960
Harrington Park	6.5	10.4	11.1	541	866	926
High Density Estates						
Kings Bay	5.4	8.7	9.6	438	701	771
Abbotsford	8.3	13.3	14.6	683	1093	1202
Cabarita	7.9	12.6	13.8	648	1036	1140
Liberty Grove	6.7	10.7	11.5	590	944	950

In the second column of figures, cconsideration is given to the additional embodied energy arising from materials and components used for repair, replacement and maintenance. Research evidence to date suggests that this energy invested in houses in the form of maintenance is of the order of 10% per decade of the initial as-built embodied energy (Treloar et al 2000, Pullen 2000c) and this estimate has been included in subsequent analysis. The period over which this estimate is made has been taken to be 60 years for all types of dwelling and this anticipates a lower level of maintenance and no upgrading in the initial and final five year periods of the buildings' life cycle.

The energy used on site for construction activities and for subsequent replacement activities over the life of the dwellings is included and the total is given in the third column of Table 8.2. For houses, there is some research indicating that construction energy could be in the region of 6 – 10% of the embodied energy of the construction materials (See 1998) and possibly higher for multi-storey commercial and residential buildings. A factor of 7% has been used for houses and 10% for case study areas with apartments.

Figure 8.1: As-Built Embodied Energy Intensities of Dwellings in the Case Study Areas



The differences between the as-built embodied energy intensities of dwellings in the various case study areas are highlighted in Figure 8.1. The multi-storey developments at Abbotsford and Cabarita show the highest intensities. The increase in embodied energy with a greater number of storeys has also been shown for commercial buildings by Treloar et al (2001). The large detached houses in the areas of Glenhaven and West Pennant Hills are next. The smaller detached houses in the older case study areas of Raby, St Andrews, St Clair and Cambridge Gardens have lower intensities. The Kings Bay development shows the lowest intensity and reflects the fact that the developer intended to use more efficient building materials and construction methodology as one of a number of sustainable development initiatives.

The total embodied energy of the dwellings for each case study area is given in Table 8.3. This table uses embodied energy intensities for typical dwellings for each area which include the additional energy for maintenance over the lifecycle of the buildings and the on site construction energy.

Table 8.3: Embodied energy (EE) of the Dwellings for each Case Study Area

	EE Intensity	Average Dwelling Size	Lifetime EE of Typical Dwelling (GJ)	Number of Dwellings	EE of all Dwellings
Low Density Estates					
Late 1970s					
St Clair	11	167	1832.6	5887	10788.8
Cambridge Gardens	10.9	181.1	1981.2	689	1365
Early 1980s					
St Andrews	11.1	172.7	1910	1586	3029.2
Raby	11.2	153.4	1714.9	1892	3244.6
Early 1990s					
Glenhaven	12.2	312.5	3803.9	1365	5192.3
West Pennant Hills	11.9	332.5	3956.2	1336	5285.5
Late 1990s					
Narrellan Vale	11.6	201.3	2329.7	2174	5064.7
Harrington Park	11.1	236.6	2636.9	902	2378.5
High Density Estates					
Kings Bay	9.6	121	1159.1	308	357
Abbotsford	14.6	107.3	1565.5	430	673.2
Cabarita	13.8	151	2088.9	452	944.2
Liberty Grove	11.5	245	2806.1	389	1091.6

8.3.2 Infrastructure

The estimation of embodied energy of infrastructure is shown in Table 8.4. The embodied energy intensities for roads were broadly in agreement with those of other researchers (Treloar et al 2004) for bitumen based asphaltic concrete on a granular sub-base (i.e. in the region of $2GJ/m^2$ depending on the type of road). Similarly, for water supply pipes, the values for embodied energy per meter length for the various types and sizes of pipes were of the same order as those developed by Ambrose et al (2002).

8.3.3 Total embodied energy per dwelling

The total embodied energy per dwelling consisted of the energy embodied in both the ‘as built’ and ‘replacement’ materials of the buildings, the on site construction energy, energy embodied in the roads and energy embodied in the water infrastructure (including pipe laying activities). The energy embodied in both the ‘as built’ and ‘replacement’ materials of the buildings was evaluated from the embodied energy intensities and the average floor areas.

Table 8.4: Embodied Energy of Dwellings and Infrastructure (TJ)

	EE of all dwellings	EE of roads	EE of water supply	EE of sewer system	EE of storm water system	Total EE for case study area
Low Density Estates						
Late 1970s						
St Clair	10788.8	2995	228.2	106	132.2	14250.2
Cambridge Gardens	1365	287.2	21.3	8.7	15.5	1697.6
Early 1980s						
St Andrews	3029.2	866.8	81.3	27.6	35.6	4040.5
Raby	3244.6	836.3	28.2	35	42.5	4186.6
Early 1990s						
Glenhaven	5192.3	734.6	40.2	38.3	30.7	6036
West Pennant Hills	5285.5	1020.5	150.2	26.5	30	6512.8
Late 1990s						
Narrellan Vale	5064.7	1340.3	88.3	40.1	48.8	6582.3
Harrington Park	2378.5	707.7	51	36.4	20.3	3193.8
High Density Estates						
Kings Bay	357	29.3	29.8	15.6	6.9	438.7
Abbotsford	673.2	65.6	3.4	5.9	9.7	757.8
Cabarita	944.2	69	13	20	10.2	1056.4
Liberty Grove	1091.6	53.1	0	7.7	8.7	1161.1

Table 8.5: Embodied Energy of Buildings and Infrastructure per Dwelling (GJ)

	Lifetime EE of typical dwelling	EE of roads per dwelling	EE of water supply per dwelling	EE of sewer system per dwelling	EE of storm water system per dwelling	Total EE (buildings and infra-structure) per dwelling	Total EE (buildings and infra-structure) per capita
Low Density Estates							
Late 1970s							
St Clair	1832.6	508.7	38.8	18	22.5	2420.6	704
Cambridge Gardens	1981.2	416.8	30.9	12.6	22.5	2463.9	782
Early 1980s							
St Andrews	1910	546.5	51.2	17.4	22.5	2547.6	743
Raby	1714.9	442	14.9	18.5	22.5	2212.8	669
Early 1990s							
Glenhaven	3803.9	538.1	29.5	28	22.5	4421.9	1301
West Pennant Hills	3956.2	763.9	112.5	19.8	22.5	4874.8	1362
Late 1990s							
Narrellan Vale	2329.7	616.5	40.6	18.5	22.5	3027.7	949
Harrington Park	2636.9	784.6	56.5	40.3	22.5	3540.8	1060
High Density Estates							
Kings Bay	1159.1	95.3	96.6	50.8	22.5	1424.2	642
Abbotsford	1565.5	152.6	7.9	13.8	22.5	1762.4	801
Cabarita	2088.9	152.6	28.8	44.3	22.5	2337.1	895
Liberty Grove	2806.1	136.4	0.1	19.8	22.5	2984.9	1106

8.3.4 Annualised embodied energy and carbon dioxide equivalent emissions

One way to relate the annual operational energy consumption of buildings and infrastructure with embodied energy is to annualise the latter. This means taking the total embodied energy of a building or infrastructure component and dividing it by the life expectancy. The life expectancies that have been used are similar to those used in Adelaide (Troy et al, 2002) which were 70, 50 and 60 years for dwellings, roads and water systems, respectively. Annualised embodied energy totals are presented in Table 8.6 on a 'per dwelling' and 'per case study area (CSA) basis'.

Similar data are presented for carbon dioxide equivalent greenhouse gas emissions. For the dwellings, the emissions have been evaluated using CO_2 equivalent coefficients derived from input-output analysis using ABS tables from 1996/97 (Australian Bureau of Statistics, 2001) in conjunction with the SEED spreadsheet. This method evaluates the emissions of the dwellings as a sum of the emissions of the individual construction components. The additional emissions for maintenance and repair are factored in on the same basis as for embodied energy. For the roads and water systems, the embodied energy data have been converted to emissions using a factor of 82.4 kg/GJ.

Table 8.6: Annualised Embodied Energy (GJ/year) and Carbon Dioxide Equivalent Emissions (kg CO_2-e/year)

	Annual EE (GJ/year)			Annual CO_2 equiv. emissions (kg CO_2-e/year)		
	per dwelling	per capita	per CSA	per dwelling	per capita	per CSA
Low Density Estates						
Late 1970s						
St Clair	37.7	11.0	22.8	3111.9	908.0	18319.8
Cambridge Gardens	37.7	12.0	26.0	3116.0	991.8	2146.9
Early 1980s						
St Andrews	39.7	11.6	63.0	3277.1	957.5	5197.4
Raby	34.3	10.4	64.8	2838.6	860.7	5370.6
Early 1990s						
Glenhaven	66.4	19.5	90.7	5521.2	1621.4	7536.5
West Pennant Hills	74.4	20.8	99.4	5626.8	1573.1	7517.4
Late 1990s						
Narrellan Vale	47.0	14.7	102.1	3889.9	1216.6	8456.7
Harrington Park	55.3	16.6	49.9	4587.3	1377.0	4137.8
High Density Estates						
Kings Bay	21.3	9.6	6.6	1722.7	776.5	530.6
Abbotsford	26.2	11.9	11.2	2155.1	978.8	926.7
Cabarita	34.5	13.2	15.6	2841.7	1087.2	1284.4
Liberty Grove	43.5	16.1	16.9	3818.3	1413.2	1485.3

8.4 Discussion

The summary of total embodied energy for a typical dwelling in each case study area is shown in the form of a bar chart in Figure 8.2. This indicates that the denser multi-storey dwellings have a lower total embodied energy compared with the low density detached houses prevalent in outer suburbs. In addition, there is a suggestion that the Landcom developments are lower in embodied energy than the privately developed equivalents. Total embodied energy of a ‘typical’ dwelling and associated infrastructure in the case study areas is highest in West Pennant Hills (4875 GJ) and Glenhaven (4422 GJ) (Table 8.5). This is followed by Harrington Park (3541 GJ). These areas, particularly the former two, are record substantially higher embodied energy levels than most of the other estates in the study. These three areas are not only among the higher socio-economic status areas, but they are also the most recently developed areas, strongly indicating the modern design and construction methods have a much greater environmental impact than those of earlier periods when houses were smaller and building materials more traditional and dwelling sizes more modest by recent standards.

The higher density areas of Abbotsford and Kings Bay have the lowest total embodied energy. However, the medium density development of Liberty Grove ranks fifth out of the twelve case study areas and has much higher total embodied energy than the other medium-higher density areas (Figure 8.2).

Compared with a similar study in Adelaide (Troy et al, 2002), the range of embodied energy values for dwellings is similar on a per floor area basis although the larger houses in certain Sydney case study areas result in larger gross values.

The embodied energy of roads was found to be significant and was on average 19% of the life cycle embodied energy of a dwelling and up to 32% of the as-built embodied energy of a dwelling. Roads comprised a much larger component of the embodied energy of houses compared to medium and higher density estates, highlighting the gains that higher density housing can achieve in terms of reduced per dwelling infrastructure provision. The combined water systems constituted 4% and 7% (on average) of the life cycle and as-built embodied energy of a dwelling. The composition of the total embodied energy for typical dwellings in each case study area is shown in Figure 8.3.

The data for the water supply for Liberty Grove appears incomplete resulting in spurious value for this embodied energy. Although this report refers to the total embodied energy, it must be remembered that the scope of the project did not allow for the derivation of new data in the areas of road maintenance or construction energy, water system maintenance energy and gas/electricity/communications infrastructure energy. It is considered that these omissions would not make a significant difference to the relative results between case study areas.

Table 8.6 also shows that estimated greenhouse gas emissions generated from the embodied energy estimates for each estates. The patterns of emissions parallel the embodied energy levels.

