Melbourne City Council CH_2

Revised Building Energy Consumption

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Melbourne City Council

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design advice

passive systems

design analysis

low energy services

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EXECUTIVE SUMMARY

This report has been prepared by Advanced Environmental Concepts as part of the design process for CH_2, the new Melbourne City Council office building, which recognises the increasing concern for the environment through adopting Ecologically Sustainable Development (ESD) practices.

This report provides predicted energy consumption and carbon emission figures for the occupied CH_2 building by looking at both base building and tenant services. Detailed three dimensional thermal modelling, calculations and design criteria provided by Lincolne Scott, Melbourne have been used to calculate energy consumption.

Discussed in this report are important issues which make significant impacts on the building's energy consumption which include air conditioning design strategy, building materials, ambient and task lighting system, thin client technology and LCD monitors.

The findings of this report show that total building energy consumption is 371,437 kWh of electricity and 125,598 kWh (452,153 MJ) of gas which equates to 453,901 kg of CO_2 released into the atmosphere.

If the carbon neutral building objective is to be achieved, it can be recommended that:

- 27 hectares of trees (26,900 trees) be planted to offset the building's carbon emissions through the carbon dioxide absorption of vegetation, or
- energy from renewable sources be provided, eg from two 100kW wind turbines, to save 453,901 kg of CO_2 from entering the atmosphere

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1 INTRODUCTION

This report presents the approach and results to the predicted energy consumption and analysis of the new Melbourne City Council Offices. Energy consumption analysis will enable us to predict the amount of carbon emissions which will be generated as a result. This is of great importance to the environmentally sustainable design of this building which aims to neutralise carbon emissions.

The Approach section will explain the main aspects of building design which influence its energy consumption. The Analysis section will provide detailed design criteria used to calculate energy consumptions. These are shown in the Results section which will form the basis of the Conclusions and Recommendations section.

1.1 Modelling

In order to accurately assess the performance of each option, a detailed three dimensional models of the building has been created.

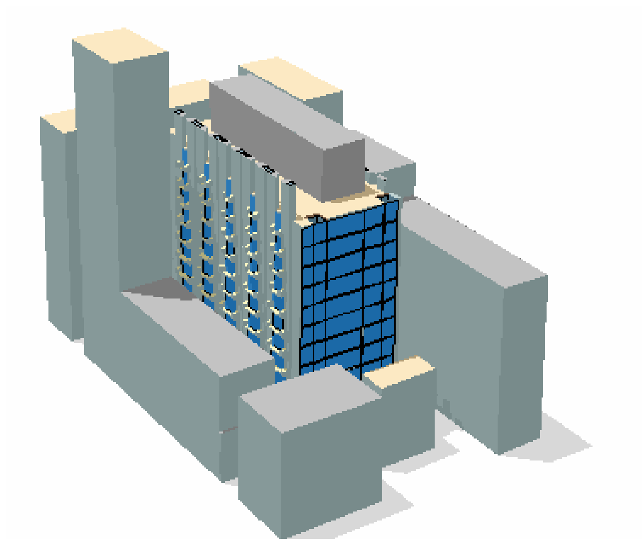

Figure 1. Three dimensional model used for thermal analysis

Described within the thermal model are geometry of building form and all associated exposure of surfaces, all material constructions, all internal diversified load profiles for people lights and equipment, and shadowing and overshadowing building effects. In accurately modelling the dynamic nature of the building's thermal response, hourly-recorded weather data is used in the simulation. Such weather data contains records of radiation, temperature, humidity, sunshine duration and additionally wind speed and direction.

1.2 Sources of Information

In the collation of this report the following sources of information were used:

1. Development Application drawings received from Design Inc current 10/08/03
2. Briefings and Discussions with the design team
3. ACADS BSG/CSIRO, Melbourne nominated TRY recorded weather data
4. "Evaluation Manual for Green Building in Taiwan", Architecture & Building Research Institute, Taiwan

1.3 Limitations

This study has been performed during the design phase of the project. Actual performance of the design will be dependant on the final implementation of the design.

