ENERGY
PARTNERS

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Matthew Drake-Brockman

v

the Minister for Planning & CUB

Land and Environment Court Proceedings
No 40186 of 2007

Expert Report Prepared

By

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for

Environmental Defender's Office Ltd.

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Executive Summary

I have been asked by the Environmental Defender's Office to prepare this report in Land and Environment Court proceedings No. 40186 of 2007. The proceedings concern a challenge to concept plan approval granted by the Minister for Planning for redevelopment of the Carlton and United Brewery site in Sydney. For the purpose of the proceedings I have been asked to estimate the likely embodied and operational energy and water requirements of the development assuming that it was completed in accordance with the concept plan approval, and following standard building practices. Based on this, I have made an estimate of the total greenhouse gas emissions likely to be generated by the development. I have also been asked to comment on water and energy saving measures which could have been adopted on the site and the extent of savings which could have been made thereby.

Embodied and Operational Energy

The embodied energy of a building includes all of the energy consumed by all processes associated with the construction of a building, from sourcing of materials through to the delivery of the finished building. This includes manufacturing, transport and administration. The total embodied energy has been estimated in section 1.1 of this report as approximately 3,862,827 GJ . This figure includes an estimated 95,000 GJ of energy from construction crews, as calculated in section 2.2.

Operational energy is the energy consumed after the structure is completed, when the occupants begin to use the building. Some significant components of this energy type are residential heating and cooling, hot water, ventilation and lighting, commercial offices and retail spaces.

The total operational energy each year comes to 89,341 GJ, or 76,192 GJ electricity and 13,147 GJ gas, based on calculations set out in section 1.2 of this report.

Embodied and Operational Water

Embodied water represents the net water consumed in all processes in the production of a building, from natural resource extraction to the finished product. Operational water is all the water required by the occupants to use the building. The development is estimated to require 7,752 ML of embodied water.

The 1,600 apartments in the CUB development will annually consume approximately 188 ML of operational water. The commercial/retail sector of the building will annually use 67 ML of water. This is a total annual consumption of approximately 255 ML of operational water.

Greenhouse Gas Emissions

The total emissions from embodied energy are estimated to be approximately 586,000 tonnes CO_2-e. It is estimated that the greenhouse gas emissions from commuting construction crews over a two year construction period will be between 5,000 t and 17,800 t CO_2-e.

The operational energy emissions from electricity and gas are expected to be 20,500 tonnes and 831 t CO_2e respectively, which means an annual emissions total of 21,331 t CO_2-e for the development.

Significance of Greenhouse Gas Emissions

The New South Wales (NSW) total greenhouse gas emissions in 2005/2006 were calculated as being 158.2 million tonnes CO_2-e.

In the 2005/6 State of Environment (SoE) Report, emissions from the City of Sydney were calculated as being 4.7 million tonnes CO_2-e.

In comparison, the total annual operational emissions from the CUB development will be 21,331 t CO_2, which translates to 0.45% of the total emissions for the City of Sydney according to the 2006 SoE report.

Energy and Water Saving Measures

Means to reduce embodied energy are mainly achieved through the selection and production of building materials.

There are often materials that can be substituted for traditional materials to considerable environmental advantage, for example, using plantation timber framing in lieu of steel. Local sourcing of materials offers savings in the transport energy, as well as the use of recycled materials, especially steel and aluminium.

Off site fabrication reduces on site waste and redundant materials, which can be recovered and put to another use.

High performance heaters and coolers, as well as energy and water efficient appliances provide substantial savings, especially when used in conjunction with solar energy collection for hot water systems. If a 65% solar contribution is made to the 13,150GJ annual hot water demand for the development, a saving of 8,550 GJ or 540 t CO_2-e will be made. By using solar cells to contribute to electricity demands, an approximate maximum annual GHG saving of 825 t CO_2-e will be made.

Ventilation energy for the carparks can be reduced by using high efficiency fans and large fan ducts, and by applying time switching and carbon monoxide (CO) monitors.

Lighting can be saved by using high efficiency luminaires and movement sensors to detect times of little or no pedestrian traffic.

Projected annual water savings from an assumed performance of 255 ML are as follows

1. Selection of high performance fittings and appliances 40 ML
2. Rainfall harvesting for potable water use (after treatment) 40 ML

3. Grey water treatment and re-use (assuming 1 is implemented) 160 ML

4. Black water treatment and re-use (assuming 1 is implemented) 55 ML

This means a potential total saving of nearly 255 ML

The potential total saving is calculated on a nett water purchase basis. Practical limits will probably impinge on this potential.

Introduction

I am principal of Energy Partners, a firm which specializes in environmental consultancy for the built environment. A copy of my CV is annexed at Appendix A. I have read the Expert Witness Code of Conduct at Schedule 7 to the Uniform Civil Procedure rules and agree to be bound by it.

I have been commissioned to report on the environmental aspects of this project by a briefing letter from the Environmental Defender's Office Ltd dated 24 May 2007 with copies of the six documents listed in that letter.

- The Scoping Paper and request for authorisation of submission of a Concept Plan dated 5 July 2006
- The Director-General's environmental Assessment Requirements dated 4th October 2006
- Plans and the proponent's environmental assessment for the project
- The Preferred Project Report, including amended plans
- The Director-General's Environmental Assessment Report, and in particular the Statement of Commitments at Appendix B of the report; and
- The Notice of Determination dated 9 February 2007, attaching the conditions of approval.

I have been asked to:

1. Estimate the embodied and operational energy and water requirements of the completed development, assuming that standard construction practices are followed;
2. Estimate the greenhouse gas emissions which are likely to result from the above energy and water use, plus vehicle use associated with the construction and operation of the development (including private car use);
3. Describe the significance of the above greenhouse gas emissions in relation to wider greenhouse gas emission figures (for example, as a proportion of total emissions for the City of Sydney); and
4. Describe energy and water saving measures, which I would recommend for use on the site, and the extent of reductions in water and energy use, which could be achieved by adopting these measures.

1. Embodied and Operational Energy and Water

1.1. Embodied Energy

The embodied energy of a building encompasses the energy consumed by all processes associated with the production of the building, from the acquisition of natural resources to product delivery. This includes the mining of natural resources, manufacturing of materials and equipment, the transport of the materials and the administrative functions.

1.1.1. Estimated Building Quantities

Due to its high content of steel and concrete, the structure is generally the most significant component of a tall building in terms of embodied energy. Estimates of these quantities in generic medium and high rise offices are in the literature (eg, Treloar et al, 2001) but these figures need to be extrapolated to estimate the content in high-rise residential buildings. The structural design loads per square metre are around 70% less in a residential storey than in an office storey but they are also usually smaller storey heights so that, per metre of height, the loads of the two building types are approximately equal and hence the steel and concrete support materials are essentially equal also.

For reinforced concrete structures, the steel and concrete required for each floor increases with the number of floors to be supported. For example, a 30 storey building will require twice the size of footing and ground floor columns as a 15 storey building. Thus, in the columns and other vertical structural elements (walls and footings) of the 30 storey building there needs to be approximately 4 times the supporting material as in the 15 storey equivalent. This relationship has been applied in the following estimates, often by the sources we cite, such that generally structural steel and concrete form a greater fraction of the embodied energy in tall buildings than they do in the shorter ones. By contrast, the quantities in the floor slabs is independent of the building height (see Table 1).

	GFA (m²)		
	Commercial/Retail	**Residential**	**Combined**
Block 1	41,315	0	41,315
Block 2	6,709	42,224	56,312
Block 3	9,953	0	9,953
Block 4	11,754	15,225	26,979
Block 5	8,850	38,635	47,485
Block 6	1,754	152	1,906
Block 7	0	866	866
Block 8	1,722	11,693	13,415
Block 9	2,003	22,055	24,058
Block 10	2,790	229	3,019
Block 11	5,808	25,410	31,218
Car parking			7,744
Total	**92,658**	**156,488**	**256,890**

Table 1 Gross Floor Areas per Block from Section 10.2 of the Environmental Assessment

The table above shows the total area of the flooring. A balcony area equal to 10% of total residential GFA should be included in any calculation of the concrete volumes.

As proposed, the apartments have the modest average GFA of only 73.5 m² (total GFA of 148,971 m² for 1,620 apartments and allowing 20% for lifts, structure, services and common areas).

On these bases, the vertical structural elements (footings, columns and some walls) and the horizontal structural elements (floors, stairs and balconies) have been estimated in proportion with recent published data for similar buildings and included in the summary table in Section 1.1.2 (Table 3).

Table 2 below displays the calculated projected façade and roof areas for each block based on the concept plans provided. These figures can be used to calculate the quantity of material used in producing the buildings' facades and the resultant embodied energy contained in those materials.

	N	E	S	W	Total	Roof
Block 1	4,886	4,224	4,886	4,224	**18,220**	3,729
Block 2	6,859	4,515	6,859	8,152	**26,385**	3,356
Block 3	939	2,673	343	2,673	**6,628**	2,283
Block 4	2,245	2,092	2,245	2,092	**8,674**	3,939
Block 5	6,255	3,915	6,255	6,564	**22,989**	4,138
Block 6	347	735	347	661	**2,090**	693
Block 7	143	286	143	286	**858**	385
Block 8	1,867	1,498	1,811	1,498	**6,674**	1,644
Block 9	3,898	2,746	3,971	2,040	**12,655**	1,826
Block 10	1,050	498	1,050	551	**3,149**	559
Block 11	4,284	2,016	4,980	1,971	**13,251**	3,849
Total	**32,773**	**25,198**	**32,890**	**30,712**	**121,573**	**26,401**

Table 2 Estimated Projected Façade and Roof Areas for each block (m²)

The total façade area is estimated to be 25% greater than the projected façade area to allow for likely façade articulation by offsets and re-entrant corners in plan. This gives a total area of 152,000 m^2. This may indicatively consist of 50% windows and 50% rendered and plastered aerated autoclaved concrete (AAC) with a standard 200 mm thickness. This is a common construction incorporating the desire for large areas of glass moderated by the need for fire separation and visual privacy between units and their respective balconies. Where required, calculated areas can be converted to volumes and from those volumes the total mass can be calculated using published densities of the materials and components.