Figure 8.2: Total Embodied Energy of Typical Dwellings (GJ)

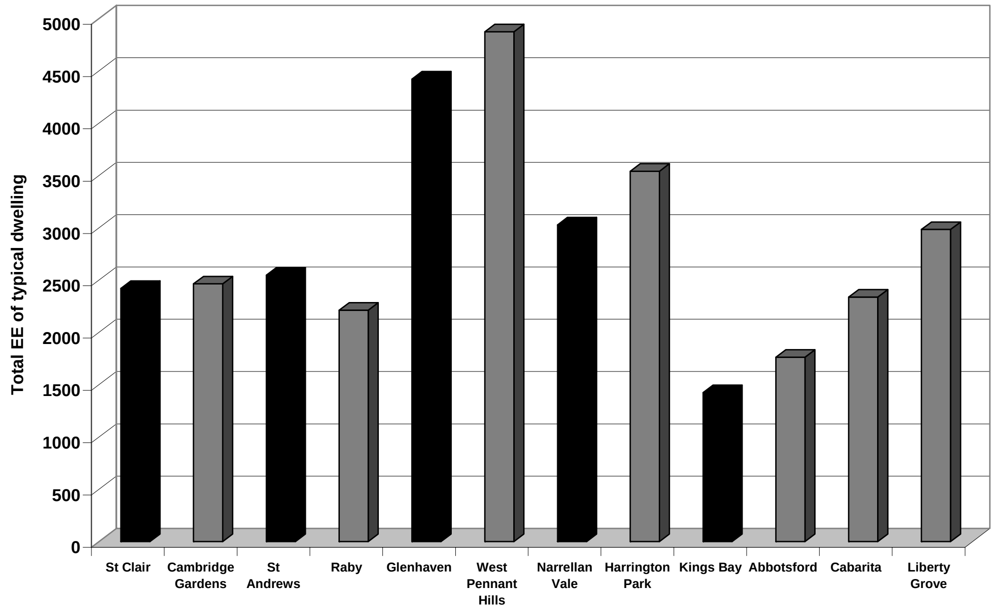
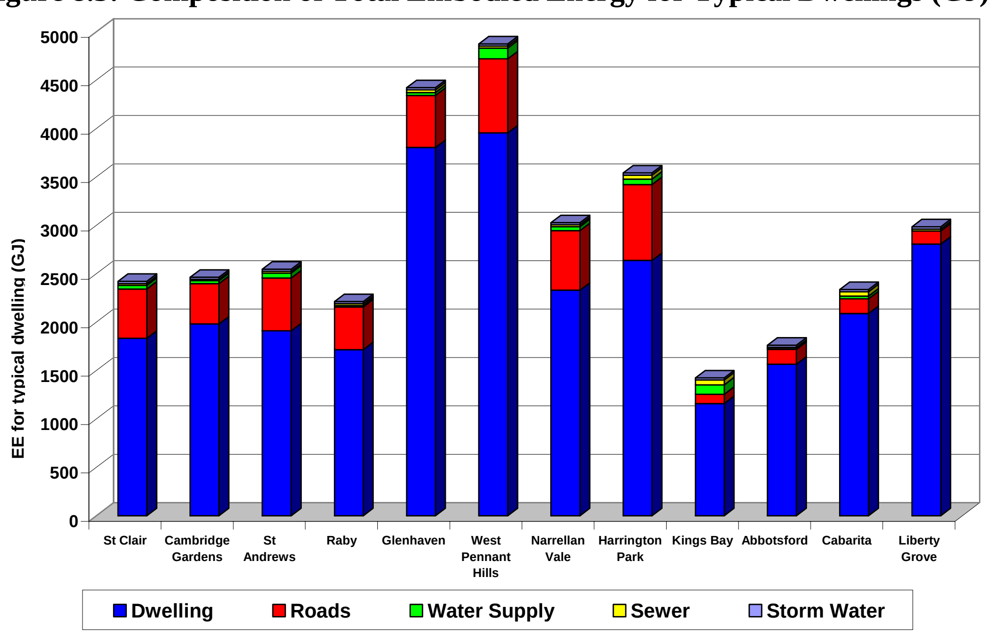


Figure 8.3: Composition of Total Embodied Energy for Typical Dwellings (GJ)



9. MONITORING WATER AND ENERGY IN LANDCOM DEVELOPMENTS

9.1 Introduction

One of the objectives of this research project was to develop a method that could be used over time to monitor the energy and water profiles of residential developments. This method could be used by Landcom (as well as other developers) to build a continual profile of the energy and water consumption in their housing developments. This section outlines a number of options available to Landcom in order to use this methodology for future environmental reporting. As the data requirements for the operational energy (including water consumption) and embodied energy elements of this methodology are different, each will be addressed separately. There are a number of issues associated with the individual data sets that would make the collection of the data from different organisations simpler, but these will be dealt with in the next section.

9.2 Options for Collecting Operational Energy and Water Consumption Data

For this part of the method the data was collected from the energy and water providers in Sydney. As previously noted this included Sydney Water, Integral Energy, Energy Australia and AGL. At the outset of the project these organisations were approached in order to obtain electricity, water and gas consumption data for individual properties in the case study areas. Due to the ambiguous nature of the Privacy Act and the experience of each individual organisation in dealing with such requests, a number of options could be explored by Landcom to obtain such data on a regular basis. Options include:

1. If Landcom is constructing the dwellings itself, at the point of sale Landcom could request that the household allow them obtain energy and water consumption information for their property for a specified period. How this would work once a dwelling is sold on would need further consideration. A voluntary agreement would be preferable, but a caveat placed on the sale of the property might also be considered.

2. Another option available to Landcom would be to request households in Landcom developed areas to sign an agreement to release their energy and water consumption information to Landcom for reporting requirements. This could be most easily undertaken by Landcom undertaking an initial survey in the area to establish some baseline information about water and energy use. The survey could also provide valuable demographic information to complement the energy and water consumption data. However, there are a number of issues associated with this option including how often Landcom might survey each of the areas and the financial costs involved.

3. One of the more fruitful options for Landcom would be to formally sign a Memorandum of Understanding (MoU) or some form of contractual

agreement with each of the energy and water providers in Sydney, so that each of these organisations would regularly supply water and energy consumption data to Landcom for regular environmental reporting purposes. Such an agreement could also be supplemented by periodic household surveys conducted by Landcom to obtain socio-demographic information about households in Landcom developed areas. This option may take some time to set up but would be the most effective for providing information for regular reporting requirements.

9.3 Options for Collecting Data for Embodied Energy Estimates

This section will examine the options for collecting the data required for estimating the embodied energy in dwellings constructed in Landcom developments. In particular the data requirements to estimate the embodied energy in the dwelling itself will be examined. This section will not examine the data required for analysing the embodied energy in other infrastructure such as roads and water pipes as this data is more readily available. The information required for embodied energy estimates for each dwelling are based on the physical nature of the dwellings. This includes floor area and materials of construction. Where Landcom constructs the buildings, or manages the development process, the information required for embodied energy estimates should already be available from detailed master plans. The data required for the embodied energy estimates of dwellings are not bound by regulations under the Privacy Act but are not available through the current valuation process. Options include:

1. Landcom could send assessors to each of the individual dwellings to obtain information, such as materials of construction. The cost of such an exercise would need to be evaluated. Such an exercise could also be used in conjunction with options two and three below. The disadvantage of this option is that, for example, floor area information, may need to be obtained from other sources.

2. As the majority of information for embodied energy estimates can be obtained from site and floor plans for each dwelling Landcom could also sign an 'Agreement' or 'MoU' with a Local Council when a development is about to begin. If the construction of the dwelling is not undertaken by Landcom, then the Local Council could provide copies of all plans to aid in providing information for estimating the embodied energy of a dwelling(s). Some on-ground fieldwork (as in Option 1) may be necessary depending on what information a Council can, or would, provide.

3. Related to the option above, if Landcom are selling land to a builder to construct the dwelling, Landcom could request as a condition of sale that Landcom be provided with copies of all plans that are submitted to Councils. Other information that may be necessary to undertake an embodied energy estimate could also be collected at this stage through the builder. For example, in the case of multi-storey residential developments, access to bills of quantity and/or pre-tender estimates of the materials required for development should be part of any agreement. The legality of such a

condition would need to be assessed. The benefit of this option is that the builder could provide all necessary information without any on-ground fieldwork being undertaken (as in Option 1) and the costs of doing so.

10. CONCLUSION

The objective of this research project was to establish a method to measure the energy and water consumption profiles of a number of different housing developments in the Sydney metropolitan area. The research was conducted in five Landcom developments and a number of nearby estates for comparative purposes. With the help of a range of energy and water utilities, this research has developed an effective and viable approach for the ongoing monitoring of energy and water use. The method was developed from the consumer databases and other information held as part of the ongoing operations of the organisations involved in the study, including Landcom's own record of building plans.

Such a method has a number of important outcomes. Firstly, information already collected and held by various planning, energy and water organisations as well as local councils can be put together effectively to monitor energy and water consumption in different forms of housing. This has important implications for future environmental modelling and monitoring of housing in both NSW and elsewhere. The method could be used by developers and planning agencies to develop a suite of tools to monitor the energy and water performance of their developments as well as obtaining a better understanding of how their previous developments are performing. Such information would represent an important additional source of information to inform future planning and development.

As has been shown in other research (Troy, et al 2005), the behaviour and attitudes of individuals and households also plays a major role in determining the levels of domestic resource consumption. Using the method developed in this research information can be provided to organisations to help target demand management initiatives to try and reduce consumption where levels are high. As an additional tool to monitor demand, the impacts of initiatives such as the NSW Government's BASIX system could be much more readily assessed over time.

Water and Energy Consumption

Water consumption was highest in the case study areas of Glenhaven and West Pennant Hills and lowest Kings Bay and Abbotsford. Water consumption for houses was also the highest in Glenhaven and West Pennant Hills and lowest in Kings Bay and Liberty Grove. In the case study areas with sufficient numbers of multi-unit dwellings Kings Bay had the lowest consumption whereas Liberty Grove had the highest.

But on a per capita basis water consumption was much less variable, averaging 101 kl per annum for houses and 83 kl per annum for multi-unit dwellings. But there was no straightforward relationship between building density and water consumption with some high density estates having higher per capita usage than some low density estates. The only exceptions were Glenhaven and West Pennant Hills which have much higher consumption than other case study areas, which we concluded was a function of the significantly higher income profile of these estates and the much larger dwelling characteristics.

A similar picture to water consumption emerged for electricity and gas consumption in the case study areas. Glenhaven and West Pennant Hills had the highest electricity consumption per dwelling in the case study areas while Kings Bay and Liberty Grove had the lowest. Electricity consumption in houses was also highest in Glenhaven and West Pennant Hills and lowest in Narellan Vale and Liberty Grove. For the four case study areas with predominantly multi-unit dwellings, Kings Bay had by far the lowest electricity consumption. On a per capita basis the higher density area of Abbotsford had the highest electricity consumption followed by low density Glenhaven. The lowest consuming households on a per capita basis were the higher density area of Kings Bay and Narellan Vale.

Gas consumption was fairly constant across the case study areas. Again, Glenhaven and West Pennant Hills had the highest gas consumption per dwelling, while Kings Bay had the lowest. This is similar to the situation for houses, although for semi detached dwellings the highest consumers of gas were in the case study areas of predominantly higher density housing – Liberty Grove, Kings Bay, Abbotsford and Cabarita.

Generally speaking this research confirms other work in that households who have gas generally use less electricity, however, this was not the case in all case study areas. The constraints of data used in this research mean that this result is only indicative but that further research may be needed across different geographical areas to assess this in more detail.

As noted ablve , the higher consuming households in this study in Glenhaven and West Pennant Hills were also the areas with the largest dwellings. The dwellings in these two areas were nearly 50% greater than areas with the next largest dwellings (Harrington Park, Liberty Grove). The implications of dwelling size on the energy and water consumption behaviour of residents is clearly an issue that requires further research.

Greenhouse Gas Emissions

Not surprisingly, the highest carbon dioxide emissions in the case study areas were recorded in Glenhaven and West Pennant Hills. The emission intensities recorded in these two areas were also significantly higher than for the other case study areas. Interestingly, two of the higher density case study areas (Abbotsford and Cabarita) had high carbon dioxide equivalent (CO_2-e) emissions which were similar to most of the detached housing areas. Nevertheless, the Landcom development of Kings Bay had the lowest level of CO_2-e emissions. Except for Glenhaven, all the Landcom developments had lower levels of CO_2-e emissions compared to their nearby comparator estates.

The CO_2-e results presented in this report are comparable to those found by other researchers (Troy, et al 2002 and 2003, SSROC 2005) once the figures are adjusted to include transport. This study has excluded transport energy from the calculations presented below mainly because of the complexity involved (Perkins 2001). Other research contends that transport energy is approximately 40%-45% of total household energy (Troy et al 2002 and 2003, SSROC 2005) and the inclusion of this factor alone would account for the differences between this report and that of Troy et al (2002 and 2003) and SSROC (2005).