2 APPROACH

This section will discuss some important aspects of base building design and tenant services which play a part in influencing energy consumption. These include:

- energy schematic
- building materials
- air conditioning design
- internal conditions, for example the use of thin client technology and LCD monitors

2.1 Base Building Energy Schematic

The figure below shows the energy schematic for CH2's base building services. The energy which the tenancy services use will come from the public electricity grid. It is the energy consumption of base building services, especially of the HVAC (heating ventilation and air conditioning) system which is unique.

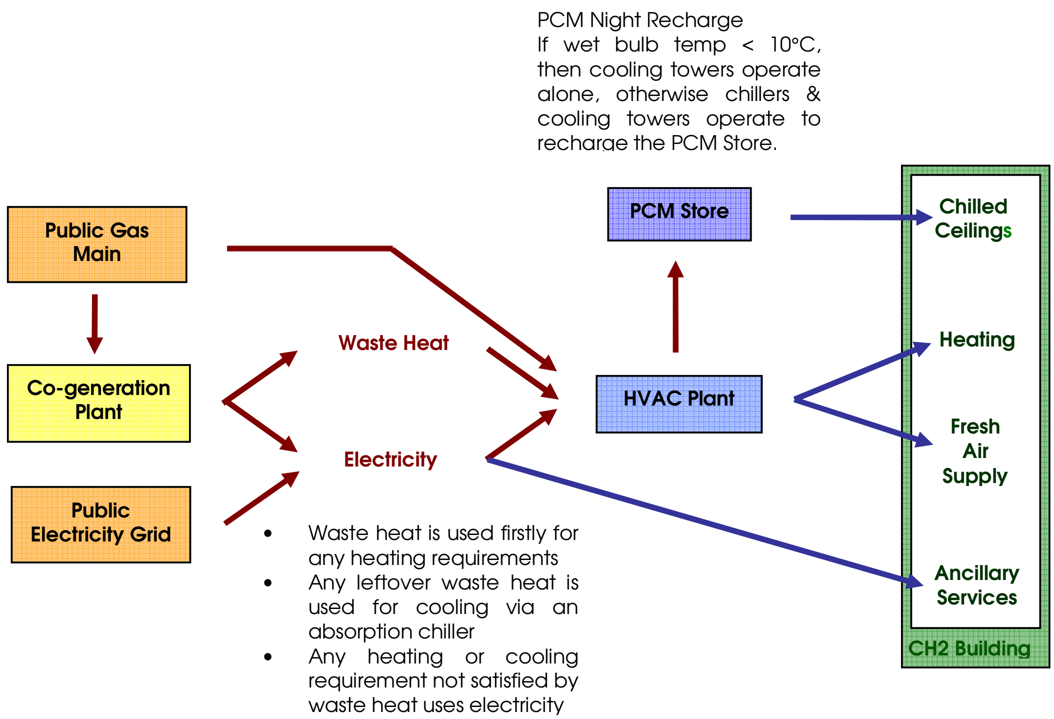

Figure 2. Base building energy schematic

2.2 Building materials

Building materials will not only influence a building's resistance to age and weather, but its behaviour and response to thermal mass, cooling, heating, internal gains, solar gains, dehumidification gains, etc.

Below is a simple diagram showing building elements used in the CH_2 model.