1.1.2. Estimated Embodied Energy

	Structure Group	Finishes Group	Sub-structure	Roof	Windows	Non-material group	Total
Block 1	392,493	20,141	45,447	40,282	1,033	175,589	674,984
Block 2	505,053	19,300	30,754	7,756	6,809	214,963	784,636
Block 3	64,695	4,479	5,225	8,460	2,239	32,596	117,694
Block 4	243,153	12,478	28,155	24,955	640	108,779	418,158
Block 5	474,908	19,876	36,849	6,508	4,793	204,606	747,541
Block 6	9,460	1,135	1,703	1,892	568	6,622	21,380
Block 7	3,935	472	708	787	236	2,755	8,893
Block 8	113,638	5,867	12,352	22,851	618	50,643	205,970
Block 9	229,351	10,497	21,921	2,735	1,478	100,099	366,080
Block 10	19,487	1,349	1,574	2,548	675	9,818	35,451
Block 11	265,954	13,731	28,908	53,480	1,445	118,523	482,041
Total	**2,322,126**	**109,326**	**213,596**	**172,254**	**20,533**	**1,024,993**	**3,862,827**

Table 3 Estimated Embodied Energy for the Full Building Complex (GJ) (after Lawson, 1996)

Table 3 displays estimates for the total embodied energy of the building complex. Embodied energy per square metre of GFA was estimated based on work by Treloar et. al. (2001) which investigated the embodied energy of office buildings by height. All components were estimated as directly proportional to plan area, façade area or GFA (as appropriate) except for the Structure Group which is adjusted for height as described above.

The embodied energy calculations were made based on work by Treloar et. al (2001) which examines the embodied energy of several buildings of different heights in Melbourne. Embodied energy figures are displayed as totals and as a rate per m² GFA. The buildings studied were 3, 7, 15, 42 and 52 storeys in height. These figures were adapted to the buildings in the CUB development by linearly interpolating the per m² figures between building heights using Equation 1 . EE_{xx} represents the EE/m² rate for a building of xx storeys. For example, Block 8 is 13 storeys high so the EE/m² figures for the 7 and 15 storey buildings were used. To get the appropriate rate for the 13 storey building the 7 storey rate was interpolated to 13 storeys according the rate of change per storey.

$$EE_{13} = EE_7 + (13-7)\left(\frac{EE_{15} - EE_7}{15-7}\right)$$

Equation 1

Energy consumed by construction crews also significantly contribute to the total embodied energy of the project. Based on the assumptions outlined in section 2.2, the total daily transport consumption for a single crew member is estimated as 121.6 MJ. For an average 3,125 workers, for a 250 day working year, the total annual consumption is calculated as 95,000 GJ.

The total embodied energy is estimated to be 3,862,827 GJ.

1.2. Operational Energy

A recent report has found that high-rise apartments are the worst form of residences for annual operational energy use (Myors et al, 2005) being the highest energy consumers on average at around 49,000 MJ/dwelling and having the most widely varying consumptions of ± 35% about that mean (i.e. ranging from 31,850 to 66,150 MJ/dwelling. They were also found to have widely varying components making up that wide range of per dwelling consumptions.

With the introduction of the energy efficiency provisions of the BCA (Section J) and the Building Application Sustainability Index (BASIX) planning approval process to NSW, (which aims to ensure homes are using less potable water and emitting fewer greenhouse gases by setting reduction targets for residential buildings), new residences are expected to be more energy efficient than the existing stock described above. Accordingly, separate estimates of the energy consumption components have been made below.

BASIX is defined (Environmental Assessment, Appendix U, p1) as:

BASIX is the NSW State Government's regulatory device through which all new residential dwellings and additions in NSW must achieve minimum specified levels of water and energy savings. There are three key sections:

- *Energy,*
- *Thermal Comfort, and*
- *Water.*

Each of these three categories are integrated and often influence each other.

The BASIX rating tool uses state average per capita consumption rates from information on existing dwellings as benchmarks for residential energy and water consumption. Predicted water and energy consumption are compared against a database of water and energy consumption figures collected from over 2 million households state-wide. This analysis allowed state-wide averages of energy and water consumption to be calculated, as listed below, against which predicted performance is compared:

- *Average water consumption – 90,340 litres of water per person per year*
- *Average energy consumption – 3,292 kg CO2 per person per year (equates to 12.0 GJ per person per year, or 3,340 kWh per person per year)*

Per capita figures are used as to give a fair distribution of allowances to different dwelling types. The BASIX rating tool calculates how many people will inhabit a particular dwelling from information entered by the user. These state average per capita figures are adjusted according to the geographical location of the project being assessed.

1.2.1. Residential Heating and Cooling

Pursuant to the Statement of Commitments Item 11, the proponent is required to achieve the BASIX benchmark at the time of final project approval. Currently, high rise apartments are required to achieve a 20% reduction on the state average value for Energy. There are grounds for expecting this stringency to increase (probably to 40% reduction) in the next few years and this may affect this project. There is a history of delays to implementation and reductions of programmed stringencies in BASIX so we cannot rely on this coming to pass before final approval is achieved. Even with that increased stringency, however, it does not follow that the Thermal Comfort (Heating and Cooling Caps) will be tightened at that time due to the modest fraction of total Energy that this end use constitutes.

BASIX currently requires Thermal Comfort annual energy demand to be predicted to be less than 70 MJ/m² for heating and 50 MJ/m² for cooling for standard occupancy patterns in multi-unit dwellings. That prediction is to be made by an accredited assessor with an accredited House Energy Rating software package such as NatHERS (the most popular one in NSW). While realistic for rating purposes, comparisons of these predicted consumptions have been found to exceed average actual consumptions due to factors like absences on holidays, conditioning lesser areas than standard and to lesser standards of comfort. Accordingly, the "constraint factors" described by Harrington (1999) have been used to estimate average actual consumptions from these BASIX values. Constraint factors specific to current practice in NSW are being developed by the same team but were not available to include in this report, so the original national constraint factors have been used.

The combined annual Thermal Comfort energy budget of 120 MJ/m² set by BASIX is marginally more stringent than the similar requirement in that same Statement of Commitments (in Subject 11. Environmentally Sustainable Design) to achieve "A 4.5 average star comfort rating using NatHERS or equivalent" so this Commitment can, in effect, be ignored.

The BASIX values cited are the maximum permitted average for all apartments in each block – but individual apartments are permitted to have worse performance. These demands (for heat to be added or removed to maintain comfort) must then be adjusted by the efficiency of the appliance used to condition the space to estimate the amount of energy demanded at the meter. A 3 star heater/cooler should allow such apartments to also meet the overall GHG limits (called Energy) per dwelling in BASIX in a cost effective way.

End Use	Thermal Comfort Energy in BASIX (MJ/m²)	Heater/Cooler Efficiency 3 Star (%)	Constraint Factor (%)	Implied Metered Energy Use (MJ/m²)
Heat (Gas)	70	70	45	45.0
Heat (Elec)	70	100	45	31.5
Heat (RCAC)	70	290	45	10.9
Cool (AC or RCAC)	50	260	40	7.7

Table 4 Estimated Heating and Cooling Energy Consumptions per m² NCFA
NCFA = Nett Conditioned Floor Area (assumed to be 80% of GFA)

In the absence of a central heating and air conditioning system, a reverse cycle air conditioner (RCAC) is the most cost effective solution and hence is used here for both heating and cooling. Gross residential floor area equals 156,488 m² (see Table 1). Assuming a 20% reduction for lifts and common areas the resulting net usable area is equal to 125,190 m². This, combined with the estimated total annual electricity consumption for space conditioning in the apartments of 10.9 + 7.7 = 18.6 MJ/m² gives a total of 2,329 GJ.

1.2.2. Residential Hot Water

Prescriptions in BASIX set an implied minimum energy efficiency for the water heater through a GHG emissions cap per person. This is unlikely to impact on this project due to the prior common preference in such projects to install a central gas-heated hot water system (Myors et al, 2005) whose efficiencies would ordinarily be in the order of 75% using a low GHG fuel (i.e. of the chemical energy available in the metered gas, 75% ends up as heat in the hot water while the remaining 25% escapes up the flue or is lost through the tank insulation between the time the water is heated and the time it is drawn off for use. On the basis of hot water consumption being estimated at 55 kL/year per dwelling, interpolated after Wilkenfeld (2004), for an average household of 1.9 persons. Applying an effective annual gas consumption similar to that for medium households AS 4234 of 115 MJ/kL in Climate Zone 3 (which includes Sydney), this gives an estimated water heating annual gas consumption of 6,325 MJ/dwelling or 10,247 GJ/year for all dwellings combined. This is an average figure of 62.5 MJ/m².

Office space and most retail outlets use only small amounts of hot water (staff showers, hand washing and kitchenettes) while the few restaurants and taverns which will be established in the retail space will be prodigious hot water consumers. It is not possible to estimate this consumption with accuracy. To establish its approximate consumption we have assumed that the commercial and retail space averages 50% of the residential hot water use per unit area, they add a further consumption of 2,900 GJ/year to arrive at an estimate for the whole complex of ~13,150 GJ/year.

1.2.3. Carpark Ventilation and Lighting

Carpark ventilation is estimated to require approximately 6 W/m² to provide adequate circulation below ground. The ventilation system is expected to run on average for 18 hours per day. This amounts to an annual energy consumption of 1,100 GJ.

In order to provide sufficient lighting for the underground carparking area an estimated 3 W/m² will be required. As the carpark is underground and will receive negligible natural light but serve a multi-residential clientele requiring to feel safe at all times, the lights are expected to operate 24 hours per day resulting in an annual energy consumption of 733 GJ.

1.2.4. Other Residential Energy Uses

Other internal energy uses in residential units are likely to be significant consumers of energy. This includes internal lighting, cooking and plug-in appliances such as personal computers and entertainment systems. The available research estimates this component of energy usage proportionately to the national average residential total including heating and cooling and water heating, rather than per square metre or per dwelling. Harrington (1999) estimates that cooking, lighting and appliances together consume 34% of total energy use. Internal energy uses are common to most lifestyles and not responsive to climate and hence, while significant in total, they can be reliably estimated after Harrington (1999) as in Table 5.

	Energy Consumption	GHG Emissions
Cooking	4%	5%
Appliances and Lighting	30%	53%
	GJ/dwelling	**t/dwelling**
Cooking	1.93	0.37
Appliances and Lighting	14.46	3.96
	GJ	**tonnes**
Cooking	3,124	606
Appliances and Lighting	23,429	6,420

Table 5 Estimated Annual Energy Consumption and GHG Emissions for Internal Purposes
(calculated from Harrington using National dwelling numbers and total use and emissions projected for 2007)

Cooking, Appliances and Lighting can be taken as ~26,500 GJ.

Additionally, multi-unit developments like this will have lift and common area lighting energy consumption which can be estimated after Myors (2006) as 4% and 10% respectively. Applying these fractions to the averages per dwelling published in that same source (see Table 23) we get the aggregate consumptions and emissions for 1,620 dwellings set out in Table 6. Although this complex includes buildings with both residential and commercial space, this estimate, being based on published averages per dwelling for high rise residential buildings, excludes the respective components for the commercial sections which are included separately under those headings. Knowledge of these separate components is not precise and no greater accuracy is practical at this stage.