Socio-Economic Implications of Consumption

From the results presented above it is evident that factors other than the physical dwelling type or density impact on energy and water consumption. This research did not specifically seek to address the issue of what these factors might be in the case study areas presented. However, it is evident that built form interacts in complex manner with both socio-demographic and behavioural factors to influence energy and water consumption. This report cannot fully explain these but a number of 'general' trends are presented here. Firstly, like many other studies on energy and water consumption, the size of the household is an important ingredient in *total* dwelling consumption, be they separate houses or higher density dwellings. The higher water and energy consuming case study areas also tend to have the larger sized households. Conversely, those case study areas with higher proportions of single person households generally tended to have lower household consumption.

Similarly, income and related socio-economic factors appear to be an important determining variables, confirming the findings of earlier studies. Those case study areas with higher proportions of high income households, of which Glenhaven and West Pennant Hills stand out, generally tended to have the highest levels of energy and water consumption.

The other 'general' trend to emerge from the research was the influence of private renters. In the higher consuming case study areas the proportion of private renters was much lower than that of the lower consuming households. For example, in the two highest consuming areas of Glenhaven and West Pennant Hills the proportion of private renters was 5% and 11% while in the two lowest consuming areas on a dwelling basis, Kings Bay and Abbotsford the proportion of private renters was 25% and 32%. Whether this result is also related to the level of income in the case study areas is a matter of future research. The findings do suggest, however, that in any analysis of energy and water consumption it is important to take into consideration the socio-economic characteristics of the household, not just the characteristics of the physical dwelling.

The embodied energy analysis highlight the much greater embodied energy profiles of the most recent estates, which coincided with those estates with the highest income profile. These estates are characterised by much larger dwellings than the older more 'traditional' suburban estates developed in the 1970s and 1980s. The analysis also highlighted the significance of road infrastructure as a component of the total embodied energy in house dwellings built on low density estates. However, the high as-built embodies energy intensities of some of the higher density estates suggests there is, again, no straightforward relationship between dwelling density and energy use. As the Kings Bay case study example indicates, housing needs to be built to achieve environmentally efficient outcomes for such gains to occur. Simply building high rise housing is no guarantee of good environmental outcomes.

Relevance of the Research to Landcom

There are a number of results from this research that are relevant to the ongoing research and development agenda of Landcom. Firstly, the method developed in this research can be applied to any of Landcom's developments to monitor their environmental outcomes. Secondly, the method could be used by Landcom to assist in the planning of future residential developments to estimate the water and energy impacts.

The method developed in this research collated data from a number of different sources, all with different data collection facilities and an understanding of what their data could be used for. Nevertheless, using the example established by this research, Landcom would be in a position to establish arrangements to regularly collect data from these organisations as part of an ongoing research and monitoring program on water and energy consumption outcomes in order to develop a much firmer understanding of the environmental impacts of different forms of development.

Of course, water and energy consumption is also influenced by the behaviour and attitudes of households which are outside the control of the developer. Nevertheless, the profiling methodology developed in this research could be used with ongoing household survey interviews with residents on Landcom estates to better understand the complex influences of water and energy consumption and provide input into future residential developments. This type of analysis could be used by Landcom to assist in enhancing planning policies in NSW. For example, Landcom are in an excellent position to evaluate the impacts of BASIX in their developments. The method developed as part of this research project combined with a household survey of a sample of developments could provide valuable information on the outcomes and implications of the BASIX planning tool.

Considerations of Future Environmental/Urban Modelling
This research project has developed a method for measuring the water and energy profiles of different forms of housing in the Sydney metropolitan area. This method can be applied to other cities in Australia and can be used to provide data for use in the development of urban/environmental models. As previously mentioned the method can also be used by developers or planning authorities to examine the energy and water profiles of different built forms.

Data Issues
There are a number of issues that need to be addressed in order to make the methodology developed in this project more efficient. It was quite clear from the negotiations with the organisations involved in this research project that the Privacy Act in NSW is ambiguous. Outside of medical and health research, the Privacy Act is inadequate for dealing with environmental planning research. Considering this has important future environmental and sustainability implications this needs to be addressed.

It is also clear from the data collected and analysed in this project that there are serious spatial information issues to be addressed at the State level in NSW. Firstly, there is a lack of consistency in data collected by organisations in NSW, including the lack of data standards, particularly with street addresses, and geo-coding. The lack of data stored centrally in NSW and readily available to researchers is problematic. Further, data for this project was not collected from some Councils due to third party and licensing restrictions imposed on councils by GIS software suppliers. If urban and environmental modelling is to develop as an important planning tool for the future, then spatial information needs to be more readily available and coordinated in a more efficient manner. Compared with other states in Australia, the availability and coordination of spatial information in NSW is not as advanced.

Future Research

Overall, this project found that water and energy consumption was highest in the case study areas of Glenhaven and West Pennant Hills. Generally speaking the detached housing areas had higher household consumption than multi-unit dwellings, but once account was taken of the household size the situation became much more mixed, with some of the higher socio-economic higher density areas having larger per capita rates of consumption than some detached areas.

While there was an implied association between higher consumption profiles and higher socio-economic status, behaviour, larger dwelling and household size, or a combination of these, it was not possible in the context of this study to determine clear correlates due to the lack of household level socio-demographic data. The variables influencing rates of consumption are difficult to determine from this research. Ideally, further information from household surveys within the case study areas would be needed to more definitively isolate the factors influencing water and energy consumption in different estates.

Nevertheless, this research project has developed a viable method using information currently held by a number of utility organisations to examine energy and water consumption in different forms of development. The method can be adapted to other locations, including non-residential developments. The method could be used as part of a more sophisticated suite of urban environmental monitoring tools. Other techniques could also be included with this method, for example transport consumption, to more develop these modelling systems. Importantly, all these ‘technological’ tools should also be supplemented with household surveys to better understand the behaviour aspects of energy and water consumption.

REFERENCES

Ambrose, M., Salomonsson, G. and Burn, S. (2002) *Piping Systems Embodied Energy Analysis,* CSIRO Manufacturing and Infrastructure Technology, CSIRO.

Australian Bureau of Statistics (2001) *Australian National Accounts: Input Output Tables 1996-97*, Catalogue No. 5209.0, ABS, Canberra.

Australian Bureau of Statistics (2004) *Water Account Australia 2000-01*, Catalogue No. 4610.0, ABS, Canberra.

Bartels, R. (1988) *Household Energy Consumption: An Analysis of the 1984 ABS NSW Energy Survey*, NSW Department of Energy, Sydney.

Bartels, R., Fiebig, D. and Nahm, D. (1995) *Regional End-Use Gas Demand in Australia*, Econometrics Discussion Papers No. 95-02, Department of Econometrics, University of Sydney, NSW.

Bartels, R., Lopert, P. and Williamson, S. (1985) *The Residential Demand for Electricity in New South Wales*, Energy Authority of New South Wales, Sydney.

Bunker, R., Holloway, D. and Randolph. B. (2005) *The expansion of urban consolidation in Sydney: social impacts and implications*, Australian Planner 42, 3, 16-25.

Crawford, R. (2005) Validation of the Use of Input-Output Data for Embodied Energy Analysis of the Australian Construction Industry, *Journal of Construction Research*, 6, 1, 71-90.

Dandy, G. (1987) *A Study of the Factors Which Affect Residential Water Consumption in Adelaide*, Report No. R78, Department of Civil Engineering, University of Adelaide, SA.

Department of Water Resources Victoria (1986) *Forecasting and Managing Urban Water Demand in Victoria*, Department of Water Resources, Melbourne.

Eardley, T., Parolin, B. and Norris, K. (2005) *The Social and Spatial Correlates of Water Use in the Sydney Region,* Final Report, University of Western Sydney.

Foran, B (2005) *The Footprint of Cities*, Paper presented at the Urbanism, Environment and Health, Fenner Conference 2006, Canberra, 24-25 May 2006 http://nceph.anu.edu.au/Fenner2006/presentation_pdfs/Thursday/Foran%20Fenner%20May%202006.pdf. Downloaded 7 March 2007.

IPART (2004a) *Residential Water Use in Sydney, the Blue Mountains and Illawarra*, Research Paper No. 26, IPART, Sydney.

IPART (2004b) *The Determinants of Urban Residential Water Demand in Sydney, the Blue Mountains and Illawarra*, Working Paper No. 1, IPART, Sydney.

IPART (2004c) *Residential Energy Use in Sydney, the Blue Mountains and Illawarra*, Research Paper No. 27, IPART, Sydney.

Lennox, J. A. and Turner, G. M. (2005) *State of the Environment Report on Human Settlements: Stocks and Flows Indicators*, Prepared for the Department of the Environment and Heritage, Canberra, CSIRO Sustainable Ecosystems, Canberra.

Lenzen, M., Dey, C. and Foran, B. (2004) Energy requirements of Sydney households, *Ecological Economics*, 49, 3, 375-399.

Metropolitan Water Authority (1985) *Domestic Water Use in Perth, Western Australia*, Metropolitan Water Authority, Leederville, WA.

Myors, *et al*. (2005) 'Multi-Unit Residential Building Energy & Peak Demand Study', *Energy News*, 23(4), 113-16

Perkins, A. (2001) *The Influence of Urban Form on Life Cycle Transport and Housing Energy and Greenhouse Gas Emissions*, Unpublished PhD thesis, School of Geoinformatics, Building & Planning, University of South Australia.

Poulsen, M. and Forrest, J. (1988) Correlates of Energy Sue: Domestic Electricity Consumption in Sydney, *Environment and Planning A*, 20, 327-338.

Pullen, S., Varley, C., Bruce, D., Perkins, A. and Lee, H. (1998) *Evaluating the Energy Requirements of Urban Water Systems*, School of Geoinformatics, Planning & Building, University of South Australia.

Pullen, S. and Perkins, A. (1999) Design Tools for Assessing the Environmental Impact of Houses, in J. Zhang (ed.) *Proceedings of the Australasian University Building Education Association 24th Annual Conference and Catalyst 99: 'Trends in Construction Management Education and Responsibly Managing the Built Environment'*, Built Environment Research Group, University of Western, 105-116.

Pullen, S. (2000a) Energy Used in the Construction and Operation of Houses, *Architectural Science Review*, 43, 2, 87-94.

Pullen, S. (2000b) Establishing Benchmarks for Life Cycle Energy Analysis. *Proceedings of the International Conference Sustainable Building 2000*, 22-25 October, Maastricht, Netherlands, 743-745.

Pullen, S., Troy, P., Holloway, D. and Bunker, R. (2002) Estimating Energy Consumption in the Urban Environment with a Focus on Embodied Energy, *Proceedings of the 36th Conference of Architectural Science Association (ANZAScA)*, 1st - 4th November, Deakin University, Australia.

See, P. (1998) *Construction Energy in Residential Building*, Unpublished Honours Thesis, School of Geoinformatics, Planning and Building, University of South Australia.

Stein, R., Serber, D. and Hannon. B. (1976) Energy *Use for Building Construction,* EDRA Report, Center for Advanced Computation, University of Illinois and Stein & Associates. New York.

Southern Sydney Regional Organisation of Councils (SSROC) (2005) *Who's Emitting What: The Results of the SSROC Household Energy Survey*, SSROC, Hurstville.

Treloar, G. (1994) *Embodied Energy Analysis of the Construction of Office Buildings*, Master of Architecture thesis, Deakin University, Geelong.

Treloar, G. (2005) Embodied Energy Coefficients, Private Communication, 11th July.

Treloar, G., Fay, R., Ilozor, B.D. and Love, P.E.D. (2001) An Analysis of the Embodied Energy of Office Buildings by Height, *Facilities,* 5/6, 204-214

Treloar, G., Fay, R., Love, P. and Iyer-Raniga, U. (2000) Analysing the Life-Cycle Energy Analysis of an Australian residential building and its Householders, *Building Research and Information*, 28, 3, 184-195.

Treloar, G., Love, P. and Crawford, R. (2004) Hybrid Life-Cycle Inventory for Road Construction and Use, *Journal of Construction Engineering and Management*, 130, 1, 43-49.

Troy, P. and Holloway, D. (2004) The Use of Residential Water Consumption as an Urban Planning Tool: A Pilot Study in Adelaide, *Journal of Environmental Planning and Management*, 47, 1, 97-114.