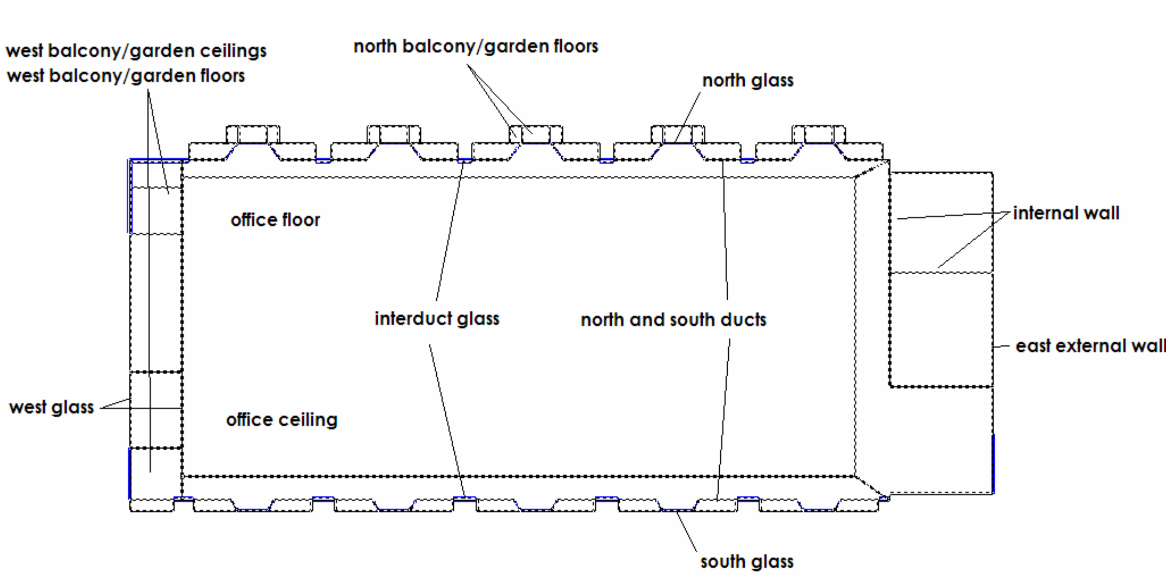

Figure 3. Building elements diagram

The following table describes building materials used during the construction of the 3D model.

Building Element	*Constructed description*
1. Wall - Internal	100mm partition stud wall - plasterboard both sides
2. Wall - External	75mm concrete filled steel/200mm solid concrete
3. Duct wall – office side	13mm plasterboard / 50mm insulation / 32mm plasterboard/ 39mm air / 25mm plasterboard
4. Duct wall – external	150mm conc
5. Wall - External	200mm solid conc / 75mm conc filled steel
6. Glass - South	6mm clear Le50 / 12mm air space / 6mm clear inner
7. Glass – North & East	6mm clear Le54 / 12mm air space / 6mm clear inner
8. Glass - West	6mm clear laminated
9. Ceiling – office	200mm conc / 550mm (averaged cavity) / 120mm conc

10. Ceiling-West balc/garden	45mm steel mesh / 150mm conc
11. Floor – raised office	7mm carpet / 35mm cement filled tiles / 250 cavity
12. Floor – West balc/garden	40mm paving / 150mm conc
13. Floor – North balc/garden	45mm steel mesh
14. Rooftop – timber deck	45mm timber / air cavity / 65mm polystyrene insulation / 195-315mm conc
15. Rooftop – landscaped	300mm lightweight soil / 65mm polystyrene insulation / 195-315mm conc
16. Rooftop – paving	40mm paving
17. Plant room roof	45mm steel sheet / 50mm insulation / 2mm wire mesh

Figure 4. Building element construction table

2.3 Air conditioning system design

The air conditioning system for the new Melbourne City Council is highly innovative and far exceeds traditional VAV (variable air volume) systems as it provides higher comfort levels, greatly reduces energy consumption and reduces carbon emission reductions by harnessing energy from more sustainable sources.

Air breathed by occupants is 100% fresh air from outside which does not get recirculated. The minimum fresh air requirements are at 22.5L/s/person, which is 3 times standard industry requirements.