	GJ	tonnes
Lifts	3,179	674
Common Area Lighting	7,948	1,685

Table 6 Estimated Annual Energy Consumption and GHG Emissions for Common Purposes (after Myors, 2006)

In addition, it is usual for developments like this to include a common swimming pool and spa with a wide range of annual energy consumptions. An example from Myors et al (2005, p.7) is of an audited high rise building with a 48,000 litre electrically heated pool and spa which required over 350,000 kWh/year (1,250 GJ). (This was calculated from the published figure of 22% of the building's operational GHG emissions.) It is possible that a complex of this size will incorporate more than one pool but we have assumed only one for this overall estimate.

1.2.5. Commercial Offices

The effective efficiency implied under the Commitment (in Subject 11. Environmentally Sustainable Design) to achieve "5 star greenhouse level" in compliance with the Australian Building Greenhouse Rating Scheme (ABGRS) is expressed as 134 kgCO_2-e/m², or approximately 9,870 t for 74,190 m^2 of NLA floor space, and is hence discussed in Sections 3.4 and 3.5. Using the emissions factor for grid electricity of 0.278 kg CO_2-e/MJ the "5 star greenhouse level" efficiency can be stated as 482 MJ/m² per year. Applying this figure to NLA floor space of 74,190 m² results in an estimated total annual energy use of 35,730 GJ.

These values can then be notionally disaggregated by end use by applying the published component fractions in a building of this type (PCA, 2001) as set out in Table 7.

Energy End Use	**Annual Energy Use**		
	MJ/m²	%	GJ
Tenant/Occupant Power	53	14.0%	5,010
Tenant/Occupant Lighting	110	29.1%	10,397
House L&P	20	5.3%	1,890
Lifts	25	6.6%	2,363
Ventilation	80	21.2%	7,562
Cooling	75	19.8%	7,089
Heating	12	3.2%	1,134
Hot Water	3	0.8%	284
Total	**378**	**100.0%**	**35,729**

Table 7 Commercial energy use by category

1.2.6. Retail Spaces

The table below shows the maximum allowable annual energy consumption for a Class 6 building (shop or shopping center).

Location	**Heating Method**	
	Gas, Oil	**Electric**
Sydney City	1,120	990

Table 8 Annual Energy Consumption Allowance (MJ/m²) (BCA, 2007)

The total GFA allocated to retail floor space amounts to 11,129 m² or 12% of the total non-residential GFA. Based on the BCA guidelines for Class 6 buildings the maximum allowable annual energy consumption for the combined retail space on the CUB site is equal to 12,500 GJ using gas or oil heating, or 11,000 GJ using electric reverse cycle heating systems.

Commitment 11. c. Retail states that the development "will comply with any reasonable future rating tool provided by the ABGR Scheme". This makes no sense. A rating tool cannot define a standard of performance to be met unless the commitment also names a measure on that rating scale. By implication, this was meant to require 5 star performance as for the offices. We could predict this performance benchmark by applying the ratio of BCA requirements for the two building classes to the 5 star definition of ABGR for offices:

$$990/590 \times 133 = 223 \text{ kgCO}_2\text{-e/m}^2 \text{ NLA}$$

No ABGR scheme for retail space is expected within the pre-construction phase of this project although there is a Green Building Council pilot for shopping centre design (GBCAus, 2007) which includes GHG emissions targets for HVAC in NSW of 130.2 $kgCO_2$-e/m² NLA for tenancies and 295 $kgCO_2$-e/m² NLA for the whole building – but there is no indication of whether these are genuinely intended targets or just "numbers for discussion" in the pilot phase.

1.3. Embodied and Operational Energy Summary

	GFA (m²)			Embodied Energy (GJ)		Operational Energy (GJ)	
	Commercial /Retail	Residential	Combined	Total	GJ/m²	Annual	GJ/m²
Block 1	41,315	0	41,315	674,984	16.34	20,836	0.504
Block 2	6,709	38,385	45,094	784,636	17.40	14,881	0.330
Block 3	9,953	0	9,953	117,694	11.83	5,019	0.504
Block 4	11,754	13,841	25,595	418,158	16.34	10,073	0.394
Block 5	8,850	35,123	43,973	747,541	17.00	14,983	0.341
Block 6	1,754	138	1,892	21,380	11.30	926	0.489
Block 7	0	787	787	8,893	11.30	236	0.300
Block 8	1,722	10,630	12,352	205,970	16.68	4,052	0.328
Block 9	2,003	20,050	22,053	366,080	16.60	7,016	0.318
Block 10	2,790	208	2,998	35,451	11.83	1,469	0.490
Block 11	5,808	23,100	28,908	482,041	16.68	9,848	0.341
Total	92,658	142,262	234,920	3,862,827	16.44	89,341	0.380

Table 9 Embodied and Operational Energy Summary by Building

	Component	GJ	Main Fuel Source
Embodied		3,862,827	various
		GJ per year	
Operational	Residential heating & cooling	2,329	electricity
	Residential hot water	10,247	gas
	Other hot water	2,900	gas
	Carpark lighting	733	electricity
	Carpark ventilation	1,099	electricity
	Other residential energy	6,274	electricity
	Swimming pool & spa	1,250	electricity and gas
	Lifts & common lighting	15,700	electricity
	Water Supply	2,079	electricity
	Commercial	35,730	electricity
	Retail	11,000	electricity
Total	Operational	**89,341**	

Table 10 Embodied and Operational Energy Summary by Component

The total embodied energy for the entire complex comes to 3,862,827 GJ, and the total operational energy each year comes to 102,032 GJ, or 88,885 GJ electricity and 13,147 GJ gas. This suggests that the construction will embody the equivalent of 38 years of operational energy.

1.4. Embodied Water

Embodied water is similar in concept to embodied energy and represents the net water consumed in all processes from natural resource extraction to finished product.

The embodied water of a typical house represents approximately 15 years worth of operational water (including garden watering), or 10 times the volume of the habitable space (Deakin University, Architecture & Building Website, 2007). No values are in the literature for water embodied in high rise apartments. The nearest is the estimate for 3-storey offices (Crawford and Treloar, 2005) which is itself highly imprecise but gives indicative values as per Table 11.

Building material	kL/m² GFA	Structure group	kL/m² GFA
Steel	9.0	finishes	10.5
Concrete	3.5	substructure	6.0
Glass	7.5	roof	5.75
Other metals	7.0	windows	2.0
Direct water	0.75	Direct water	8.25
other items	22.0	Structure group	0.5

Table 11 Indicative Indices for Embodied Water (Source: Crawford and Treloar (2005))

Using the breakup into the six component groups for full buildings from the same source, and adjusting for building height as for embodied energy, we arrive at the aggregates set out in Table 12.

	Structure Group	Finishes Group	Sub-structure	Roof	Windows	Direct	Combined
Block 1	20.7	433.8	247.9	237.6	82.6	340.8	1,363.4
Block 2	22.5	473.5	270.6	259.3	90.2	372.0	1,488.1
Block 3	5.0	104.5	59.7	57.2	19.9	82.1	328.4
Block 4	12.8	268.7	153.6	147.2	51.2	211.2	844.6
Block 5	22.0	461.7	263.8	252.8	87.9	362.8	1,451.1
Block 6	0.9	19.9	11.4	10.9	3.8	15.6	62.4
Block 7	0.4	8.3	4.7	4.5	1.6	6.5	26.0
Block 8	6.2	129.7	74.1	71.0	24.7	101.9	407.6
Block 9	11.0	231.6	132.3	126.8	44.1	181.9	727.7
Block 10	1.5	31.5	18.0	17.2	6.0	24.7	98.9
Block 11	14.5	303.5	173.4	166.2	57.8	238.5	954.0
Total	**117**	**2,467**	**1,410**	**1,351**	**470**	**1,938**	**7,752**

Table 12 Total Embodied Water (ML) (Source: Crawford and Treloar (2005))

1.5. Operational Water

1.5.1. Projected Consumption

The BASIX water consumption target is a reduction of 40% over the NSW residential average but this is not volumetrically defined in the literature (Environmental Assessment, Appendix U, p5). Instead the means to meet it is described in qualitative terms. These have been assumed in our calculations of expected potable water purchase and use.

While not required for a 4 star Green Star rating (GBCAus, 2007) as per Commitment 11, some water efficiency features are rewarded in that scale so we should assume a modest improvement over the unrated development, say 10%. The Green Star scale is described by the Green Buildings Council of Australia (its originator) as:

- 4 Star Green Star Certified Rating recognises and rewards "Best Practice";
- 5 Star Green Star Certified Rating recognises and rewards "Australian Excellence"; and
- 6 Star Green Star Certified Rating recognises and rewards "World Leadership".

However, these descriptors are generic and trade-offs are encouraged such that use of recycled steel and exemplary access to public transport (which may apply to this project) can off-set a pedestrian performance in operational energy and water conservation, for example.

	GFA (m^2)			Water Consumption (ML)		
	Commercial / Retail	Residential	Combined	Commercial / Retail	Residential	Combined
Block 1	41,315	0	41,315	29.87	0	29.87
Block 2	6,709	38,385	45,094	4.85	50.73	55.58
Block 3	9,953	0	9,953	7.20	0	7.20
Block 4	11,754	13,841	25,595	8.50	18.29	26.79
Block 5	8,850	35,123	43,973	6.40	46.42	52.82
Block 6	1,754	138	1,892	1.27	0.18	1.45
Block 7	0	787	787	0	1.04	1.04
Block 8	1,722	10,630	12,352	1.25	14.05	15.29
Block 9	2,003	20,050	22,053	1.45	26.50	27.94
Block 10	2,790	208	2,998	2.02	0.27	2.29
Block 11	5,808	23,100	28,908	4.19	30.53	34.73
Total	**92,658**	**142,262**	**234,920**	**67**	**188**	**255**

Table 13 Annual Water Consumption for Whole Development (after Quinn et al, 2006)
(individual block consumption based on percentage of total floor space)

1.5.2. Projected Rainfall Harvesting

Conventional design directs all stormwater from the site through subsurface drains. However, Subject 13 of the Commitments published in February 2007 requires the inclusion of a "Stormwater Detention and Retention System" in accordance with DEC

(2006). An estimate of the scope for this technique to reduce the demand for potable water supply by around 12% is set out in Section 4.3.1. This is proposed for watering public areas but may exceed this requirement due to the large fraction of the site which will built on or hard paved.

1.5.3. Projected Grey Water Treatment and Re-Use

None. Conventional design does not separate grey water from black water and directs all sewage from the site through subsurface sewer drains.