Troy, P., Holloway, D. and Randolph, B. (2005) *Water Use and the Built Environment: Patterns of Water Consumption in Sydney*, City Futures Research Centre, Faculty of the Built Environment, University of NSW.

Troy, P., Holloway, D., Pullen, S. and Bunker, R. (2002) *Toward Sustainability: an Adelaide case study.* Research Paper No. 14, Urban Frontiers Program, University of Western Sydney, Campbelltown.

Troy, P., Holloway, D., Pullen, S. and Bunker, R. (2003) Embodied and Operational Energy Consumption in the City, *Urban Policy and Research*, 21, 1, 9-44.

APPENDICES

APPENDIX 1: List of CDs in Case Study Areas

Glenhaven (Landcom)
1261401
1261402
1261405
1261406
1261411

West Pennant Hills (non-Landcom)
1261602
1261603
1261606
1261607
1261608
1261610

Narellan Vale (Landcom)
1291903
1291904
1291908
1291912
1291913
1291914

Harrington Park (non-Landcom)
1291513
1291517
1291518

St Andrews (Landcom)
1300105
1300106
1300109
1300201
1300209
1300401

Raby (non-Landcom)
1300102
1300103
1300104
1300107
1300110
1300111
1300112
1300113
1300114

St Clair (Landcom)
1281504
1281505
1281506
1281508
1281509
1281510
1281511
1281604
1281605
1281606
1281607
1281608
1281609
1281610
1281701
1281702
1281703
1281704
1281705
1281706
1281707
1281708
1281709
1281710
1281711
1281712

Cambridge Gardens (non-Landcom)
1281101
1281102
1281103

Kings Bay (Landcom)
1411805

Abbotsford (non-Landcom)
1412006

Canada Bay (non-Landcom)
1410214

Liberty Grove (non-Landcom)
1410104

Cabarita (non-Landcom)
1410203

APPENDIX 2: Socio-Economic Characteristics of the Case Study Areas, 2001 (Source: ABS CDATA 2001)

	Low Density Estates								High Density Estates			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	Cambridge Gardens	St. Andrews	Raby	Glenhaven	West Pennant Hills	Narellan Vale	Harrington Park	Kings Bay	Abbotsford	Cabarita	Liberty Grove
Persons												
Male	10147	1110	2716	3203	2304	2348	3413	1476	334	440	566	528
Female	10350	1084	2776	3181	2398	2511	3567	1551	354	537	609	549
Not Stated	5	0	0	0	0	0	0	0	6	0	0	0
Total	20502	2194	5492	6384	4702	4859	6980	3027	694	977	1175	1077
Age												
0-14yrs	5576	550	1496	1698	1192	1169	2199	924	106	100	191	202
15-24yrs	3550	395	934	1160	748	904	793	357	91	105	138	173
25-34yrs	2873	310	681	703	358	378	1524	618	175	229	141	248
35-44yrs	3844	316	998	1302	800	749	1227	522	108	158	169	203
45-54yrs	2939	370	855	954	934	973	667	316	85	162	216	18
55-64yrs	993	158	290	312	407	392	315	165	65	99	163	53
65+yrs	727	95	190	237	249	215	212	99	64	106	147	31
Not stated	0	0	48	18	14	79	43	26	0	18	10	149
Total	20502	2194	5492	6384	4702	4859	6980	3027	694	977	1175	1077
Household type												
Couple with children	3544	349	937	1106	896	935	1182	565	70	92	170	142
Couple without children	1030	133	268	341	303	229	496	225	73	173	140	107
One-parent family	791	103	190	251	94	89	249	68	33	30	36	46
Lone person household	453	76	148	184	73	56	175	41	85	79	67	47
Group household	61	17	17	22	6	15	41	10	17	35	9	29
Other household	41	4	18	13	11	14	19	6	1	10	4	9
Not Stated	40	10	27	13	0	5	37	0	29	14	20	11
Total	5960	692	1605	1930	1383	1343	2199	915	308	433	446	391

	Low Density Estates								High Density Estates			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	**Cambridge Gardens**	**St. Andrews**	**Raby**	**Glenhaven**	**West Pennant Hills**	**Narellan Vale**	**Harrington Park**	**Kings Bay**	**Abbotsford**	**Cabarita**	**Liberty Grove**
Weekly H/hold Income												
<$399	411	59	125	129	58	68	143	40	67	25	48	20
$400-$599	398	68	135	161	58	36	117	43	13	24	25	21
$600-$799	573	70	142	171	58	43	164	63	20	21	24	12
$800-$999	636	71	179	209	64	60	222	74	19	19	24	21
$1000-$1199	629	65	169	184	93	65	236	86	22	41	31	27
$1200-$1499	847	90	228	275	108	89	346	135	18	29	34	26
$1500-$1999	930	102	255	309	280	267	428	210	52	83	75	90
$2000 or more	665	65	146	211	443	464	264	165	52	136	113	113
Not stated	871	102	226	281	221	251	279	99	45	55	72	61
Total	5960	692	1605	1930	1383	1343	2199	915	308	433	446	391
Dwelling Type												
Separate House	5856	683	1530	1788	1288	1229	2047	899	55	3	218	55
Semi-detached	28	6	49	114	74	107	127	3	54	43	91	249
Flat, unit or apartment	18	0	7	3	6	4	6	0	199	384	133	85
Not stated	58	3	19	25	15	3	19	13	0	3	4	2
Total	5960	692	1605	1930	1383	1343	2199	915	308	433	446	391
Tenure Type												
Fully owned	1900	242	493	590	669	692	393	179	60	158	251	98
Being purchased	2964	312	769	943	592	441	1326	571	66	108	103	147
Rented	776	93	248	301	72	144	377	121	141	137	65	117
Other type	86	14	33	21	21	18	22	16	7	13	6	7
Not stated	234	31	62	75	29	48	81	28	34	17	21	19
Total	5960	692	1605	1930	1383	1343	2199	915	308	433	446	391

	Low Density Estates								High Density Estates			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	**Cambridge Gardens**	**St. Andrews**	**Raby**	**Glenhaven**	**West Pennant Hills**	**Narellan Vale**	**Harrington Park**	**Kings Bay**	**Abbotsford**	**Cabarita**	**Liberty Grove**
Occupation												
Manager & Administrators	532	49	130	179	459	406	250	156	57	116	124	88
Professionals	1086	111	300	373	599	683	472	216	84	199	155	200
Associate Professionals	970	108	249	329	317	322	452	217	56	106	107	78
Tradespersons & Related Workers	1452	165	406	490	227	141	537	199	15	28	43	26
Advanced Clerical & Service Workers	436	52	98	135	186	140	169	102	13	44	39	36
Intermediate Clerical, Sales & Serv. Workers	2223	252	566	670	402	348	735	342	55	90	85	91
Intermediate Production & Transport Workers	1289	129	336	368	76	45	340	120	13	16	25	14
Elementary Clerical Sales & Serv. Workers	1098	126	283	350	221	215	304	124	20	22	34	37
Labourers & Related Workers	789	100	213	254	65	66	169	68	15	6	25	25
Inadequately described	102	10	9	33	15	18	15	12	6	6	6	6
Not stated	99	6	30	27	14	30	63	29	16	15	8	7
Total	10076	1108	2620	3208	2581	2414	3506	1585	350	648	651	608
Labour Force												
Employed	10076	1108	2620	3197	2581	2414	3506	1585	350	648	651	608
Unemployed	486	77	196	173	55	110	127	54	30	9	24	18
Not in Labour Force	3746	414	1065	1191	798	1035	992	414	151	183	277	187
Not stated	618	45	115	125	76	131	156	50	57	37	32	62
Total (persons aged 15yrs+)	14926	1644	3996	4686	3510	3690	4781	2103	588	877	984	875

	Low Density Estates								High Density Estates			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	**Cambridge Gardens**	**St. Andrews**	**Raby**	**Glenhaven**	**West Pennant Hills**	**Narellan Vale**	**Harrington Park**	**Kings Bay**	**Abbotsford**	**Cabarita**	**Liberty Grove**
Place of Birth												
Australia	14230	1711	3751	4599	3428	2818	5637	2392	398	654	777	472
Overseas	5093	368	1449	1463	1157	1762	998	519	219	275	336	529
Not stated	1179	115	292	322	117	279	345	116	77	48	62	76
Total	20502	2194	5492	6384	4702	4859	6980	3027	694	977	1175	1077
Address 5 years ago												
Sames address 5yrs ago	12473	1405	3145	3884	2458	2447	2047	353	188	42	445	27
Different address 5yrs ago	5713	585	1747	1872	1905	1999	3902	2246	393	841	618	914
Not stated	722	52	177	186	81	177	239	47	69	51	43	71
Total (persons aged 5yrs+)	18908	2042	5069	5942	4444	4623	6188	2646	650	934	1106	1012

	Low Density Estates								High Density Estates			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	**Cambridge Gardens**	**St. Andrews**	**Raby**	**Glenhaven**	**West Pennant Hills**	**Narellan Vale**	**Harrington Park**	**Kings Bay**	**Abbotsford**	**Cabarita**	**Liberty Grove**
Households	5,960	692	1,605	1,930	1,383	1,343	2,199	915	308	433	446	391
Persons	20,502	2,194	5,492	6,384	4,702	4,859	6,980	3,027	694	977	1,175	1,077
Index of Disadvantage Score	1,019	1,000	1,009	1,016	1,135	1,135	1,056	1,085	1,028	1,141	1,112	1,108
Persons												
Male	49.50%	50.60%	49.50%	50.20%	49.00%	48.30%	48.90%	48.80%	48.10%	45.00%	48.20%	49.00%
Female	50.50%	49.40%	50.50%	49.80%	51.00%	51.70%	51.10%	51.20%	51.00%	55.00%	51.80%	51.00%
Not Stated	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.90%	0.00%	0.00%	0.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Age												
0-14yrs	27.20%	25.10%	27.20%	26.60%	25.40%	24.10%	31.50%	30.50%	15.30%	10.20%	16.30%	18.80%
15-24yrs	17.30%	18.00%	17.00%	18.20%	15.90%	18.60%	11.40%	11.80%	13.10%	10.70%	11.70%	16.10%
25-34yrs	14.00%	14.10%	12.40%	11.00%	7.60%	7.80%	21.80%	20.40%	25.20%	23.40%	12.00%	23.00%
35-44yrs	18.70%	14.40%	18.20%	20.40%	17.00%	15.40%	17.60%	17.20%	15.60%	16.20%	14.40%	18.80%
45-54yrs	14.30%	16.90%	15.60%	14.90%	19.90%	20.00%	9.60%	10.40%	12.20%	16.60%	18.40%	1.70%
55-64yrs	4.80%	7.20%	5.30%	4.90%	8.70%	8.10%	4.50%	5.50%	9.40%	10.10%	13.90%	4.90%
65+yrs	3.50%	4.30%	3.50%	3.70%	5.30%	4.40%	3.00%	3.30%	9.20%	10.80%	12.50%	2.90%
Not stated	0.00%	0.00%	0.90%	0.30%	0.30%	1.60%	0.60%	0.90%	0.00%	1.80%	0.90%	13.80%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Household type												
Couple with children	59.50%	50.40%	58.40%	57.30%	64.80%	69.60%	53.80%	61.70%	22.70%	21.20%	38.10%	36.30%
Couple without children	17.30%	19.20%	16.70%	17.70%	21.90%	17.10%	22.60%	24.60%	23.70%	40.00%	31.40%	27.40%
One-parent family	13.30%	14.90%	11.80%	13.00%	6.80%	6.60%	11.30%	7.40%	10.70%	6.90%	8.10%	11.80%
Lone person household	7.60%	11.00%	9.20%	9.50%	5.30%	4.20%	8.00%	4.50%	27.60%	18.20%	15.00%	12.00%
Group household	1.00%	2.50%	1.10%	1.10%	0.40%	1.10%	1.90%	1.10%	5.50%	8.10%	2.00%	7.40%
Other household	0.70%	0.60%	1.10%	0.70%	0.80%	1.00%	0.90%	0.70%	0.30%	2.30%	0.90%	2.30%
Not Stated	0.70%	1.40%	1.70%	0.70%	0.00%	0.40%	1.70%	0.00%	9.40%	3.20%	4.50%	2.80%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