The innovative design of the air conditioning system includes features such as:

- A night purge system where operable windows open at night to cool down daily heat gain
- Displacement ventilation where fresh air is supplied at floor level and exhausted at high level to enable the effective flushing out of contaminants by minimising mixing and significantly increasing indoor air quality
- Phase Change Material (PCM) filled spheres which acts as a thermal storage tank to provide cooling for the chilled ceilings
- A night time PCM recharge system where if wet bulb temperatures fall below 10°C, the cooling towers take advantage of the cold night air and recharge the PCM tank alone. On warmer nights when wet bulb temperatures are above 10°C,

electric chillers, cooling towers and shower towers will be used to recharge the energy lost from the previous day's cooling

- The generation of electricity and waste heat by gas fired cogeneration which is used by the base building and the air conditioning plant
- The use of gas fired boiler and electric screw chillers to handle the remainder of heating and cooling loads after waste heated collected from cogeneration has been utilised firstly for heating, and then for cooling via an absorption chiller

2.3.1 Air conditioning design parameters

The air conditioning plant will operate from 7am – 6pm.

Different zones will have different design parameters detailed in the following table.

	Design Temperature °C	*Cooling*	*Heating*	*Infiltration air (ach)*	*Radiant proportions*
Centre zones	20.0 – 25.0	Fixed at 12kW per floor	None	0.001	Heating: 0.4 Cooling: 0.4
Perimeter zones	20.0 – 25.0	Sized	Sized	0.50	Heating: 0 Cooling: 0.1

Figure 5. Air conditioning design parameters

2.3.2 Zones

Air conditioning design is based on zones because different zones have different cooling requirements depending on their location.

The following diagram shows the zone layout in the new Melbourne City Council building.

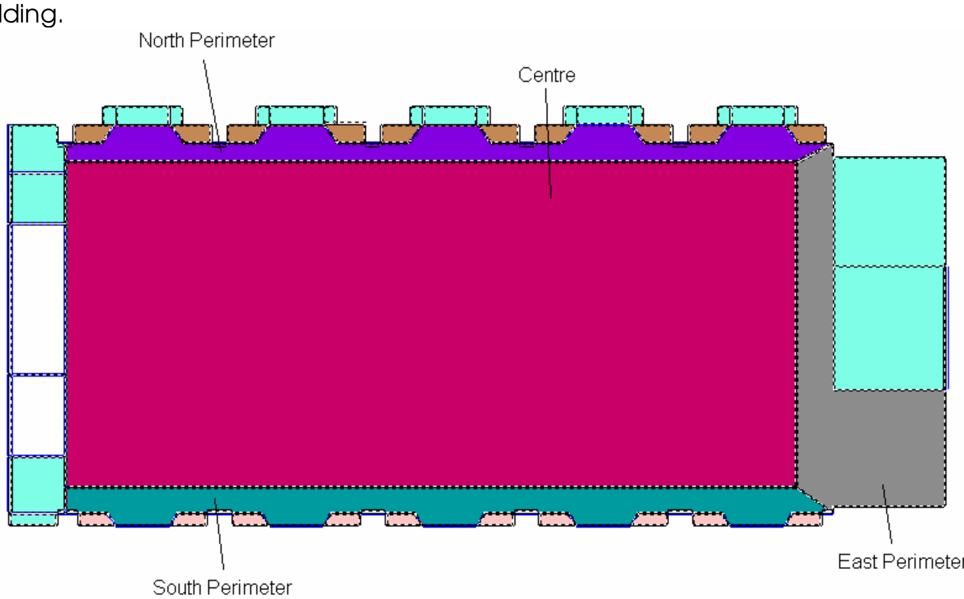

Figure 6. Zone Layout

The perimeter zones protect the centre zone from the external environment. Notice that there is no West Perimeter because on the West, a zone consisting of lifts, stairs and balconies isolate the centre from the external environment.

The relationship between zones and conditions can be summarised as follows:

- Centre zones – subject only to internal conditions with fixed, sized loads
- Perimeter zones - subject to both internal and external conditions with unfixed sized loads

2.4 Internal Conditions

The internal conditions of a building come from lighting, equipment and occupants. They cause heat gain and create the need for space cooling loads.

A more detailed description of internal conditions can be viewed in the following Analysis section,

2.4.1 Lighting

The system adopted here for office lighting consists of low level ambient floor lighting and individual task lighting ie desk lamps. The ambient lighting will provide 150 Lux levels at floor level around workspaces whilst task lighting will provide sufficient lighting for office work.