Additionally, the proposal does not include any grey water reuse on site (see Appendix T).

2. Greenhouse Gas Emissions

GHG emissions from the construction and operation of buildings is a combination of the amount of fuels used to build and operate them, greenhouse intensities of the fuels used and, for some processes, the GHG emissions unrelated to energy that occur through the chemical reactions employed to carry out those tasks (e.g. the CO_2 emitted in the manufacture of Portland Cement, the binding chemical in concrete). Not all of the GHG emissions are in the form of CO_2 although that is the dominant source. Other GHG emissions include methane and oxides of nitrogen. These other gases have published factors by which their emissions quantities can be compared with and added to those of CO_2. Thus the effect of each is expressed in terms of equivalent quantities of CO_2 and the aggregate effect is expressed in terms of CO_2-e (carbon dioxide equivalent).

For operational energy in these buildings, only emissions from the use of electricity and natural gas need be considered as all others are of only tiny proportions. For the purposes of these estimations, the following GHG emissions factors have been used for retail metered quantities of those fuels (Australian Institute of Energy, 2001):

Electricity	1 kWh releases 0.968 kg of CO_2-e
	1 MJ releases 0.278 kg of CO_2-e
Natural Gas	1 MJ releases 0.0632 kg of CO_2-e

It is worth noting that on a retail metered energy basis, electricity is almost 5 times as GHG intensive as natural gas. Appliance efficiencies will however close that apparent gap, especially in the case of space and water heating where heat pump technology allows substantial efficiency advantage to the electrical systems currently on the market.

2.1. Emissions from Embodied Energy

Whilst it is possible to estimate the GHG intensity of materials manufacture (as is Section 3.1) and apply that to the estimated embodied energy values calculated above to obtain estimates for the embodied (invested) emissions for this project, we have instead drawn the indicator values published for similar projects and set out the resultant estimate in Table 14 and Table 15.

Structure Group	Finishes Group	Substructure	Roof	Windows	Direct	Combined
253,112	11,917	23,282	18,776	2,238	276,748	586,072

Table 14 Embodied energy associated CO_2 emissions by Building Component (t) (after Treloar et al, 2001 and "Direct" from AIE, 2001)

	Materials	Non-material	Combined
Emissions factor (t/GJ)	0.109	0.27	
Embodied Energy (GJ)	2,837,835	1,024,993	3,862,827
Total Emissions (t CO_2)	309,324	276,748	586,071

Table 15 Embodied energy and associated emissions disaggregated by materials and energy used in the act of construction (non-material) (after Treloar et al, 2001 and "Direct" from AIE, 2001)

(Refer to Table 3 for a breakup by individual building.)

Table 15 shows the embodied energy and greenhouse gas emissions for the whole complex divided into those associated with the building materials and the direct emissions from the construction process (non-material). The material emissions factor represents the average emissions per unit of energy for materials production adapted from RMIT (2007) data. Considering the site's proximity to mains electricity it is expected that most of the energy requirements for the construction process will be provided via mains electricity. As a result the emissions factor for the non-material embodied energy is that of the NSW electricity supply which is published as 270 kg CO_2/MJ (AIE, 2001).

Total emissions from embodied energy are estimated to be approximately 586,000 tonnes CO_2-e.

2.2. Emissions from Construction Crews

To estimate the GHG emissions of construction crew commuting, two calculations were carried out to provide lower and upper bounds. The lower bound is where the crew commutes using modes and distances equal to the Sydney average. The upper bound is based on the crew all commuting by private car over distances implied by the current relevant Enterprise Agreement.

Lower Bound

NSW per capita transport emissions amounted to 3.3 tonnes CO_2e for 2004. On average, 25% of transport undertaken by Sydney residents is travel to and from work. On this basis, the annual emissions for people traveling to and from work amounts to approximately 800 kg per capita (ABS, 2007). We were briefed that this project will have a peak construction workforce of about 5,000 persons. Assuming a two year project ramping up to maximum construction rates in the first 6 months and tapering down in the completion stages over the last six months we get an average of 3,125 workers over those two years. Based on this average of 3,125 workers over a two year construction period the average annual emissions from construction crew commuting amounts to 2.5 kt CO_2e. This estimate represents the lower bound of the likely construction crew emissions as the per capita average is spread over the entire population of NSW. The actual per capita emissions of workers in NSW (and construction workers in particular who are unable to choose to live near their work) will be higher as they tend to travel more frequently than non-workers such as children and retirees.

Upper Bound

The current Enterprise Agreement for Sydney construction workers includes a travel to site allowance of $25/day. The ATO's rates for 2006-7 state a $0.67/km allowance for the costs of car use for engines over 2.6L. Combining these rates, the average daily travel distance to and from work for Sydney construction workers was estimated at 38 km. Taking an average fuel consumption rate of 10L/100km the average daily fuel consumption per worker is therefore 3.8L. The GHG emissions intensity for combustion of premium unleaded petrol (PULP) is estimated at 0.089 kg/MJ (AGO, 2003). Based on an energy intensity of 32 MJ/L for PULP this results in daily consumptions of 121.6 MJ and emissions of 10.9 kg/day or 2,725 kg/year for a 250 day working year.

Based on the average of 3,125 workers over a two year construction period the total annual emissions from construction crew commuting is estimated to equal a maximum of 8.5 kt CO_2e. This upper estimate is based on 100% of the workforce driving to work (with no car pooling) which is unlikely to occur; hence the actual emissions that will be produced will most likely be lower than the estimated value.

Best Estimate

On these bases, in the absence of more reliable data, we have taken the most likely reality to be midway between these lower and upper bounds. We estimate the commuting GHG emissions over a two-year construction period to be between 5,000 t and 17,000 t, say 11,000 t CO_2e.

2.3. Emissions from Operational Energy

As estimated in section 1.3, the annual consumption of operational energy is estimated as being 88,885GJ electricity and 13,147GJ gas. Natural gas consumption for the complex is expected to be attributed to the hot water service which is estimated to consume 13,150 GJ/year.

Table 16 has been calculated using the published emissions factors for New South Wales electricity and gas of 270kg CO_2/MJ and 63.2kg CO_2/GJ respectively (AIE, 2001). The total annual emissions comes to 23,998.95 tCO_2-e for electricity, and 830.89 tCO_{2}-e for gas, which means an annual emissions total of 24,829 tCO_2-e for the development.

The CO_2 emissions for natural gas consumption for the complex are included in Table 16 The CO_2 emissions factor for natural gas consumption in NSW is published as 63.2 kg/GJ (AIE, 2001). This results in total annual emissions from natural gas of 831 tonnes.

Component	GJ per year	Main Fuel Source	Emissions (t CO2-e)
Residential heating & cooling	2,329	electricity	629
Residential hot water	10,247	gas	648
Other hot water	2,900	gas	183
Carpark lighting	733	electricity	198
Carpark ventilation	1,099	electricity	297
Other residential energy	6,274	electricity	1694
Swimming pool & spa	1,250	Electricity and gas	338
Lifts & common lighting	15,700	electricity	4,239
Water Supply	2,079	electricity	561
Commercial	35,730	electricity	9647
Retail	11,000	electricity	2970
TOTAL	**89,341,**		**21,403**

Table 16 Total Annual Operational Energy Emissions

2.4. Emissions from Water Use

2.4.1. Public Sector Pumping Energy

Table 17 below displays the typical energy consumption associated with mains water supply and waste water disposal. The total amount of water supplied to the site is expected to equal approximately 255 ML per year once it is fully occupied (Environmental Assessment, Appendix T). Waste water removal from the site is assumed to equal the amount supplied as the harvested rainwater is slated for use on landscaping.

	kWh/ML	Water use (ML)	Total energy (GJ)	Emissions (kg CO_2)
Pumping energy	441	255	2.51	673.73
Waste water	300	255	2.0	537.24

Table 17 Annual Energy Consumption for Water Supply and Disposal (Sydney Water. WSAA, 2001) and (AIE, 2001)

Total annual emissions from pumping water to and wastewater from the site are therefore estimated as 1,210 t CO_2-e.

On-site Pumping Energy

Additional pumping will be required to service all but the lower levels of the development. This will be done through storage of water in tanks on the roofs of the buildings which are assumed to store a minimum of 1 day's usage. The average pumping power required to supply the rooftop tanks with the almost 255 ML per year is estimated to be 65 kW which results in an annual energy consumption of 2,050 GJ (65 kW x 8,760 hours is 569,400 kWh or 569.4 MWh or 2,050 GJ). On site waste water pumping is ignored as all above-ground waste water will run to the sewers without pumping and most of the subterranean space is allotted for car parking which produces minimal waste water.

	Water Use	Height	Pump Head Required	Avg. flow rate	Pump Power (kW)	Annual Energy (GJ)
Block 1	29.87	62	47	0.95	6.36	200.56
Block 2	55.58	110	95	1.76	23.92	754.30
Block 3	7.2	23	8	0.23	0.26	8.23
Block 4	26.79	45	30	0.85	3.64	144.81
Block 5	52.82	88	73	1.67	17.47	550.84
Block 6	1.45	10	0	0.05	0.00	0.00
Block 7	1.04	6	0	0.03	0.00	0.00
Block 8	15.29	42	27	0.48	1.87	58.98
Block 9	27.94	67	52	0.89	6.58	207.55
Block 10	2.29	23	8	0.07	0.08	2.62
Block 11	34.73	43	28	1.10	4.41	138.92
Total	255				64.59	2066.81

Table 18 Annual Energy Consumption for On-Site Pumping

Annual Energy (GJ)	**Emissions factor (kg CO_2/MJ)**	**Total emissions (tCO_2)**
2,067	0.278	575

The water supply from the rooftop tank to the floors below will be primarily gravity fed however some extra pumping will be required to maintain sufficient pressure for the highest floors. The extra energy requirement will be much smaller than the energy required to fill the rooftop tanks and is insignificant when compared to the total operational energy consumption of the complex.

Total annual emissions from pumping water and wastewater on the site are therefore estimated as 575 t CO_2-e.

2.5. Estimated Total Emissions

Component	**Emissions (tCO_2-e)**
Embodied Energy	586,000
Construction Crews	11,000
Total Embodied Emissions	**597,000**
Operational Energy	20,842
Water Use	561
Total Annual Operational Emissions	**26,146**

Table 19 Estimated total emissions (t CO2-e)

As outlined in Table 19 components, annual total operational emissions from operational energy and water use are estimated as 26,146 t CO_2-e, while the total embodied energy including emissions from construction crews is calculated at 597,000 tCO_2-e.