	Low Density Estates								High Density Estates			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	**Cambridge Gardens**	**St. Andrews**	**Raby**	**Glenhaven**	**West Pennant Hills**	**Narellan Vale**	**Harrington Park**	**Kings Bay**	**Abbotsford**	**Cabarita**	**Liberty Grove**
Weekly H/hold Income												
<$399	6.90%	8.50%	7.80%	6.70%	4.20%	5.10%	6.50%	4.40%	21.80%	5.80%	10.80%	5.10%
$400-$599	6.70%	9.80%	8.40%	8.30%	4.20%	2.70%	5.30%	4.70%	4.20%	5.50%	5.60%	5.40%
$600-$799	9.60%	10.10%	8.80%	8.90%	4.20%	3.20%	7.50%	6.90%	6.50%	4.80%	5.40%	3.10%
$800-$999	10.70%	10.30%	11.20%	10.80%	4.60%	4.50%	10.10%	8.10%	6.20%	4.40%	5.40%	5.40%
$1000-$1199	10.60%	9.40%	10.50%	9.50%	6.70%	4.80%	10.70%	9.40%	7.10%	9.50%	7.00%	6.90%
$1200-$1499	14.20%	13.00%	14.20%	14.20%	7.80%	6.60%	15.70%	14.80%	5.80%	6.70%	7.60%	6.60%
$1500-$1999	15.60%	14.70%	15.90%	16.00%	20.20%	19.90%	19.50%	23.00%	16.90%	19.20%	16.80%	23.00%
$2000 or more	11.20%	9.40%	9.10%	10.90%	32.00%	34.50%	12.00%	18.00%	16.90%	31.40%	25.30%	28.90%
Not stated	14.60%	14.70%	14.10%	14.60%	16.00%	18.70%	12.70%	10.80%	14.60%	12.70%	16.10%	15.60%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Dwelling Type												
Separate House	98.30%	98.70%	95.30%	92.60%	93.10%	91.50%	93.10%	98.30%	17.90%	0.70%	48.90%	14.10%
Semi-detached	0.50%	0.90%	3.10%	5.90%	5.40%	8.00%	5.80%	0.30%	17.50%	9.90%	20.40%	63.70%
Flat, unit or apartment	0.30%	0.00%	0.40%	0.20%	0.40%	0.30%	0.30%	0.00%	64.60%	88.70%	29.80%	21.70%
Other dwelling	0.00%	0.40%	0.00%	0.00%	0.20%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Not stated	1.00%	0.00%	1.20%	1.30%	0.90%	0.20%	0.90%	1.40%	0.00%	0.70%	0.90%	0.50%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Tenure Type												
Fully owned	31.90%	35.00%	30.70%	30.60%	48.40%	51.50%	17.90%	19.60%	19.50%	36.50%	56.30%	25.10%
Being purchased	49.70%	45.10%	47.90%	48.90%	42.80%	32.80%	60.30%	62.40%	21.40%	24.90%	23.10%	37.60%
Rented: Housing Authority	1.00%	1.60%	2.70%	0.50%	0.00%	0.00%	0.60%	0.00%	21.10%	0.00%	0.70%	0.00%
Rented: Other	12.00%	11.80%	12.80%	15.10%	5.20%	10.70%	16.50%	13.20%	24.70%	31.60%	13.90%	29.90%
Other type	1.40%	2.00%	2.10%	1.10%	1.50%	1.30%	1.00%	1.70%	2.30%	3.00%	1.30%	1.80%
Not stated	3.90%	4.50%	3.90%	3.90%	2.10%	3.60%	3.70%	3.10%	11.00%	3.90%	4.70%	4.90%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

	Low Density Estates								High Density Estates			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	**Cambridge Gardens**	**St. Andrews**	**Raby**	**Glenhaven**	**West Pennant Hills**	**Narellan Vale**	**Harrington Park**	**Kings Bay**	**Abbotsford**	**Cabarita**	**Liberty Grove**
Occupation												
Manager & Administrators	5.30%	4.40%	5.00%	5.60%	17.80%	16.80%	7.10%	9.80%	16.30%	17.90%	19.00%	14.50%
Professionals	10.80%	10.00%	11.50%	11.60%	23.20%	28.30%	13.50%	13.60%	24.00%	30.70%	23.80%	32.90%
Associate Professionals	9.60%	9.70%	9.50%	10.30%	12.30%	13.30%	12.90%	13.70%	16.00%	16.40%	16.40%	12.80%
Tradespersons & Related Workers	14.40%	14.90%	15.50%	15.30%	8.80%	5.80%	15.30%	12.60%	4.30%	4.30%	6.60%	4.30%
Advanced Clerical & Service Workers	4.30%	4.70%	3.70%	4.20%	7.20%	5.80%	4.80%	6.40%	3.70%	6.80%	6.00%	5.90%
Intermediate Clerical, Sales & Serv. Workers	22.10%	22.70%	21.60%	20.90%	15.60%	14.40%	21.00%	21.60%	15.70%	13.90%	13.10%	15.00%
Intermediate Production & Transport Workers	12.80%	11.60%	12.80%	11.50%	2.90%	1.90%	9.70%	7.60%	3.70%	2.50%	3.80%	2.30%
Elementary Clerical Sales & Serv. Workers	10.90%	11.40%	10.80%	10.90%	8.60%	8.90%	8.70%	7.80%	5.70%	3.40%	5.20%	6.10%
Labourers & Related Workers	7.80%	9.00%	8.10%	7.90%	2.50%	2.70%	4.80%	4.30%	4.30%	0.90%	3.80%	4.10%
Inadequately described	1.00%	0.90%	0.30%	1.00%	0.60%	0.70%	0.40%	0.80%	1.70%	0.90%	0.90%	1.00%
Not stated	1.00%	0.50%	1.10%	0.80%	0.50%	1.20%	1.80%	1.80%	4.60%	2.30%	1.20%	1.20%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Labour Force												
Employed	67.50%	67.40%	65.60%	68.20%	73.50%	65.40%	73.30%	75.40%	59.50%	73.90%	66.20%	69.50%
Unemployed	3.30%	4.70%	4.90%	3.70%	1.60%	3.00%	2.70%	2.60%	5.10%	1.00%	2.40%	2.10%
Not in Labour Force	25.10%	25.20%	26.70%	25.40%	22.70%	28.00%	20.70%	19.70%	25.70%	20.90%	28.20%	21.40%
Not stated	4.10%	2.70%	2.90%	2.70%	2.20%	3.60%	3.30%	2.40%	9.70%	4.20%	3.30%	7.10%
Total (persons aged 15yrs+)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

	Low Density Estates								**High Density Estates**			
	Late 1970s		Early 1980s		Early 1990s		Late 1990s					
	St. Clair	**Cambridge Gardens**	**St. Andrews**	**Raby**	**Glenhaven**	**West Pennant Hills**	**Narellan Vale**	**Harrington Park**	**Kings Bay**	**Abbotsford**	**Cabarita**	**Liberty Grove**
Place of Birth												
Australia	69.40%	78.00%	68.30%	72.00%	72.90%	58.00%	80.80%	79.00%	57.30%	66.90%	66.10%	43.80%
Overseas	24.80%	16.80%	26.40%	22.90%	24.60%	36.30%	14.30%	17.10%	31.60%	28.10%	28.60%	49.10%
Not stated	5.80%	5.20%	5.30%	5.00%	2.50%	5.70%	4.90%	3.80%	11.10%	4.90%	5.30%	7.10%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Address 5 years ago												
Same address 5yrs ago	66.00%	68.80%	62.00%	65.40%	55.30%	52.90%	33.10%	13.30%	28.90%	4.50%	40.20%	2.70%
Different address 5yrs ago	30.20%	28.60%	34.50%	31.50%	42.90%	43.20%	63.10%	84.90%	60.50%	90.00%	55.90%	90.30%
Not stated	3.80%	2.50%	3.50%	3.10%	1.80%	3.80%	3.90%	1.80%	10.60%	5.50%	3.90%	7.00%
Total (persons aged 5yrs+)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

APPENDIX 3: Summary of Drive-by-Survey

LGA	Suburb	Age range	Critical age range?	Homog-eneity	No of Storeys	Mix of Storeys	Roofs, wall, window frame	Drawings required?	Other information (addresses of typical)	Sample
Penrith	St Clair (Landcom)	Early 80s to early 90s	Yes	Yes	1 & 2	98% single 2% double	As in Cambridge Gardens	Yes	Approx 60% appear to be suspended floor 41,43,45 Melville Rd	100%
Penrith	Cambridge Gardens (Non Landcom)	Early 80s to early 90s	Yes	Yes	1 & 2	98% single 2% double	95% concrete tiles 5% clay 90% aluminium frame 10% timber	Yes	Approx 70% appear to be suspended floors with, maybe, double brick. 74,76,78 Trinity Dr Are timber floor possibilities 39,17,19 Lewis Rd possibly not	100%
Campbell-town	St Andrews (Landcom)	Early 80s to mid 90s	Yes	Yes	1 & 2	5% double 95% single	Concrete roof tiles 90%, clay 10% Aluminium frames 100% Brick veneer?	Yes	70% seem to be possibly suspended timber floors Check footings Lower value area 25.27.29,31,33 Stranraer Drive	50
Campbelltown	Raby (Non Landcom)	Early 80s to mid 90s	Maybe	Yes	1 & 2	5% double 95% single	Concrete roof tiles 90%, clay 10% Aluminium frames 100% Brick veneer	Yes	30% seem to be possibly suspended timber floors ie not cut and fill 21,23,27 Spitfire Drive – built up front Check footings. Lower value area.	50

Baulkham Hills	Glenhaven (Landcom)	Late 90s	No	Yes	1 & 2	90% 2 storey 10% 1 storey	50% concrete roofs 50% clay roof tiles Brick veneer 90% powder coated aluminium window frames Ceiling height not known but >2.4m		Elaborate architectural features, window frames, turret roofs etc. All with double garages. Upmarket. Suggest 2.7m & 2.4m ceiling heights, up and downstairs	200
	West Pennant Hills Non-(Landcom)	Late 90s	Bi	Yes	1 & 2	80% 2 storey 20% 1 storey	60% concrete roofs 40% clay roof tiles Brick Veneer 90% powder coated aluminium Ceiling height estimated at 2.7m down & 2.4m up	Yes, for footings	Architecture as in Glenhaven. 50% of garages under living floors. Increased footing requirements. 10,12,14 Salisbury Downs Drive	200
Camden	Narellan Vale (Landcom)	From early 1990s	No	Yes	1 & 2	12% 2 storey 88% 1 storey	10% clay tiles 90% concrete. Brick veneer.	? ceiling height	90% of 20° pitched roof. 10% are 30° pitched roof.	200

							10% timber 90% aluminium window frame. 90% 2.4m ceiling.		51,53 Manna Gum Rd. Some gable ends & ½ gable ends. Fancy window frames	
Camden	Harrington Park (Non Landcom)	From early 1990s	No	Yes	1 & 2	50%/50%	10% clay 90% concrete tiles. Majority brick veneer. 100% powder coated window frame. Mix of 2.4m/2.7m. Probably 2 store are 2.7m on ground floor & 2.4m on 1st floor.	? ceiling height	18,16 William Campbell Avenue. 20° pitched roof. Minimum eaves (600mm) Some gable ends & ½ gable ends. Fancy window frames.	200
Canada Bay	Kings Bay (Landcom)	Late 90s	No	Yes	2 & 3	50% 3 storey 50% 2 storey	Concrete roofs Rendered brick veneer	Yes	Mainly terraced or end of terrace town houses. 3,4 Kings Park Circuit	
Canada Bay	Abbotsford, (Non Landcom)				All 4 storey with parking under			Need drawings due to undercroft parking	1-24 1 Blackwall Point Rd 1-24 3 Figtree Ave	
Canada Bay	Cabarita (Non Landcom)	Late 90s	No	Yes		70% 5 storey 30% 2 storey	5 Storey	Yes Bills of Quantity	41-45 and 28-32 Phillips St.	