The advantages of this system are that:

- It allows more occupant control of workspaces
- It allows maximum usage of daylight throughout the office area
- It consumes much less energy than the traditional system of only fixed ceiling lighting

2.4.2 Occupants

Building design incorporates workspaces of 14m² per person which allows room for approximately 60 people per floor. Each person is assumed to be seated doing light work and provides 67.5W in both sensible and latent internal loads.

2.4.3 Equipment

The adoption of LCD monitors and thin client technology for the personal computing requirements of occupants has made a drastic impact on internal loads.

Thin client technology eliminates the need for a CPU at each workstation as it is replaced by a desktop device which allows connection to a large, shared, and powerful central computer/server.

Traditionally, each workstation would be equipped with its own 85W computer CPU (central processing unit) and 80W CRT screen. This set up consumes 165 Watts per hour, per person. This will now be replaced by a 38W system where an 8W thin client desktop device uses a 30W LCD flat screen monitor.

165 Watts 38 Watts

Figure 7. Traditional personal computers vs thin client + LCD monitors

Advantages to adopting this thin client and LCD system include:

- A 60% decrease in internal building loads
- Significantly large reduction in building cooling requirements
- Significantly large decreases in energy consumption
- Significantly large reductions in carbon emissions
- Increased in workspace/office areas
- Lower costs of ownership and maintenance
- Ease of upgrades and maintenance procedures – applications and data are centrally maintained
- Reduced cost per user
- No desktop CPU eliminates the CPU fan which means less noise, dust and moving parts.
- Increase workspace flexibility - workstations are not CPU dependent

2.4.4 Occupancy Profile

These calculated internal conditions were then applied to the occupancy profiles recommended by the Australian Greenhouse Rating Scheme to produce the following occupancy profile:

Hours	*Infiltration Air (ach)*	*Lighting Load*	*Equipment Load*	*Occupant Load - Latent*	*Occupant Load - Sensible*
	All loads are in W/m²				
1 – 7	Centre = 0.001 Perims = 0.50	0.25	2.16	0	0
7 – 8		2.5	2.808	0.72	0.72
8 – 9		5	3.456	2.88	2.88
9 – 17		5	4.32	4.8	4.8
17 – 18		5	3.456	2.4	2.4
18 – 19		1.25	2.808	0.72	0.72
19 – 21		0.75	2.376	0.24	0.24
21 - 24		0.25	2.16	0	0

Figure 8. Internal Loads Occupancy Profile

3 ANALYSIS

The energy consumption of the building, which impacts on its carbon emissions comprise of the energy consumption of:

- base building services
- tenant services

Base building services are described as building services which are common to tenants such as air conditioning, lifts and common area lighting. Tenant services refer to services under the control of the tenant such as workspace lighting and office equipment.

The data used to calculate both base building and tenant services will be detailed in this section.

3.1 Electricity from Cogeneration

Electricity will be produced on site via a gas fired co-generation plant which will turn on during plant hours ie 8am to 6pm.

Based on co-generation plant specifications, 255 kWh of gas input produces:
- 60 kW of electricity, and
- 100 kW of waste heat

If the greenhouse gas emissions produced by using Melbourne gas from the public network (which has a co-efficient of 0.21, source ABGR) is reflected in the electricity produced, not in the waste heat, then:

> *The greenhouse gas co-efficient of electricity from this co-generation plant is 0.89*

This electricity generation will be completely consumed by base building services. The waste heat produced will be used in the air conditioning plant directly for heating and/or cooling, via an absorption chiller.

Annually 60kW x 10 plant hours x 5 working days x 50 working weeks produces 156,000kWh of electricity. Therefore 156,000 kWh of electricity consumed by base building services will come from electricity co-generation (with a greenhouse gas co-efficient of 0.89), and the remainder of electricity needed will come from the public electricity network (with a greenhouse gas co-efficient of 1.34).

3.2 Base Building Energy Consumption

The following table is a breakdown of base building services.