3. Significance of Greenhouse Gas Emissions

3.1. Total NSW Emissions

The preliminary estimated resident population of New South Wales (NSW) at 31 March 2006 was 6.82 million (Australian Bureau of Statistics (ABS) 2006a). New South Wales total greenhouse gas emissions were calculated as being 158.2 million tonnes CO_2-e in 2005/2006 (NSW NGGI, 2005). This gives an average annual emission from all activities of just over 23 tonnes per capita.

To estimate the GHG emissions associated with the calculated Embodied Energy for building components we have used national GHG emissions and energy use in (ANZSIC Code) Division C “Manufacturing”. Although equivalent figures are available specifically for NSW they are heavily skewed by the high emissions of the iron and steel sectors and would be misleading if applied to this purpose.

- Energy consumption 2004-5 1,248.80 PJ (ABARE, 2006)
- GHG Emissions 2005 69.0 Mt CO_2-e (AGO, 2007)
- Average Emissions Intensity 0.055 kg/MJ

3.1.1. City of Sydney Emissions

The City of Sydney Local Government Area (LGA) covers approximately 26.15 square kilometres. Since 1996, the resident population of the City of Sydney has increased by just under 50,000 people, over 40 %, and by more than 20,000 since the last published Population census in 2001.

At the end of December 2006, the estimated resident population of the City of Sydney was 160,838 based on dwelling completions. (City of Sydney, 2006)

In the 2005/6 State of Environment (SOE) Report, the City of Sydney emissions were calculated as being 4,690,000 tonnes CO2-e. This figure was generated for the SOE using BAU assumptions and Cities for Climate Protection (CCP^{TM}) group software. The breakdown in emissions by building sector is given in Table 20 below. From the same report, City of Sydney area total electricity usage was 4,216,211 (MWh) for 2005/6.

SECTOR	Tonnes of CO_2-e	percent
Commercial	2,467,900 (t)	53%
Industrial	1,242,300 (t)	26%
Residential	446,900 (t)	10%
Transport	436,400 (t)	9%
Waste	96,300 (t)	2%

Table 20 Breakdown of Annual GHG Emissions (City of Sydney), Source: City of Sydney (2006a)

This allows the estimate of annual residential emissions as 2.78 t/person.

3.2. NSW Emissions from the Residential Sector

NSW emissions apportioned to the residential sector amounted to 22,567,000 tonnes/CO_2-e according to (ABARE, 2006) which translates to 3.4 tonnes per capita, somewhat higher than the average for the City of Sydney.

3.2.1. High-Rise Residential Emissions

Myors et al (2005, p.4, 9) calculated from an audit of 17 high rise residential buildings (above 9 storeys) covering 2,952 dwellings the annual greenhouse gas emissions per dwelling of operational energy was 10.4 tonnes CO_2-e. This equates to 5.4 tonnes CO_2-e per person per year.

The emissions per capita is derived from dividing the per-dwelling emissions by Australian Bureau of Statistics (ABS) 2001 Census occupancy rates for each housing type. Myors et al (2005, p.13) quotes NSW average residential greenhouse gas emissions adopted by BASIX as 3.392 tonnes CO_2/person.year. The BASIX target requires a 25% reduction in greenhouse gas emissions compared to the NSW average to 2.5 tonnes CO_2-e per person per year.

3.3. CUB Development Contextual Analysis

	CUB Development	City of Sydney	CUB %	NSW	CUB %
Total tCO2-e	21,402	4,690,000	0.45	158,200,000	0.014
Residential t CO2-e	8,786	446,900	1.97	17,500,000	0.050
Commercial t CO2-e	12,617	2,467,900	0.51	7,100,000	0.177

Table 21 Overall Contextual analysis for City of Sydney and New South Wales

To place this development in the wider Sydney context, the total annual operational emissions from the development will be 21,402 t CO_2-e, which translates to 0.45% of the total 4,690,000 t CO_2-e emissions for the City of Sydney according to the 2006 SoE report.

For the wider New South Wales context, NSW operational emissions are calculated at being 158.2 million t CO_2-e. The CUB development emissions translate to 0.014% of this figure.

As calculated from Table 20, the residential sector of Sydney development annually emits 446,900 t CO_2-e, which is approximately 10% of Sydney's total emissions. From Table 16, the total residential emissions for this development are calculated at 8,786 t CO_2-e, which is equal to 1.97% of Sydney's total residential emissions.

The NSW residential emissions are calculated as an annual figure of 17.5 Mt CO_2-e (Harrington et al 1999). As such, this project represents 0.050% of NSW total residential emissions.

The total commercial emissions for the project are 12,617 t CO_2-e (from Table 16). When compared with Sydney commercial figures, this development contributes 0.51% of these emissions. In NSW, the emissions from the commercial services and construction sector are published at 7.1 Mt per year (AGO 2007). As such, the CUB development will contribute approximately 0.18% to these emissions, acknowledging that the emissions from the construction industry included in the NSW figure will lower the actual percentage contribution than if the commercial sector alone were analysed.

3.4. Proposal Relative to the Building Stock

Comparing the proposal with its similar predecessors as measured in the field (as in Myors et al (2005)) it stands up as a modest improvement in the residential sections and proudly in the commercial floorspace. In large part this favorable comparison is due to the gulf that currently lies between the predicted (or simulated) performance potential of a building and the reality of routinely dilatory maintenance and the quasi-sabotage of indifferent occupants who often have little or no incentive to save energy or water. Often this is due to the nature of the lease and/or strata title ownership.

Residential

Comparing the proposal at 4.5 stars (56 MJ/m² 2nd generation NatHERS) with housing in suburbia with an average energy rating of around 2 stars (142 MJ/m²) this represents a 60% improvement for heating and cooling assuming no improvement in the efficiency of the heat/cooling appliances. It does not, however, offer any real improvement over the building stock for water heating and other internal uses which are far more important in Sydney's rather benign climate.

Commercial

Most commercial office space performs in the range of 2 to 3 stars on the ABGR scale (annual emissions of 311 to 252 kg CO_2-e / m² for the standard occupancies). Performing to 5 star ABGR (133 kg CO_2-e / m²) represents an improvement in the range of 57% to 47%.

3.5. Proposal Relative to the Best Practice

Residential

The targeting of 4.5 star NatHERS performance is not challenging and is only 14% less than compliance with the energy efficiency minima of the BCA which is nominally 4.0 stars for Class 2 dwellings. Detached homes and townhouses (BCA Class 1) require a 5 star standard outside NSW.

The second generation NatHERS now in pilot use in NSW has a 10 star scale with 10 stars being awarded for dwellings requiring no energy to heat or cool the spaces except for any requisite dehumidification in torrid conditions (an annual allowance of 6 MJ/m²). There is no reason why this project could not target 6 star performance (2nd generation 41 MJ/m² compared with 56 MJ/m² for 4.5 stars and 65 MJ/m² for 4.0 stars) which is the top of the range in the soon-to-be superseded version of the NatHERS scales. Thus heating and cooling energy could be reduced by 27%.

Commercial

The proposal is exemplary in its targeting 5 star ABGR for the commercial areas. I suspect the proponents are unaware of the challenge they have accepted. An ABGR is the measured outcome of the combination of the building's energy efficiency potential and how its occupants realize or subvert that potential. As such it is a threatening commitment for a developer to make and it is likely that they will choose "occupant proof" ways of meeting this requirement like installing co- or even tri-generation into the buildings' energy systems rather than be exposed to the risk of unrestrained use of lighting and HVAC systems by the new owners and tenants.

4. Energy and Water Saving Measures

4.1. Reduced Embodied Energy

4.1.1. Material Substitutions

There are often materials which can be substituted for traditional ones to significant environmental advantage in the form of reduced embodied energy. These can be located through supplier advice services like Ecospecifier (originally established by RMIT's Centre for Design). For example, choosing plantation timber framing in lieu of steel in internal partitions offers a saving of 147 – 37 = 110 MJ/m² of wall (after Lawson, 1996, p59-60).

- Kiln dried softwood has embodied energy of 3.2 MJ/kg (Ecospecifier)
- Galvanised steel has embodied energy of 38 MJ/kg (Ecospecifier)

4.1.2. Local Sourcing

Where available, local sourcing of materials, especially the bulky or massive ones, offers substantial savings in transport energy being embodied in the new building. It is not practical to quantify this in the context of the current stage of this project.

4.1.3. Recycled and Reused Materials

Large savings in embodied energy can be derived from the use of recycled materials. The two best examples are steel and aluminium as per Table 22.

Material	Virgin	Recycled
Aluminium	19.0	0.9
Steel	2.1	1.1

Table 22 Comparison of Embodied GHG Emissions (kilograms of CO2-e)

Reuse of materials in such a large construction project will not be easy but should be applied where practical such as in the use of crushed masonry rubble from demolition in paving sub-grade bases.

4.1.4. Off-site Fabrication

This technique can reduce the embodied energy in the building primarily by reducing on-site waste and double carting of redundant materials which are turned to waste by the on-site building process. It also enhances the potential for reuse of such "waste" such as wood shavings and sawdust which are unrecoverable in the context of an active building site.

4.2. Reduced Operational Energy

4.2.1. Choice of Housing Form

For comparison purposes, Myors (2006) compares the relative operational energy and GHG emissions for lower density residential forms (see Table 23). High rise is the worst form in the Sydney building stock with energy consumption 90% greater than the best (townhouses and villas) and 35% worse than the average. Clearly there is scope for reduce emissions per dwelling by the selection of a less dense housing form, although this will reduce the number of dwellings able to be accommodated on the site and hence reduce the economic value of the site itself.

	Annual Energy (elec + gas) per Dwelling MJ/dwelling.year	**Annual Greenhouse Gas Emissions per Dwelling t CO_2/dwelling.year**	**Annual Greenhouse Gas Emissions per Person t CO_2/person.year**
High Rise	49,063	10.4	5.4
Mid Rise	30,594	7.3	3.8
Low Rise	27,158	6.5	3.4
Townhouse / Villa	25,547	5.1	2.1
Detached	39,974	9.0	2.9
Average of All	**36,309**	**8.0**	**4.1**

Table 23 Average Annual Energy Consumption and GHG Emissions for Housing Forms (after Myors, 2006)

4.2.2. Residential Heating and Cooling

See the discussion of the Thermal Comfort energy efficiency rating in Sections 3.4 and 3.5.

In addition, substantial savings are also available from the selection of high performance heaters and coolers to provide the diminished space conditioning demand. Table 24 sets out the combined impact of improved apartment design and construction and top end appliance efficiencies. This can be directly compared with the expected outcome for the proposal as set out in Table 4.