							2 storey Colorbond roof Brick veneer (bagged) Some weatherboard upper cladding (30%)		2, 4 and 6, Jacaranda Drive, Cabarita.	
Canada Bay	Liberty Grove etc (Non Landcom)	Late 90s	No	Yes	2 & 3	95% 2 storey	Brick veneer or rendered brick veneer. Probably 30° pitch roof. Concrete tile. Aluminium window frame.	Yes	3,4,5,6,7,8,9 Settlers Blvd. 3 Wentworth Drive	
Canada Bay	Phillips Landing, Non (Landcom)				2 & 3 storey town-houses Terraced			Use drawings from Liberty Grove		

APPENDIX 4: Detailed Information on Case Study Dwellings

St Clair
41, Melville Road.
Suspended floor, 2400 ceiling height, built end of 1978.
Builder: E. Long Industries, Toongabbu Road, Girraween, NSW 2145.
Floor umr (7.5 x 13.5) + (5.5 x 6.5) + garage (6.5 x 3.5)
Footings: 450mm square piers. Beams reinforced with F8 trench mesh reinforcement top & bottom 6mm diameter ties at 1200mm centres + extra C16 bars at rear corner to garage.

43, Melville Road.
Laundry, b'room + verandah concrete area = (5.5 x 2.5) + (3x1) m area.
Total floor area = (12 x 6.5) + (6.5 x 5.5). Ceiling height = 2.45m, truss roof.

45, Melville Road.
Total floor area = (14 x 7.5) + (1.4 x 5.0) + (6 x 2).
Ceiling height = 2.45m
Laundry & b'room + patio (front & rear) = (2.7 x 2.7) + (5 x 1.5) + (1 x 1)
Garage (3.2 x 7.4) umr.

Cambridge Gardens
74, Trinity Drive.
Builder: Neeta Homes P/L, Paramatta. Area = 101.43m^2.
Timber suspended floor. No garage.
Internal concrete floor: (1.5 x 2.5) + (2.5 x 2.5) + 1.5 x 1) + (1 x 1) + (1 x 1)
2400mm ceiling height. Brick veneer.

76, Trinity Drive.
No carport. Timber suspended floors. As in 74 for ceiling height & floor.
Total floor area = 105.12m^2.
100 x 50 hardwood joists on 100 x 79 hardwood bearers – timber floor.
2.7m external wall height. Underfloor piers 400mm high.
450 x 250mm RC footings (beams)
450 eaves overhang. Timber windows (front), aluminum at rear.

78, Trinity Drive.
Builder: Harburn Developments. Harvey L. Little & Assocts P/L, 13 – 15, St. Johns Ave, Gordon, NSW 2072.
Total floor area (11.5 x 6.5) + (4 x 1.7). Brick veneer. Timber suspended floor.
Ceiling height 2.4m. Internal concrete floor (3.5 x 2.0) + (2 x 1.5)
Floor joists: 100 x 38 at 600 centres.
Bearers: 100 x 79 on piers
Eaves: 375mm
Piers at between 1300 – 2000 centres, but typically 1800mm.

39, Lewis Road.
Only later house plans available. 1989, Neeta Homes. Brick veneer, slab on ground.
2400mm ceiling height (2100mm external wall height). 375mm eaves. Floor area (m^2): 92.36 + 16.47 (garage). Roof pitch 23°.
Aluminum windows.

West Pennant Hills
10, Salisbury Downs Drive.
Builder: J.D. Holden, 43, Warwick Road, Castle Hill, NSW 2154.
1989/90. Three storey building.
a) Garage floor
Single leaf walls. 125m long 2.7m high. 4 roller doors. Timber staircase.
Pier and beamed footings with concrete floor on garage floor (6.7 x 11m).
166m^2 area.
Piers, 450 diam piers x 2.5m deep x 10no. + (8no. x 1.0m deep)
All single leaf was on RC strip footings approx. 300mm deep x 450 wide. 4 x R6 reinforcing rods top & bottom.
First floor
Timber floor over 2 x I beams each 11 meters long. Total I beam length = 29m x 250UB. Brick veneer walls. 2.7m ceiling height.
166m^2 floor area.
Aluminum frames?
c) Second floor
142m^2. Timber floor. Brick veneer walls. 2.4 ceiling height. Gable end roof.
Note: 400m^2 area but this includes the garage area of garage floor (not sloping parts).

14, Salisbury Downs Drive.
3 storey residence.
a) Garage floor
Raft footing. 105 lineal meters of brickwork, ⅓ of which appeared to be double brick. 183m^2 of floor area. No piers indicated. 2.9m high. 5m^2 of shower room wet area.
b) Ground floor
Suspended reinforced concrete slab. Floor 2.7m to ceiling height.
2.47m^2 total floor area. Brick veneer walls. Aluminum windows.
c) First floor
Timber floor. 2.6m ceiling height. 20° pitched roof. Brick veneer 153m^2.
Fancy gable ends.

2, Mildara Place.
2 storey residence
a) Ground floor
Timber windows. Slab on ground. Fancy porch, chimney to full height of house with corbelled brickwork. Area = 252m^2. Brick veneer with triple garage umr.
67 piers - 300mm to rock under slab on ground. Length?
Half of main slab was 130mm thick. Remaining half was 100/110mm thick.
b) First floor
50m of stell UBs, 35m is 250UB and 15m is 150UB. Timber floor.
4 fancy stucco gable ends with timber finials. Stained glass windows. 153m^2.
415m^2 total.

4, Mildara Place
1989. Builder: P.G.Binet P/L, 2 storey, brick veneer. Total floor area 399m^2.
Triple garage umr.

(Note: 230mm by 75mm beam =	25.1 Kg/m)
250mm	31.0
200mm	30.0
310mm	46.0

a) Ground floor
Timber suspended floor! 240m^2 ground floor.
Fancy gable ends with finials and stain glass windows.
b) 156m^2. Timber floor. Similar steel work to no. 2, Mildara Place.

Liberty Grove

First 6 boxes all Liberty Grove aka 1, Oulton Ave, Concord.

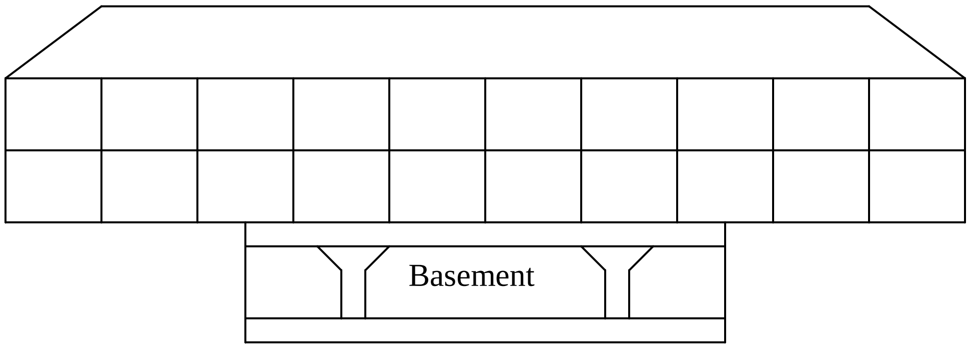
Road information:			
	subbase	185 or	235
	basecourse	125 or	100
	wearing	40 or	40
	Total	350	375mm

Slab on ground, two storey houses with timber first floor.
Typically, 7m x 240mm x 36mm hyspan beam (timber) + 2m x 150mm UB.
Approx. 245m^2 total.
Note all family rooms tiled as well as wet areas – an extra 14m^2 of ceramic tiles. Brick veneer ground floor except for garage (single leaf wall).
Brick veneer upper floor.
Note: face brick at ground floor/ rendered common brick 1st floor.
Aluminum window frames. Concrete roof tiles.
Both lower and upper ceiling heights are 2.5m.
Porch and balustrade typical with posts (double timber) and fancy metal balustrade. Roof pitch 25°.

Kings Bay

Eastern Precinct

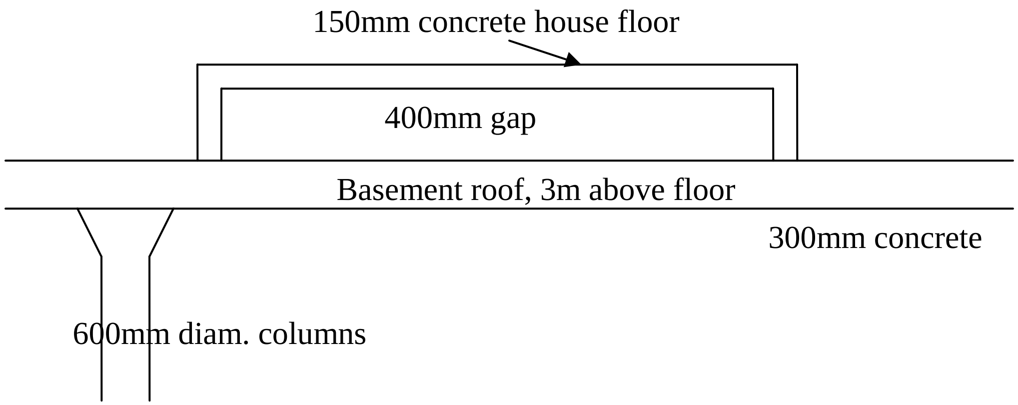
Concrete slab on ground. First and second floors were 'ultra-floor'. This development had a mix of single and two storey houses according to the drawings (drive by also indicated 3 storey but these not found at Canada Bay Council. As a typical example, a row of 13 townhouses selected, nos 21 – 33, Hycraft Walk, eastern precinct. 6 of this row of townhouses were constructed over basements. Other single storey rows were also over basement carparks to the extent of approx. 50%. Columns at 8m spacing.



Extent of basement is not known; appears to extend across a significant proportion of this development. Consists of ground slab, basement slab and columns. Appears to be approx. 44m x 55m = 2420m^2.

Architecture by Devine, Erby and Mazin, 115, Sailors Bay Road, Northbridge.
02 9958 2388.

These town houses have a total floor area of approx. 192m^2. Other townhouses have a floor area of approx. 192m^2. 35° roof pitch.



Each house over basement has a concrete staircase.
Ground floor ceiling height = 2.5m. Upper floor ceiling height = 2.5m. Double brick walls. Party wall is double leaf with cavity. Bagged finishes. Internal walls are timber stud. Concrete tiled roof. Porch with two 350 x 350 brick columns.

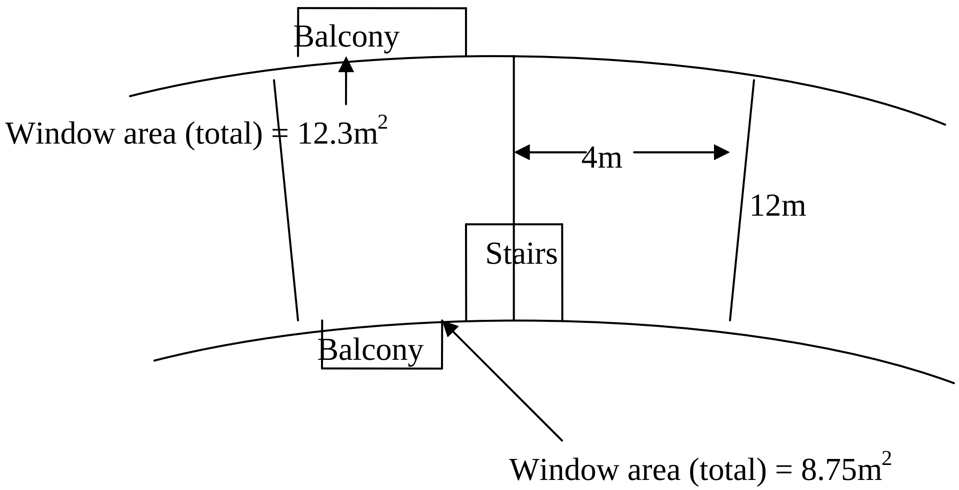
First floor is mainly 150R Ultrafloor (36m^2) with 14m^2 of 130R Ultrafloor.
7m of 150mm steel lintels in each unit.

Note: meeting with Gary Bauer (8347 3402) and James Adcock (8347 3403) of Landcom at Little Bay site.

The eastern precinct was built over an existing basement which was part of a previous carpet factory. 95% of the factory building materials were recycled. This basement had about 60 car parking spaces with about 33 townhouses built over. All other buildings at King's Bay had basement car parks constructed.

Northern Precinct
Consists of 3, 4 and 5 storey apartments each being approx. 104m^2 plus 15m^2 of balcony.
Basement car parking, 3m high. 600 diam. columns at 5m and 7m spacings. Concrete roof tiles.