BASE BUILDING ENERGY CONSUMPTION		Electric (kWh)	Gas (kWh)
Air conditioning		60,958	118,518
Ancillary services	Domestic hot water - solar	0	7,080
	Multi-Water Reuse Plant	22,643	0
	Lifts	34.859	0
	Lighting	3,331	0
	Mechanical ventilation	77,402	0
	Computer room cooling	43,800	0
	TOTALS	242,993	125,598

Figure 9. Base building energy consumption breakdown

The base building energy consumption can also be viewed in proportions graphically:

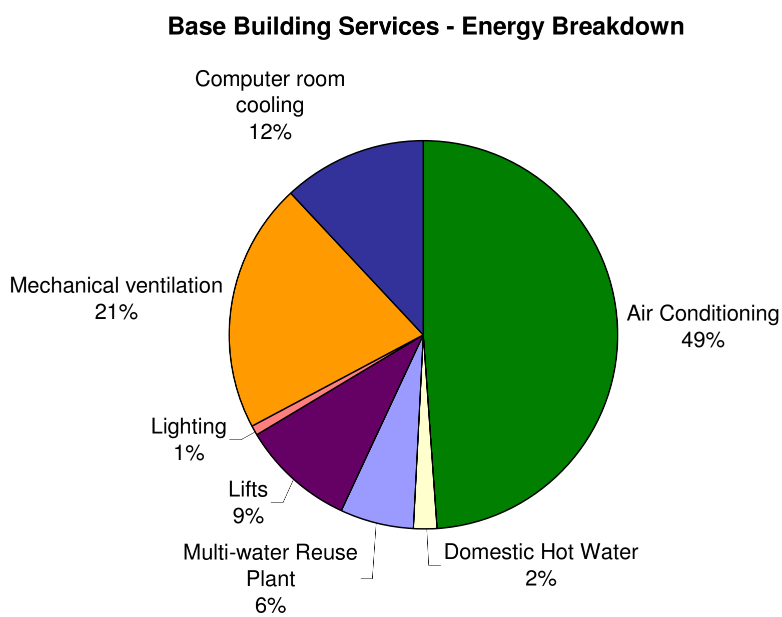

Figure 10. Base building - proportional energy consumption chart

3.2.1 Base Building Design Criteria

The following table details how calculations were carried out for the base building.

Base Building	*Energy Consumption (kWh)*		*Design Criteria NLA = 7488m²*
	Elec	*Gas*	
Air conditioning Services			
A/C	60,958	118,518	• Operating 7am – 6pm, 5 days/week • Based on detailed thermal modelling
Ancillary Services			
DOMESTIC HOT WATER	0	7,080	• Operating 7am – 6pm, 5 days/week • Solar gas boosted values obtained from AEC's Solar Renewable Energy Report where solar contributes to 75% of water heating
MULTI-WATER REUSE PLANT	22,643	0	• Operating 7am – 6pm, 5 days/week • Values provided by Lincolne Scott, Melbourne
LIFTS Lift operation Lift cooling	 34,700 159	 0 0	• 3 public lifts at 8,400kWh, 1 goods lift at 9,500 p.a. • Operating 7am – 6pm, 5 days/week • Values provided by Transportation Design Consultants and Lincolne Scott, Melbourne
LIGHTING Common area lighting Car park lighting	 2,250 1,081	 0 0	• Operating 7am – 6pm, 5 days/week • Assumed area of 135m² per floor • Values provided by Lincolne Scott, Melbourne at 4W/m²
MECHANICAL VENTILATION Common area ventilation Car park ventilation Toilet ventilation	 31,034 40,076 6,292	 0 0 0	• Operating 7am – 6pm, 5 days/week • Car park values modified by AEC using car park usage profile. See below • Toilet exhaust only for mezzanine levels as all other levels use natural ventilation • Values provided by Lincolne Scott, Melb
COMPUTER ROOM COOLING	43,800	0	• Operating 24 hrs, 365 days • Estimation based on values provided by Lincolne Scott, Melbourne: 24kW plant with COP = 5

Figure 11. Base building design criteria

3.3 Tenancy Services Energy Consumption

The following is a breakdown of tenant services.