End Use	6 Star (MJ/m^2)	Efficiency 6 Star (%)	Constraint Factor (%)	Energy Use (MJ/m^2)
Heat (Gas)	36.0	70	45	23.1
Heat (Elec)	36.0	100	45	16.2
Heat (RCAC)	36.0	230	45	7.0
Cool (AC)	25.7	220	40	4.7

Table 24 Estimated Energy Consumption for High Efficiency Heaters and Coolers (assuming 6 star performance of the apartment itself)

This represents a total saving of 864 GJ/year.

4.2.3. Residential Hot Water

There is scope for substantial savings from energy and water efficient appliances as discussed in Section 3.5 and also from applying solar energy collection to the central hot water systems as discussed in Section 4.2.9.

4.2.4. Carpark Ventilation and Lighting

Ventilation energy can be reduced by using high efficiency fans and larger ducts to reduce the frictional resistance that the fans have to work against. Bigger savings are available by controlling the fans to only operate as needed by applying sophisticated time switching or Carbon monoxide (CO) pollution monitoring and modulating the ventilation to maintain a healthy atmosphere but reduce the ventilation when low car traffic allows.

Lighting can be saved by installing high efficiency luminaires and by switching by movement sensors during times of little or no pedestrian traffic.

4.2.5. Other Residential Energy Uses

Selection of high efficiency lighting and appliances (including low standby demand) all offer significant energy savings in energy and GHG emissions. Also, cooking by gas offers excellent service using a similar amount of energy but with less than half of the GHG emissions.

4.2.6. Commercial Offices

Annual allowance	PCA (NLA) Gas, oil	PCA (NLA) Electric	BCA (GFA) Gas, oil	BCA (GFA) Electric
MJ/m^2	438	378	670	590
Total (GJ)	**28,823**	**24,875**	**55,114**	**48,533**

Table 25 PCA new building design targets compared to BCA minimum compliance

Table 25 displays the Property Council of Australia (PCA, 2001) annual energy consumption targets for new office buildings which are observed by the industry as indicators of sound (but not exemplary) design and operation. They compare favorably with the minimum compliance standards set out by the BCA (2006). Based on a total commercial office GFA of 82,000 m² the new building design target represents a reduction in energy consumption of between 25 and 35 percent depending on the choice of heating system. Assuming electric heat pump heating, this suggests a potential saving for this development of almost 20,000 GJ.

Compared with 5 star ABGR (134 kg/m².a), the PCA's targets for "good practice" appear quite advanced. For example, the PCA annual target for an all electric building of 378 MJ/m² represents 105 kg/m² (1 MJ of electricity releases 0.278 kg of CO_2-e). It does, however, assume diligent switching of tenant light and power services whereas the ABGR allows some "slack" of around 40% of such load being left on out of hours. As a result the two benchmarks are not readily comparable.

4.2.7. Retail Spaces

	PCA (NLA)		BCA (GFA)	
Annual allowance	Gas, oil	Electric	Gas, oil	Electric
MJ/m²	847	731	1,120	990
Total (GJ)	**7,541**	**6,508**	**12,464**	**11,018**

Table 26 PCA new building design targets compared to BCA minimum compliance

Table 26 displays a new building design target for retail space energy consumption adapted from the PCA target for new office buildings. Comparison of this target with the BCA minimum compliance standards shows a potential reduction in energy consumption of up to 48%. Assuming electric heat pump heating, these same figures suggest a potential saving for this development of almost 4,500 GJ.

4.2.8. Cogeneration

Cogeneration, also referred to as Combined Heat and Power (CHP), is the generation of electricity combined with productive use of otherwise waste heat from the combustion of the same primary fuel. It is typically two to three times more fuel efficient compared to conventional technologies and offers even greater savings of GHG emissions where it is fired by natural gas.

A usual cogeneration system might be a reciprocating gas engine, gas turbine or steam turbine. Particularly for buildings with large air conditioning and/or refrigeration needs, steam or hot water can be used during the cooling season to generate chilled water using an absorption chiller rather than an electric driven chiller plant. This arrangement, combined with the use of heat in the winter, is often called "tri-generation".

The potential savings from this technology are very site-specific and usually depend on the scope for use or sale of the heat (and/or chilled water) in close proximity. If the buildings adopted a central heating, cooling and hot water system the tri-generation system could be sized to meet those thermal demands. The resultant electricity, which would be of a similar order of energy content, would be used on site or sold to the grid at times of surplus.

4.2.9. Renewable Energy

Solar Hot Water

Solar hot water systems are generally flat plate, cylindrical evacuated tube or heat pump systems. Using an example from the Victorian Government Property Group (2007), a 14 panel flat plate pre-heat system with a 1,130 litre capacity provides the equivalent of 560 GJ of delivered energy a year or around 36 tonnes of CO_2-e (if displacing electric resistance heat). For a typical 300 litre solar hot water system the deemed Renewable Energy Certificates (RECs) over 10 years can range between 15 and 65 certificates depending on the location, the system time and if it replaces an existing electric or gas hot water system. For solar hot water systems in new a building in Sydney, the RECs are closer to 35 certificates on average for a system with 4 m² of flat plate collector.

At 50% average efficiency, a flat plate collector will produce ~3.5 GJ/m².a in hot water in Sydney (Lee et al, 2006) when facing north and tilted at the latitude angle. With the whole complex estimated to have an annual hot water demand of ~13,150 GJ/year, a 65% solar contribution would require around 2,500 m² and save 65% of 831 or 540 tonnes.

The complex has a projected roof area of ~26,000 m² so, even with the difficult geometry likely to be applied to protect properties to the south from undesirable winter shading, this is eminently feasible on the complex as planned.

Solar Electrics

Given the surface façade and roof area of this substantial development proposal (refer to Table 2), the potential for harnessing solar energy, in particular, is noteworthy. Typically, a 1 kWp (1 kilowatt peak) crystalline silicon solar power (photovoltaic) system covers around 8 m^2 and can generate around 1,400 to 1,600 kWh/year under Sydney climatic conditions if installed at optimum slope and orientation. As an example, a 40 kWp system would require 320 m² of roof and could obviate over 55 tonnes CO_2-e per year, and provide embedded generation capacity to reduce stress and peak load needs on the distribution network.

The roof lines as proposed are sloped to reduce the winter shading impact on sites to the south, as noted above, and as such are not ideal for such use. As a result only about 30% of the roof area in plan is usable for solar energy systems, say 8,000 m². Allowing the 2,500 m² for water heating and some maintenance access space, say 4,800 m² is available for solar electrics or space for 15 of the 40 kWp systems cited above. This would give an annual GHG saving of around 825 tonnes.

A saving of a similar order is available by using PV panels in the balustrades of the northern balconies but would need detailed shading analysis to estimate with any accuracy.

4.2.10. Potential from RECs and NGACs

Renewable energy generation and greenhouse gas abatement achieved on the site can earn added income for the owner/developer to add to the value of the actual energy saved or generated on-site.

Renewable Energy Certificates

Renewable Energy Certificates (RECs) are an electronic form of currency initiated by the Commonwealth's Renewable Energy (Electricity) Act 2000. RECs are created by registered persons, validated by the Office of the Renewable Energy Regulator, traded between registered persons, and eventually surrendered to demonstrate liability compliance against the requirements of the Australian Government's mandatory renewable energy target.

The current REC value spot price as of 23rd May 2007 was $33.54 (AFMA, 2007) for a MWh of eligible renewable energy.

Greenhouse Gas Abatement Certificates

The NSW Greenhouse Gas Abatement Certificate (NGAC)s for the same date was $11.84 (ibid). These certificates each represent a tonne of abated GHG and at current greenhouse intensities for the electricity sector this is approximately equal to 1 MWh of "clean" (carbon free) electricity.

4.3. Reduced Household Water Consumption

4.3.1. Selection of High Performance Fittings and Appliances

The National Water Conservation Rating and Labelling Scheme is managed by the Water Services Association of Australia. Indicatively, about 30% of internal residential water use can be saved by the adoption of 5 star appliances and fittings in lieu of their more common 2 star or worse equivalents. For this development proposal, 3 star appliances and fittings can be assumed to meet the BASIX water benchmark. Hence the available saving from 5 star appliances and fittings is only around 15%. Additionally, WELS rated 5 star product is not well represented in the market at present and a lower practical target may need to be set for this project for pragmatic reasons.

4.3.2. Projected Rainfall Harvesting

From the table below it can be seen that an average of 48 ML of stormwater will land on the CUB site each year. These figures are based on the average annual rainfall for Sydney since 1973 of 1,100 mm (City of Sydney, 2005).

Roof-captured storm water could be safely made potable with only minor treatment and precautions (and with negligible on-site pumping if stored where it is caught). If 90% of the roof incident storm water were captured and treated, annual mains water consumption could be reduced by 26 ML or 8%.

	Surface area (m²)			Annual Incident Rainfall (ML)		
	Total	**Roof**	**Ground**	**Total**	**Roof**	**Ground**
Block 1	4,155	3,729	426	4.57	4.10	0.47
Block 2	3,516	3,356	160	3.87	3.69	0.18
Block 3	2,357	2,283	74	2.59	2.51	0.08
Block 4	5,707	3,939	1,768	6.28	4.33	1.94
Block 5	5,631	4,138	1,493	6.19	4.55	1.64
Block 6	778	693	85	0.86	0.76	0.09
Block 7	693	385	308	0.76	0.42	0.34
Block 8	2,260	1,644	616	2.49	1.81	0.68
Block 9	2,899	1,826	1,073	3.19	2.01	1.18
Block 10	605	559	46	0.67	0.61	0.05
Block 11	6,335	3,849	2,486	6.97	4.23	2.73
Main Park	4,749	0	4,749	5.22	0.00	5.22
Total	**39,685**	**26,401**	**13,284**	**43.65**	**29.04**	**14.61**

Table 27 Estimated Rainwater Resources Available for On-site Use

14.6 ML of stormwater is available for ground capture each year (including wind driven rain intercepted by the walls and fenestration and captured at or near ground level). This water can then be treated for use as grey water to offset some of the demand for mains water for the site. Ground incident storm water equates to approximately 4% of total annual water use for the site. Considering that toilets are estimated to make up approximately 25% of all indoor residential water consumption in the City of Sydney (City of Sydney, 2006) all of the ground level water captured on site can be used even if none is required for landscape maintenance.

Note that these two techniques are cited in Environmental Assessment, Appendix U, p5 as possible ways of meeting the BASIX water savings requirement and may be included in the proposal if unavoidable.

4.3.3. Projected Grey Water Treatment and Re-Use

"Grey Water" is wastewater free of human excrement and/or toxic materials. Generally it is harvested from showers, basins, kitchen and laundry (assuming benign detergents are used). Given that toilets are estimated to make up approximately 25% of all indoor residential water consumption, three quarters of the residential water consumption on the site will "grey water" and be available for capture and reuse (provided the water flows are separated at source). Thus, assuming a similar ratio applies in commercial and retail space, the annual grey water resource is estimated to be 225 ML. If all toilet flushing is done with this resource, 85 ML will go to that use leaving around 140 ML available for other uses or sale off-site.