Three storey block:

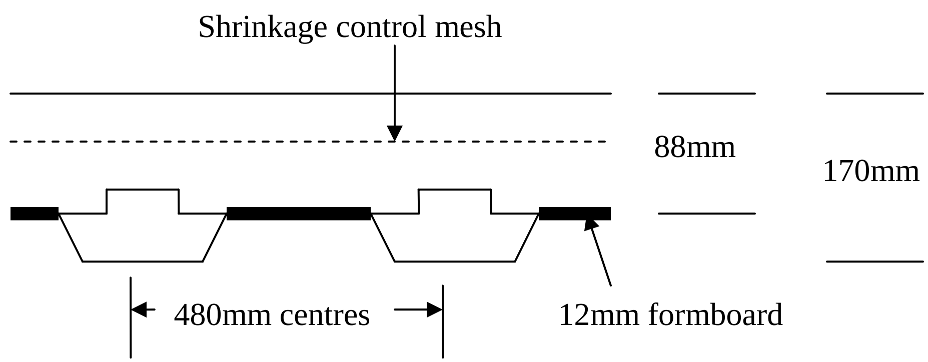


Approx. 20.4 lineal meters of internal walls.
Kitchen = 2.8 x 2.8m
Bathroom = 2.8 x 2.2m
Ensuite and laundry = 3.6 x 1.6m
External walls are double brick with cavity. Timber and steel stud walls. Party walls consist of 140mm Power Brick Wall + 13mm render both sides. Known as ‘walk ups’ – no lifts.

Information from Nick Ridgwell, St. Hilliers 0408 418 642.
Piles were used up to 15m deep but not all over (Could be 400mm diam. at 8m centres?)
Anything of 4 storeys or above had reinforced concrete columns. Load bearing masonry for 3 storeys.

Slabs post tensioned with grouted tendons. 10 steel beams, 6.5m long, type B4.

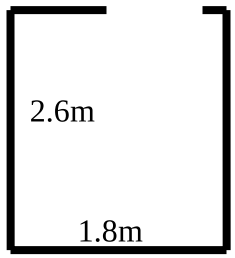
Typical Ultrafloor 130R/400 Section:

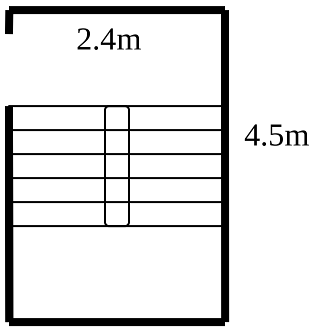

Shrinkage control mesh
88mm
170mm
480mm centres
12mm formboard

Cabarita
22, Jacaranda Drive. 2 storey house.
Upper floor . 4 bedrooms, ensuite + 2 bathrooms.
Lower floor: Living, dining, family, kitchen + breakfast area, toilet, foyer, laundry and garage. Approx 225m^2.
Tiled areas = 67m^2 gross ie area of tiled rooms not tiles which will be less due to cupboards, benches, etc.
Roofing: Colorbond Kliplok.
Upper floor is painted fibre cement cladding – single leaf.
Lower floor is brick veneer with rendered finish. Timber 1st floor.
2.7m lower ceiling height, 2.8m upper but with 0.5m space between upper floor and lower ceiling (height to gutter = 6.1m).
Bagged and painted brick fence. Balustrade with 4 columns.

5 storey building.
60 space basement carpark under each building approx. 50m x 35m. Columns 300mm x 600mm x 60no. 200 mm thick walls.
Communal swimming pool: 22.5 x 7.5m.
Each 5 storey block approx. 50m x 20m with 6 units on each floor.
150m (lineal) of walling in basement, concrete or concrete blocks – 150mm thick.

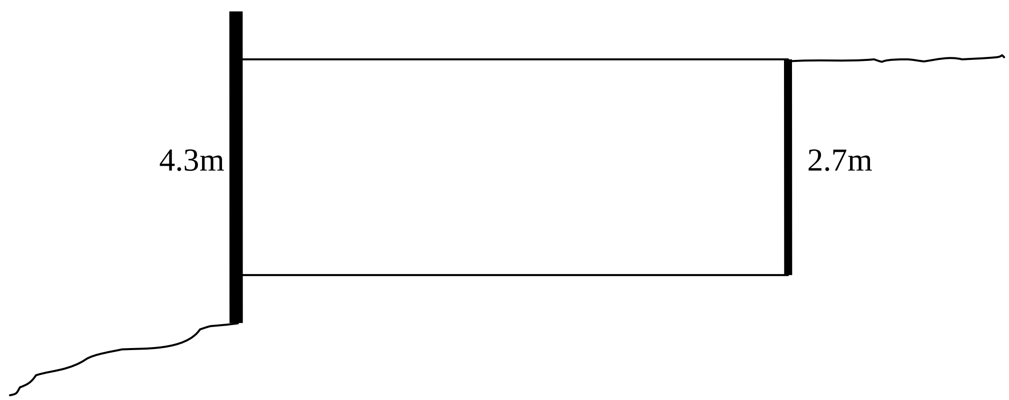
Each apartment approx. 6m x 20m. Balconies front and rear (5.6 x 3.0) + (3.5 x 2.0)
Ceiling height 2.55m, basement height 3.0m, floor thickness 250mm.
Tiled roof pitch for most with 35° for some.
Double brick external walls with aluminum windows.
Window areas; north elevation 9.4m^2 total; south elevation 12.7m^2 total.
3 lift shafts and 3 staircases shown.





Internal wall length (excluding part walls) = 39m (lineal). Appears to be a single leaf, timber stud? Not much information on specific materials.

Abbotsford
4 storey building similar to Cabarita.
Building 12.
Underground parking, 1st, 2nd, 3rd, 4th floors and roof.
Basement car park.
Footprint approx. 72m x 24m. 2 stair wells + 2 lift shafts internal.
56 car parking spaces for 28 units.
2 sets of steps external from ground level to basement.
Drainage system (6 open square drains shown) in concrete floor (150mm thick).
Height of basement 2.7m. Roof of basement is 150mm thick.
300mm x 600mm columns x 63no.
12no. x 24m x 700mm x 500mm thickened RC beams in basement roof.
82 lineal meters of concrete walling 150mm thick in basement forming the lift shaft, stair well and electrical switching room.
Concrete in steps to be added.
100 lineal meters of 100mm thick internal walling to form ventilation plenum and garbage rooms.
External walls to basement 150mm thick. 45% of this is visible blockwork on low side of building. This blockwork is approx. 4.3m

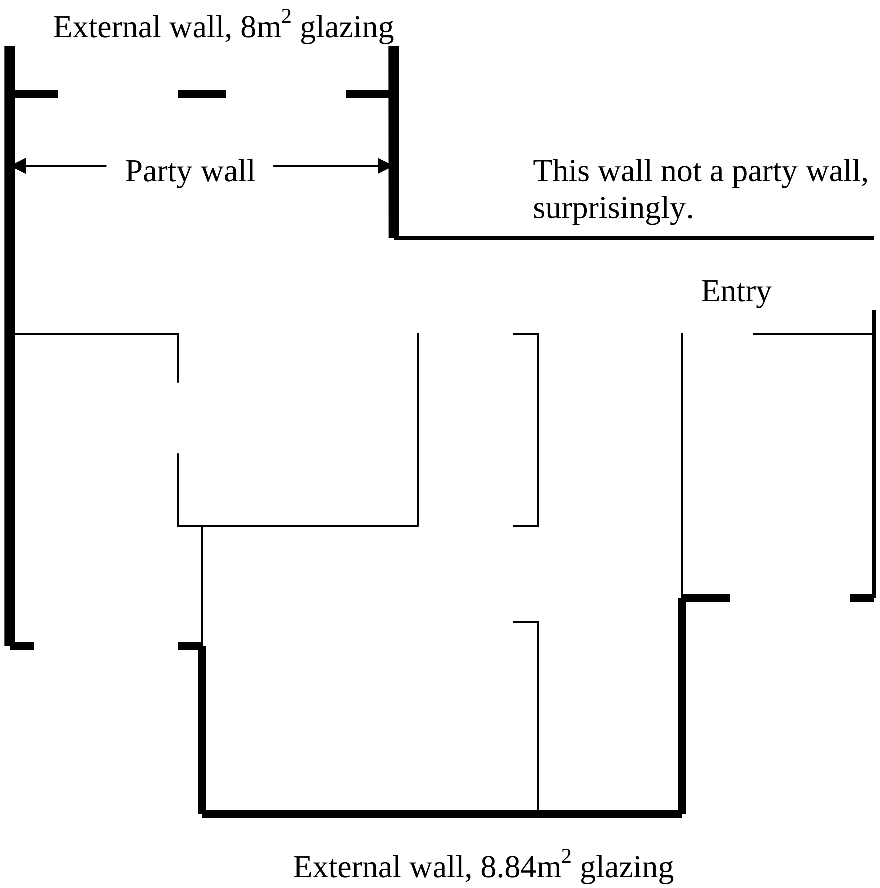


high (150mm thick).

Footings for blockwork were 300 x 800 RC footing.
2 x 4.5m wide roller doors.
3 x 600mm diameter gas water heaters and electrical switchboard in basement.

Ground floor
8 apartments, 4 @ 93m^2 (2 bed) and 4 @ 121.5m^2 (3 bed).
3 bed also has 15m^2 balcony and 2 bed has 9m^2 balcony.
External wall length (3 bed) = 25.5m
Internal wall length (3 bed) = 41.0m
Party wall (3 bed) = 14.0m
Non party wall = 8.0m (see plan below)
2 x stair wells and lift shafts in each floor.

46 lineal meters in total of 150mm thick walls for stairs and lifts plus concrete/steel steps to be added.



Total of $16.84m^2$ of glazing.
Concrete roof tiles. Aluminum window frames.
125mm thick concrete ceiling, 2.55m high + balconies/balustrades.
Note: 2 flights of concrete steps 1m wide x 6.8m x 0.2m thick + reinforcement.

APPENDIX 5: Spreadsheets for Embodied Energy Calculations

Harrington Park - 1 storey, Camden Council Area

Element		Sub-Element	Detail	Area or number m2 or no.	Material	Material Intensity (kg/m2) (except items)	Energy Coeff. (MJ/kg)	Embodied Energy (MJ)	Embodied Energy Prop. of Total(%)
1	Footings/Floor	Concrete slab on ground		170	Steel	8.57	55.5024771	80861.5589	7.1049115
					Concrete	528	2.38421694	214007.312	18.803781
					Blinding	80	1.7047826	23185.0433	2.0371569
					Membrane	0.285	65.2437492	3161.05965	0.2777469
		Suspended timber			Steel	5.2	55.5024771	0	0
					Concrete	348	2.38421694	0	0
					Brickwork	29.5	5.43920665	0	0
					Timber	18	22.6110952	0	0
					Drains	0.274682039	121.480933	5672.6672	0.4984297
5	Roof	Framing	Timber	176.5	Timber	18.48	22.6110952	73751.0614	6.4801467
			Steel		Steel	16.313	55.5024771	0	0
		Cladding	Concrete Tile	158.85	Concrete Tile	52.64	4.48449174	47504.1485	4.1739583
			Clay Tile	17.7	Clay Tile	48.1	17.341625	24674.5353	2.1680313
			Steel Sheet		Steel Sheet	4.3	192.103092	0	0
					Eaves soffit	1.617354359	19.2984981	5306.1267	0.4662235
		Insulation(R2)		150	Insulation	1.02	114.841859	17570.8044	1.543861
		Reflec. Insul.			Aluminium Foil	0.368	302.957307	0	0
		Ceiling			Plasterboard	7.6	13.3094752	17853.33	1.5686852
		Guttering			Steel	0.453436847	192.103092	15374.3185	1.3508665