TENANCY SERVICES BUILDING CONSUMPTION	Electric (kWh)	Gas (kWh)
Shared office equipment	28,710	0
Personal computing	58,320	0
Lighting	41,414	0
TOTALS	128,444	0

Figure 12. Tenant services energy consumption breakdown

This can also be viewed proportionally:

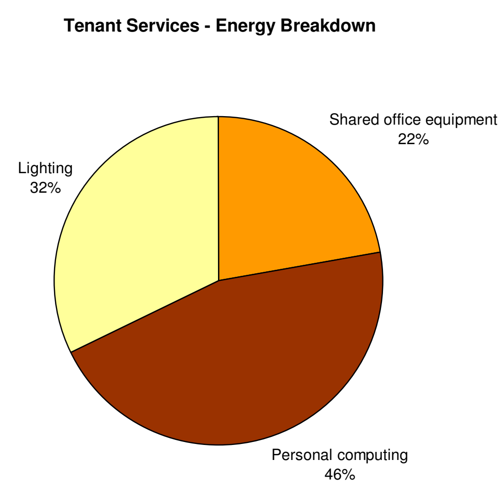

Figure 13. Tenant services - proportional energy consumption

3.3.1 Tenancy Services Design Criteria

The following table details how calculations were made for the energy consumption of tenant services.

<table>
<tr><th rowspan="2">Tenancy</th><th colspan="2">Energy Consumption (kWh)</th><th rowspan="2">Design Criteria</th></tr>
<tr><th>Elec</th><th>Gas</th></tr>
<tr><td colspan="3"></td><td>General design criteria:
• Total Net Lettable Area = 7488. NB This NLA is only used for thermal modelling as it corresponds with the 3D model
• Working week is 5 days
• Working year is 50 weeks
• Working hours are 9am – 5pm (8 hours)
• 1 person per 14m² workspace
• 60 people per floor maximum</td></tr>
<tr><td>OFFICE EQUIPMENT</td><td>28,710</td><td>0</td><td>• Values calculated using Australian Greenhouse Office energy calculator for conventional (non energy star) equipment; 4 printers, 2 fax machines, 2 copiers for business use
• Calculates to 1.61 W/m² during office hours, 0.8W/m² during non-office hours</td></tr>
<tr><td>PERSONAL COMPUTING</td><td>41,040 (office hours)
17,280 (non-office hours)</td><td>0</td><td>• Use of thin client system with LCD monitor
• Values taken from Wyse Thin Client Energy Consumption Study
• In use 8 hrs/day
• Energy usage per unit: 38W in use (30W for monitor), 5W standby (only for monitor)
• Calculates to 2.71W/m² when in use, and 0.36W/m² standby
★If monitors are switched off instead of in standby mode, there would be no energy consumption for personal computing during non-office hours.</td></tr>
<tr><td>LIGHTING
Ambient lighting
Task lighting
Additional feature lighting</td><td>
30,670
9,304
1,440</td><td>0</td><td>• Values approved by Lincolne Scott, Melb
• Ambient lighting - use of 6 single 14W T5 lamps per 4 x 8.2m² area grid which provides 150 Lux
• Ambient lighting - on for 8 hours per day with 20% reduction in usage due to daylight sensors
• Task lighting – use of 10W compact fluorescents per desk,
• Task lighting - on for 7 hours/day
• Calculates to 2.56W/m² for ambient lighting, 0.71W/m² task lighting, 1.73 W/m² for additional feature lighting</td></tr>
</table>

Figure 14. Tenant services design criteria

4 RESULTS

Energy consumption figures will use kilowatt hours (kWh) of energy which can then be translated into kilograms (kg) of carbon dioxide emissions using greenhouse gas co-efficients.

The last section will show how carbon emissions can be offset through using vegetation – keeping in mind that the objective of this building is to be carbon neutral.