A system on this scale would cost around $0.6 million (Caldwell, 2007) but would use very little energy in its operation other than pumping energy to return the treated grey water to the upper floors for reuse (which would be approximately the same as the pumping energy saved by lifting less potable, mains, water to the rooftop storage).

4.3.4. Projected Black Water Treatment and Re-Use

"Black Water" is any waste water stream which includes human excrement. Generally it refers to residential waste water without the grey water component. Such a large complex admits the potential for on-site sewage treatment and re-use and may be more cost effective than constructing a dual sewerage system to process grey water only. Combined with captured rainwater devoted to potable use, this could make the complex effectively self-sufficient for water services in theory. Realizing this in practice will require the finding of a large customer for treated effluent nearby (sufficient water to irrigate about 15 Ha in addition to the 30% estimated as useful in toilet flushing on site). Alternatively, a smaller system could be adopted limited in size to produce only as much treated effluent as can be used on the site.

A system on a scale to treat all effluent from the site would cost around $3 million (Clancy, 2007) and have a further need for space that would likely impose added cost on a constrained site like this; but it would use very little energy in its operation.

4.3.5. Summary of Potential Mains Water Savings

Projected annual water savings from an assumed performance of 255 ML are as follows

5. Selection of high performance fittings and appliances 40 ML
6. Rainfall harvesting for potable water use (after treatment) 40 ML
7. Grey water treatment and re-use (assuming 1 is implemented) 160 ML
8. Black water treatment and re-use (assuming 1 is implemented) 55 ML

This means a potential total saving of nearly 255 ML

The potential total saving is calculated on a nett water purchase basis. Practical limits will probably impinge on this potential. Savings from fittings and appliances reduce the potential grey and black water resources and the combination of all potential savings will cause a need to find an economic end use off site as they can exceed the overall demand of the complex. Also, the high performance fittings and appliances cannot be effectively imposed on the occupants and hence this saving may not be fully realised the way it would be in a motivated household.

Signed:

Trevor Lee

Date: 5 July 2007
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5. Appendices

5.1. Sources of Information

5.1.1. Household Energy Use

City Of Sydney (2003), Draft Greenhouse Action Plan, 2002-2003, SOLARCH Group, University of New South Wales, February 2003

City of Sydney (2006), *City of Sydney Residential Monitor June 2006 - Issue No. 38*

Lee, T R et al (2006), *Australian Solar Radiation Data Handbook,* Edition 4, Australian and New Zealand Solar Energy Society

Lloyd Harrington et al (1999), *Study of Greenhouse Gas Emissions from the Australian Residential Building Sector to 2010*, Australian Greenhouse Office, Canberra

Paul Myors, Rachel O'Leary & Rob Helstroom (2005), *Multi Unit Residential Buildings Energy & Peak Demand Study*, NSW Department of Infrastructure, Planning & Natural Resources

Myors, P., O'Leary, R., and Helstroom, R. (2005) Multi-Unit Residential Building Energy & Peak Demand Study (October 2005), *Energy News*, Vol 23 No. 4, December 2005.pp.113-116

Standards Australia, AS 4234 – 1994 with Amendments1- 4, *"Solar water heaters – Domestic and heat pump – Calculation of Energy Consumption"*

Victorian Government Property Group (2007), http://www.bcse.org.au/default.asp?id=231&articleid=87

Wilkenfeld, G, 2004 (Feb), *"NFEE – Energy Efficiency Improvement Potential Case Studies, Residential Water Heaters"*, Report to Sustainable Energy Authority of Victoria, George Wilkenfeld and Associates

5.1.2. Commercial Energy

BCA (2007), *Building Code of Australia*, Australian Building Codes Board, Canberra

PCA (2001), *Energy Guidelines*, Property Council of Australia, Sydney

GBCAus (2007), *Shopping Centre Design (Pilot)*, and other rating tools, Green Buildings Council of Australia, http://www.gbcaus.org/

5.1.3. Embodied Energy

Crawford, R.H. and Treloar, G. J (2005) An Assessment of the Energy and Water Embodied in Commercial Building Construction, *in proceedings of the 4th Australian LCA Conference*, February 2005, Sydney

Ecospecifier, http://www.ecospecifier.org/, self-described as a knowledge base of well over 3000 environmentally preferable products, materials, technologies and resources, e.g. http://www.ecospecifier.org/products/private/timber_technical_guide_overview.

Lawson, B (1996) *Building Materials, Energy and the Environment: Towards Ecologically Sustainable Development*, Royal Australian Institute of Architects

RMIT (2007), Centre for Design – personal correspondence

Treloar, G.J., Fay, R., Ilozar, B. and Love, P.E.D. (2001) *An analysis of the embodied energy of office buildings by height,* MCB University Press Vol 19 Number 5/6 pp 204-214

5.1.4. Embodied Water

Crawford, R.H. and Treloar, G. J (2005) *An Assessment of the Energy and Water Embodied in Commercial Building Construction*, in proceedings of the 4th Australian LCA Conference, February 2005, Sydney

Deakin University, Architecture & Building Website (2007), Treloar, G profile, Faculty of Science & Technology, Deakin University
http://www.deakin.edu.au/scitech/a+b/people/index.php?op=showDetail&type=academic&id=20)

WSAA (2001) Water Supply Association of Australia – personal correspondence

5.1.5. Operational Water

Caldwell, Brett (2007) *personal communication*, www.perpetualwater.com.au

City of Sydney (2006), *Water Demand,* http://www.cityofsydney.nsw.gov.au/Environment/Water/CurrentStatus/WaterConservation/WaterDemand.asp , Accessed: 21/6/2007

Clancy, Jerry (2007) *personal communication*, www.biolytix.com

(DEC) Department of Environment and Conservation NSW (2001), *Managing urban stormwater: harvesting and reuse*

Environmental Assessment (2006), various authors, http://www.cubproject.com.au/EnvironmentalAssessment.html

Quinn, R, Bannister, P, Munzinger, M and Bloomfield, C, (2006) *Water Efficiency Guide: Office and Public Buildings*, Department of the Environment and Heritage, Canberra

Sydney Water (2001), *Sydney Water's Submission for IPART's Review of the System Performance Standards*, January 2001

Patrick Troy, Darren Holloway and Bill Randolph (2005), *Water Use and the Built Environment: Patterns of Water Consumption in Sydney*, City Futures Research Centre, Research Paper No. 1, December 2005

5.1.6. Greenhouse Gas Emissions

AGO (2007), *Australia's National Greenhouse Accounts – National Inventory by Economic Sector*, Australian Greenhouse Office, Canberra

Australian Bureau of Statistics (2001) ABS census, http://www.abs.gov.au

Australian Bureau of Statistics (2006a) *Australian demographic statistics, March quarter 2006*, Cat. no. 3101.0, ABS ,Canberra.

Australian Bureau of Statistics (2007), *New South Wales in Focus, 2007,* Cat. No. 1338.1, ABS, Canberra

ABARE (2006)*, Fuel and Equipment Survey (FES),* Table A (including tables a and f feature revised data as of 19 July, 2006)
http://www.abareconomics.com/interactive/energy/excel.htm

NSW NGGI (2005) *New South Wales Greenhouse Gas Inventory,* 2005, pp 6,18-19

City of Sydney (2006a) *State of Environment Report 2006*
http://www.cityofsydney.nsw.gov.au/Council/documents/AnnualReport/20052006/06AR_StateOfEnvrnmt.pdf

City of Sydney (2006b) *City of Sydney - Residential Monitor December 2006.* Issue No.39
http://www.cityofsydney.nsw.gov.au/AboutSydney/documents/cityresearch/Dec2006ResidentialMonitor.pdf

AFMA (2007) Australian Financial Markets Association – extract from Environmental Product Curve. http://www.afma.com.au

Australian Greenhouse Office (2003), *Comparison of Transport Fuels – Part 2 Details of Fuels – Premium Unleaded Petrol.*
http://www.greenhouse.gov.au/transport/comparison/pubs/2ch12.pdf

Australian Institute of Energy (2001), *Energy Value and Greenhouse Emission Factor of Selected Fuels*, http://www.aie.org.au/melb/material/resource/fuels.htm

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5.3. Key Data and Inputs

Some key check figures were obtained as below. Much of this knowledge is based on Lawson (1996) but updated subsequently in some cases where more recent or otherwise more reliable data was obtained by the Centre for Design at RMIT.

Building Material by Area	EE MJ/m²	GHGE kg CO_2/m^2	Water use Litres/m²
Concrete-in-situ	223	29.700	192.600
Concrete - suspended slab	296	49.700	384.000
Concrete slab on ground	381	37.500	221.500
Concrete panel	422	57.100	475.800
Glass curtain walling, single	1,039	87.400	338.400
Non-perimeter Walls, brick (non-residential)	432	49.300	95.100
Perimeter Walls, brick Double (non-residential)	836	95.400	132.700
External Wall Cladding, glass Curtain Walling (non-residential)	857	75.400	226.800
External Wall Cladding, concrete Block Light (non-residential)	689	63.200	260.900
External Wall Cladding, Fibre Cement (non-residential)	210	20.500	90.100

Building Material by Mass	MJ/kg	kg CO_2/kg	Litres/kg
20 MPa concrete, average, customisable / AU U[1]	0.51	0.070	1.200
25 MPa concrete, average, customisable / AU U	0.59	0.080	1.300
Steel sheet, 5% recycled/AU U	22.06	1.900	-0.300
Rolled steel, 10% recycled, structural applications/AU U	25.18	2.070	-0.200
Electro arc steel, recycled / AU U	12.11	1.140	1.600
Aluminium, primary, including NPI[2] emission estimates / AU U	205.73	19.010	213.600
Pilkington Glass	12.60	0.890	2.200
Sawn Hardwood, mass allocation / AU U	2.17	0.490	1.100
Structural Pine, mass allocation, u=12%[3] / AU U	8.42	0.230	0.200

Table 28 Embodied Energy, GHG and Water Indicators for Key Building Materials (Source: RMIT)

[1] AU U means Australian data, unit processing
[2] NPI means National Pollution Inventory
[3] u = moisture content

5.4. Commercial and Retail BCA Benchmarks

5.4.1. Commercial Spaces

The table below shows the maximum allowable annual energy consumption (BCA, 2007) for Class 5 buildings (offices). This is a value based on standard occupancy hours and includes lighting, heating, cooling and ventilation. These figures have been adopted for estimation purposes as, although the actual project might exceed the minimum efficiency permitted by the BCA, allowance must also be made for building mismanagement and for occupancies which exceed the standard 2,500 hours per year (standard office hours allowing for flexible working hours for start and end times).