6	External Walls	Double Brick			Brick(Standard)	352	5.43920665	0	0
					DPC	0.053687549	59.1957513	0	0
					Mortar	48.6	2.38421694	0	0
					Plaster	14	8.94279854	0	0
		Brick Veneer	Standard brick	83.2	Brick(Standard)	176	5.43920665	79647.3908	6.9982285
					Mortar	23.4	2.38421694	4641.78428	0.407851
			Modular brick		Brick(Modular)	143	5.43920665	0	0
					Mortar	16.2	2.38421694	0	0
			Timber framing	128.96	Timber Framing	7.09	22.6110952	20673.9213	1.8165168
			Steel framing		Steel Framing	6.163	55.5024771	0	0
			Insulation(R1.5)	124	Insulation (R1.5)	0.98	114.841859	13955.5827	1.2262091
					DPC	0.053687549	59.1957513	264.415824	0.0232329
					Plaster Board	7.6	13.3094752	8415.84735	0.7394595
		AAC Block	200mm thick		AAC Block	100	6.78405283	0	0
					4mm Render	8	2.38421694	0	0
					Coating	0.1	194.251556		0
					Plaster Board	7.6	13.3094752	0	0
		Timber clad	Cladding		Cladding	10	22.6110952	0	0
			Paint		Paint	0.15	194.251556	0	0
			Timber framing		Timber framing	7.09	22.6110952	0	0
			Insulation(R1.5)		Insulation(R1.5)	0.98	114.841859	0	0
					DPC	0.053687549	59.1957513	0	0
					Plaster Board	7.6	13.3094752	0	0
7	Windows	Frames	Timber		Timber	16.3	22.6110952	0	0
			Aluminium	28	Aluminium	6.9	378.469914	73120.3873	6.4247325
					Glass	7.5	83.5895902	17553.8139	1.5423682
9	Internal Walls	Brick	Brick		Brick(Standard)	176	5.43920665	0	0
			Mortar			25.2	2.38421694	0	0
			Plaster			28	8.94279854	0	0
		Frame	Timber	113.36	Timber	7.06	22.6110952	18096.1479	1.5900204
			Steel		Steel	4.625	55.5024771	0	0
			Insulation (R1.5)		Insulation (R1.5)	0.98	114.841859	0	0
					Plaster Board	15.2	13.3094752	22933.184	2.0150272
		AAC Block	100mm thick		AAC Block	50	8.0167985	0	0
					Plaster Board	15.2	13.3094752	0	0

11	Doors	Doors	Solid	1	Solid	36	74.3393639	2676.2171	0.2351462
			Hollow	8	Hollow	14	48.3287557	5412.82064	0.4755982
		Frames	Timber	9	Timber	12	22.6110952	2441.99828	0.2145665
			Steel		Steel	6	192.103092	0	0
12	Finishes	Tiles	Ceramic Tiles	21		14.3	31.9890764		0
		Floor cover.	Carpet	123		2.36	212.301814	61626.9706	5.4148619
		Paint	(Enter 1)	1		0.15	194.251556	10363.709	0.9106087
15	Fitments	Cabinets	Kitchen	10		89.2	37.7097516	11436.6135	1.0048795
		Oven/hob		1		60	301.085966	18065.158	1.5872975
		Air Con.		1		58	301.085966	17462.986	1.5343876
17	Plumbing	Piping				17.05423349	384.562492		0
		Steel Sinks		2		6	216.154052	2593.84863	0.2279089
		WCs		1		12	31.9890764	383.868916	0.0337287
		Handbasins		1		13	31.9890764	415.857993	0.0365394
		Taps/fittings				3.6	47		0
		Baths		1	Acrylic	6.75	64.233055	433.573121	0.038096
		Water Service		1	Gas fired	70	301.085966	21076.0176	1.8518471
26	Wiring	Wire				23.46912866	136.027434		0
		Fittings		40		0.075	64.233055	192.699165	0.0169315
34	External	Pavers		120		80.6	3.19281767	30880.9325	2.7133572
		Driveway		40	Concrete	240	2.38421694	22888.4826	2.0110995
		Fences (lin.m.)	Timber	85		8.4	22.6110952	16144.322	1.418523
			Steel			3.6	192.103092	0	0
		Pergola		40		10.65	22.6110952	9632.32656	0.8463456
		Shed		25		4.93	192.103092	61559.4358	5.4089279
Total					**Embodied Energy(MJ)**			**1138108**	
					Embodied Energy Intensity (MJ/m2)			**6694.752**	

Harrington Park - 2 storey, Camden Council Area

Element	Sub-Element	Detail	Area or number m2 or no.	Material	Material Intensity (kg/m2) (except items)	Energy Coeff. (MJ/kg)	Embodied Energy (MJ)	Embodied Energy Prop. of Total(%)
1 Footings/Floor	Concrete slab on ground		171	Steel	10.3	55.5	97871	5.68
				Concrete	570.7	2.38	232947	13.53
				Blinding	80	1.7	23349	1.36
				Membrane	0.3	65.24	3183	0.18
	Suspended timber			Steel	5.2	55.5	0	0
				Concrete	348	2.38	0	0
				Brickwork	29.5	5.44	0	0
				Timber	18	22.61	0	0
	Suspended timber			Steel	2.2	55.5	0	0
	(AS2870.1 design - Victoria)			Concrete	165.8	2.38	0	0
				Brickwork	56	5.44	0	0
				Timber	26.9	22.61	0	0
				Drains	0.3	121.48	5693	0.33
First floor	Reinforced concrete			Steel	10.8	55.5	0	0
				Concrete	368.7	2.38	0	0
	Timber			22mm particle board	10	9.43	0	0
			108	20mm softwood boards	10	22.61	24465	1.42
				Pinus beams	3.8	22.61	9346	0.54
				LVL beams	1.3	28.83	4056	0.24
				Hybeam	10	38.29	41430	2.41
				Plasterboard	7.6	13.31	10945	0.64
	Stairs	Enter 1	1				4980	0.29

5	Roof	Framing	Timber		177	Timber	17.4	22.61	69481	4.04
			Steel			Steel	16.3	55.5	0	0
		Cladding	Concrete Tile		159	Concrete Tile	52.6	4.48	45907	2.67
			Clay Tile		18	Clay Tile	48.1	17.34	24675	1.43
			Steel Sheet			Steel Sheet	4.3	192.1	0	0
			Asbestos cement			Corrugated	13.3	7.6	0	0
			AC Shingles			Painted	25.2	7.6	0	0
						Eaves soffit	1.6	19.3	5324	0.31
		Insulation(R2)			150	Insulation	1	114.84	17571	1.02
		Reflec. Insul.				Aluminium Foil	0.4	302.96	0	0
		Ceiling				Plasterboard	7.6	13.31	17853	1.04
		Guttering				Steel	0.5	192.1	15318	0.89
		Embellishments		Enter 1	1	Balcony/porch/verandah			56718	3.29
6	External Walls	Double Brick			40	Brick(Standard)	352	5.44	76584	4.45
						8mm Render	16	2.38	0	0
						DPC	0.1	59.2	127	0.01
						Mortar	48.6	2.38	4635	0.27
						Plaster	14	8.94	5008	0.29
		Stone (solid construction)				Dressed stone	920	5.11	0	0
						Mortar	10	2.38	0	0
						Plaster	14	8.94	0	0
		Brick Veneer	Standard brick		188	Brick(Standard)	176	5.44	179972	10.45
						Mortar	23.4	2.38	10489	0.61
			Modular brick			Brick(Modular)	143	5.44	0	0
						Mortar	16.2	2.38	0	0
		Stone (veneer construction)				Dressed stone	345	5.11	0	0
						Mortar	4	2.38	0	0
			Timber framing		188	Timber Framing	7.1	22.61	30139	1.75
			Steel framing			Steel Framing	6.2	55.5	0	0
			Insulation(R1.5)		180	Insulation (R1.5)	1	114.84	20258	1.18
						DPC	0.1	59.2	595	0.03
						Plaster Board	7.6	13.31	19017	1.1
		AAC Block	200mm thick			AAC Block	100	6.78	0	0

					4mm Render	8	2.38	0	0
					Coating	0.1	194.25	0	0
					Plaster Board	7.6	13.31	0	0
		Timber clad	Cladding		Cladding	10	22.61	0	0
			Paint		Paint	0.2	194.25	0	0
			Timber framing		Timber framing	7.1	22.61	0	0
			Insulation(R1.5)		Insulation(R1.5)	1	114.84	0	0
					DPC	0.1	59.2	0	0
					Plaster Board	7.6	13.31	0	0
7	Windows	Frames	Timber	71	Timber	16.3	22.61	26131	1.52
			Aluminium		Aluminium	6.9	378.47	0	0
					Glass	10	83.59	59265	3.44
9	Internal Walls	Brick	Brick		Brick(Standard)	176	5.44	0	0
			Mortar			25.2	2.38	0	0
			Plaster			28	8.94	0	0
		Frame	Timber	175	Timber	7.1	22.61	27856	1.62
			Steel		Steel	4.6	55.5	0	0
			Insulation (R1.5)		Insulation (R1.5)	1	114.84	0	0
					Plaster Board	15.2	13.31	35302	2.05
		AAC Block	100mm thick		AAC Block	50	8.02	0	0
					Plaster Board	15.2	13.31	0	0
#	Doors	Doors	Solid	2	Solid	36	74.34	5888	0.34
			Hollow	11	Hollow	14	48.33	7443	0.43
		Frames	Timber	13	Timber	12	22.61	3582	0.21
			Steel	1	Steel	6	192.1	1153	0.07
		Roller	Steel	1	Door +frame	4.5	192.1	864	0.05
#	Finishes	Tiles	Ceramic Tiles (wet areas)	57		14.3	31.99	44255	2.57
			Other ceramic	46		14.3	31.99	20867	1.21
		Floor cover.	Carpet	131		2.4	212.3	65876	3.83
			Vinyl			1.8	65.24	0	0
		Paint	(Enter 1)	1		0.2	194.25	16976	0.99
#	Fitments	Cabinets	Kitchen	12		89.2	37.71	13724	0.8
		Oven/hob		1		60	301.09	18065	1.05
		Air Con.		2		58	301.09	34926	2.03

# Plumbing	Piping					43.7	384.56	16816	0.98
	Steel Sinks			2		6	216.15	2594	0.15
	WCs			3		12	31.99	1152	0.07
	Handbasins			3		13	31.99	1248	0.07
	Taps/fittings					3.6	47	169	0.01
	Baths			1	Acrylic	6.8	64.23	434	0.03
	Water Service			1	Gas fired	70	301.09	21076	1.22
# Wiring	Wire					60.2	136.03	8185	0.48
	Fittings			30		0.1	64.23	145	0.01
# External	Pavers			115		80.6	3.19	29466	1.71
	Driveway			21	Concrete	240	2.38	12016	0.7
	Fences (lin.m.)	Timber				8.4	22.61	0	0
		Steel				3.6	192.1	0	0
		Various	enter 1	1	Mixture			61400	3.57
	Pergola			30		10.7	22.61	7224	0.42
	Shed			12		4.9	192.1	37611	2.18
	Carport							0	0
	Garage							0	0
Total						**Embodied Energy(MJ)**		**1721622**	
					Embodied Energy Intensity (MJ/m2)			**6162**	

Apartment Block - Glenelg - Provisional Estimate

			Calculation	Material Intensity (kg/m2)	Qty (kg)	EE (MJ)
PART OF GROUND FLOOR -CAR PARK						
1	18	Concrete columns	3.142*0.3^2*3192*2400		2166321.0	5164979.2
	21	Concrete	705*2400		1692000.0	4034095.1
	22				53800.0	2986033.3
	24		304*2400		729600.0	1739524.7
	25				39310.0	2181802.4
	26	Paving slabs	8202	80.6	661081.2	2110711.7
	30	Lift overrun pit				1560000.0
2	44	100mm thick Concrete	52*2400		124800.0	297550.3
	45	Retaining Wall Units	161*2.4 m2	100.0	38640.0	173280.8
	52	Retaining Wall reinforcement			7800.0	432919.3
	1	Columns	155*2400		372000.0	886928.7
	3	Reinforcement			30530.0	1694490.6
	41	Stairs 5000mm				468000.0
	42	Stairs 2500mm				416000.0
	43	Stairs 1200mm				91520.0
	46	Lift shaft walls	Reinforced block 185m2	100.0	18500.0	82963.1
			Render	8.0	1480.0	3831.3
			Paint	0.2	27.8	5390.5
3	47	Masonry partition	Brick 211m2	176.0	37136.0	201990.4
			Mortar	25.2	5317.2	13764.6
			2xplasterboard	15.2	3207.2	42686.1
			2xpaint	0.3	63.3	12296.1
	48	Fire doors with frames	6 @ 72MJ			432.0
	4	Plaster & paint	plaster	8.0	6688.0	17313.2
			paint	0.2	125.4	24359.1
		Carpark signage				
	38-	Stormwater equipment				
	54	Stormwater equipment services				260000.0
			Total embodied enegy	GJ		24902.9