Location	Heating Method	
	Gas, Oil	Electric
Sydney City	670	590

Table 29 Annual Energy Consumption Allowance (MJ/m) (BCA, 2007)

Of the total 92,738 m² GFA allocated to non-residential use, 88.7% comprises commercial office space. This amounts to a total commercial office GFA of 82,259 m². Based on the aforementioned BCA requirements the maximum annual energy consumption for the combined commercial office space on the CUB site is equal to 55,000 GJ using gas or oil heating, or 48,500 GJ using electric reverse cycle heating systems. Internal plug-in items like desk top computers and copiers are included in the BCA allowances cited above.

In addition to this, it is estimated that another, say, 2,000 GJ will be used annually for external purposes like security lighting and advertising displays.

The effective efficiency implied under the Commitment (in Subject 11. Environmentally Sustainable Design) to achieve "5 star greenhouse level" in compliance with the Australian Building Greenhouse Rating Scheme (ABGRS) is far greater than this and is expressed as 133 $kgCO_2$-e/m², or approximately 9,870 t for 74,190 m^2 of NLA floor space, and is hence discussed in Sections 3.4 and 3.5.

5.4.2. Retail Spaces

The table below shows the maximum allowable annual energy consumption for a Class 6 building (shop or shopping center).

Location	Heating Method	
	Gas, Oil	Electric
Sydney City	1,120	990

Table 30 Annual Energy Consumption Allowance (MJ/m²) (BCA, 2007)

The total GFA allocated to retail floor space amounts to 11,129 m² or 12% of the total non-residential GFA. Based on the BCA guidelines for Class 6 buildings the maximum allowable annual energy consumption for the combined retail space on the CUB site is equal to 12,500 GJ using gas or oil heating, or 11,000 GJ using electric reverse cycle heating systems.

Glossary of Terms

Abatement
The reduction of greenhouse gases

Adaptation Measures
Action in response to, or anticipation of, climate change to reduce or avoid adverse consequences or to take advantage of beneficial changes.

Alternative Fuels
Fuels which are less greenhouse intensive than petrol and diesel, for example, ethanol.

Anthropogenic
Caused by human activity; in relation to climate change it describes greenhouse gas emissions resulting from human activities.

Base Year
The reference year (i.e. starting year) from which all emissions baseline projections are initiated.

BASIX
The Building Sustainability Index applies in NSW and aims to ensure homes are designed to use less potable water and be responsible for fewer greenhouse gas emissions by setting energy and water reduction targets for houses, units and (more recently) apartments.

Biodiversity
The variety of all life forms – the different plants, animals and microorganisms, the genes they contain and the ecosystems of which they form a component.

Biomass
The total dry organic matter or stored energy content of living organisms. Biomass can be used directly by burning it (e.g wood), indirectly by fermentation to an alcohol (e.g sugar) or extraction of combustible oils (e.g soybeans).

Black Water
Any waste water stream which includes human excrement. Generally it refers to residential waste water without the grey water component.

Carbon Dioxide Equivalent
The basis for comparing the warming potential of greenhouse gases as compared to carbon dioxide. It is calculated by multiplying the quantity of a greenhouse gas by its global warming potential.

Carbon Sequestration
The long term storage of carbon or carbon dioxide in forests, soils, oceans, or underground in depleted oil and gas reservoirs, coal seams and saline aquifers

Carbon Sink

Natural or man-made systems that absorb carbon dioxide from the atmosphere and store it. Trees, soils and oceans all absorb CO_2 and therefore are carbon sinks.

Clean Development Mechanism
Projects are those undertaken in developing countries by investors from industrialised nations that limit or reduce greenhouse gas emissions.

Cleaner Production
The continuous application of an integrated preventative environmental strategy to processes, products and services that increase efficiency and reduce risks to humans and the environment.

Cogeneration
Generation of electricity combined with the production of heat for commercial or industrial use. Excess electricity produced can be fed back into the power grid. Cogeneration is an energy efficient way of using fossil fuels.

Combined Cycle
Electricity generation where the waste heat of a gas-turbine generator is used to heat water in a boiler to drive a steam-turbine generator, thereby increasing efficiency.

Demand-Side Management
The active pursuit of changing market behaviour regarding the use of energy to permanently or temporarily effect the hourly pattern of energy consumption resulting in an improved economic utilisation of energy generation, transmission and distribution resources.

Displacement
Abatement achieved when a different, less emissions intense activity is substitutes for a current or proposed activity, thereby displacing the emissions of the current or proposed activity.

Distribution
In relation to electricity, refers to low voltage assets for electricity transportation.

Emissions Factor
Time series data about the mass of a greenhouse gas emitted per unit of activity. For example: the mass of carbon dioxide emitted per vehicle kilometres travelled. This is also known as greenhouse intensity. In general, emissions are calculated by multiplying activity levels by their associated emissions factors.

Energy Efficiency
Ratio of energy output of a conversion process or of a system to its energy input.

Enhanced Greenhouse Effect
Changes in the earth's climate as a result of increasing levels of greenhouse gases in the atmosphere due to human activity.

Fossil Fuels

Coal, natural gas, liquefied petroleum gas, and fuels derived from crude oil (including petrol and diesel). They are called fossil fuels because they have formed over long periods of time from ancient organic matter.

Fuel Switching
Supplying energy services using different fuels. Often used to refer to actions that reduce CO_2 emissions from electric utilities by switching from coal to natural gas.

Fugitive Emissions
These emissions are not fully controlled, but in most cases are not accidental. Examples of fugitive emissions are leaks from gas pipelines and valves, venting and flaring of gases, methane emissions from coal seams, and vapour given off by petroleum stores.

Gas Absorption Chillers
The process of using a fossil fuel engine to drive a cooling machine to produce chilled water.

Global Warming Potential
A time dependent index used to compare the radiative forcing, on a mass basis, of an impulse of a specific greenhouse gas relative to that of CO_2. Gases in the Kyoto Protocol are weighted according to their GWP over a 100-year time horizon. According to that weighting, a kilogram of methane for example, has a radiative force of about 21 times greater than that of a kilogram of CO_2.. The GWP of CO_2 is defined as 1, thus methane has a GWP of 21 over the 100-year time horizon.

Green Power
Electricity generated from a renewable source. A number of electricity retailers are now offering green power schemes to their customers.

Greenhouse Challenge
A cooperative agreements program established in 1995 to provide the opportunity for Australian industry to work with government to reduce greenhouse gas emissions through continuous improvements in energy efficiency.

Greenhouse Gases
Gases that affect the temperature of the earth's surface. They include water vapour, ozone, chloroflurocarbons, carbon dioxide, methane, and nitrous oxide. The last three gases are of particular concern as they take a long time to be removed from the atmosphere.

Greenhouse Intensity
An indication of the quantity or potency of the emissions resulting from a particular activity. It is often used to compare activities.

Grey Water
Wastewater free of human excrement and/or toxic materials. Generally it is harvested from showers, basins, kitchen and laundry (assuming benign detergents are used).

Hydro Electricity
The generation of electricity by the use of moving water to turn a turbine or generator.

Intergovernmental Panel on Climate Change
The IPCC was established in 1988 by the World Meteorological Organisation and the United Nations Environment Program. The IPCC carries out internationally coordinated assessments of the magnitude, timing and potential impacts of climate change, and also provides technical assessments of potential measures to mitigate the effects of climate change.

International Emissions Trading;
A market based approach to achieving environmental objectives that allows those countries reducing greenhouse gas emissions below their Kyoto limit to sell the excess reductions to offset emissions in that country.

Joint Implementation
Projects are those undertaken by investors in Annex 1 countries that limit or reduce greenhouse gas emissions or enhance sinks in other developed countries.

Kyoto Protocol
An international agreement reached in 1997 in Kyoto Japan, which extends the commitment of the United Nations Framework Convention on Climate Change. In particular, it sets targets for future emissions by each developed country.

Land Use Change
Includes land clearing, pasture improvement and emissions from prescribed burning and bush fires.

Passive Solar Energy
Energy derived indirectly from solar energy. For example, solar energy boils water that creates steam which drives a turbine which produces energy.

Renewables
Energy forms that never run out or can be replaced, unlike fossil fuels. This includes solar energy, wind, tidal, geothermal and ocean thermal power, and fuels derived from plants, such as ethanol derived from sugar cane.

Stationary Energy
Energy use associated with non-mobile end-uses.

Transmission
In relation to electricity, refers to high voltage assets for electricity transportation. Typically refers to transport inter-regional or inter-state.

Sinks
Any process or activity or mechanism that removes a greenhouse gas or a precursor from the atmosphere.

Glossary of Acronyms

ABCB	Australian Building Codes Board
ABGR	Australian Building Greenhouse Rating
AGO	Australian Greenhouse Office
ATO	Australian Taxation Office
BCA	Business Council of Australia
BCA	Building Code of Australia
CBD	central business district
CCP	Cities for Climate Protection
CNG	compressed natural gas
COAG	Council of Australian Governments
CRC	Cooperative Research Centre
CSIRO	Commonwealth Scientific and Industrial Research Organisation
EPA	Environmental Protection Authority
FPC	Forests Products Commission
GDP	Gross domestic product
GFA	gross floor area (defined by the ABCB's BCA)
GHG	greenhouse gas
HIA	Housing Industry Association
IPCC	Inter-Government Panel on Climate Change
LNG	Liquid natural gas
LPG	Liquefied petroleum gas
LUC&F	Land use change and forestry
MBA	Master Builders Association
MEPS	Minimum Energy Performance Standards
NAEEEC	National Appliance and Equipment Energy Efficiency Committee
NAP	National Action Plan for Salinity and Water Quality
NatHERS	Nationwide House and Energy Rating Scheme
NGGI	National Greenhouse Gas Inventory
NGPASG	National Green Power Accreditation Steering Group
NGS	National Greenhouse Strategy
NLA	nett lettable area (defined by the PCA)
NRM	Natural resource management
PATHE	Partnership Advancing the Housing Sector
PCA	Property Council of Australia
ppm	parts per million
TDM	Travel demand management
UNFCCC	United Nations Framework Convention on Climate Change

Powers of 10

Prefix	Symbol	Value	Example	Symbol
kilo	k	10^{3}	kilowatt	kW
mega	M	10^{6}	megawatt	MW
giga	G	10^{9}	gigajoule	GJ
tera	T	10^{12}	terawatt-hour	TWh
peta	P	10^{15}	petajoule	PJ