4.1 Building Energy Consumption

The following table provides total building energy consumption which consists of base building and tenant services.

BUILDING ENERGY CONSUMPTION	Electric (kWh)	Gas (kWh)
Base Building Public Electricity Co-generation Electricity	**242,993** (86,993) (156,000)	**125,598**
Tenant Services	**128,444**	**0**
TOTAL	**371,437**	**125,598** **(452,153 MJ)**

Figure 15. Total building energy consumption summary

Viewed graphically:

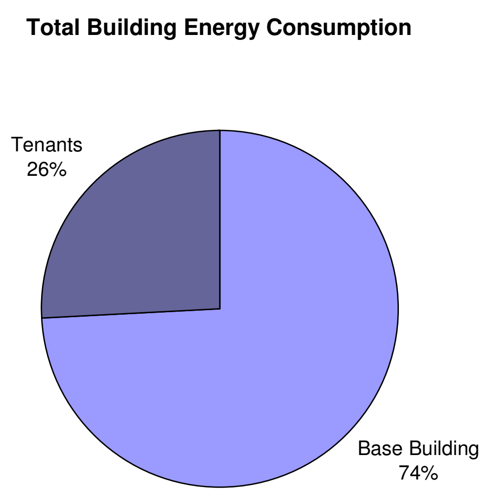

Figure 16. Total building energy consumption breakdown

4.2 Building Carbon Emissions

A breakdown of base building carbon emissions can be produced using co-efficients of 0.21 for gas, 0.89 for electricity from cogeneration, and 1.34 for electricity from the public network. The figure below shows the amount of carbon emissions that are produced through the building's energy consumption.

BUILDING CARBON EMISSIONS	Kg of CO_2
Electricity from Public Grid Electricity from Co-generation	288,686 138,840
Gas	26,375
TOTAL	453,901

Figure 17. Total building carbon emissions summary

Viewed graphically:

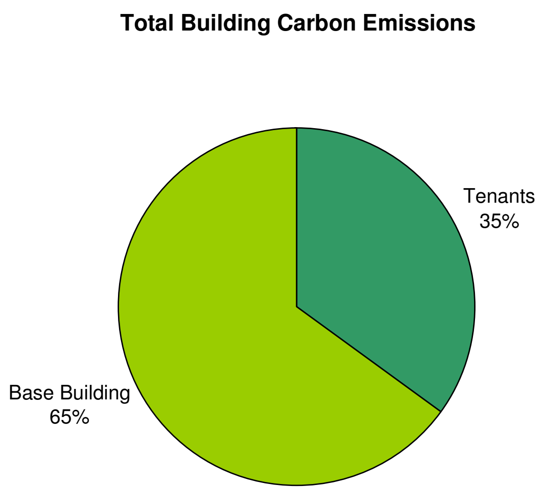

Figure 18. Total building carbon emission breakdown

Using a Net Lettable Area of 7488m², this equates to 60.6 kg CO_2/m^2 for CH_2 annually.

Using AGBR (Australian Greenhouse Building Rating) benchmarks:

- A 4.5 star building emits 197kg CO_2/m^2
- A 5 star building emits 170 kg/m²

Therefore, in comparison, carbon emissions for CH_2 far exceed best current practice.

4.3 Offsetting Carbon Emissions

The 453,901 kg of carbon emissions can be offset via several options:

1. Planting vegetation to absorb CO_2 from the atmosphere
2. Utilising sources of renewable energy which do not release CO_2

4.3.1 Vegetation

The following graph shows the CO_2 fixation amount of various plants over a 40 year period.

Kind of Plant	*CO_2 fixation amount (kg/m² over 40 years)*
*Tall bamboo (above 9m² per plant)	1090
*Short bamboo (above 6.25m² per plant)	724
Big trees with large leaves (above 9m² per tree, soil depth above 0.9m)	808
Small trees with large leaves, needle evergreens or trees with sparse leaves (above 6.25m² per tree, soil depth above 0.9m)	536
Big palm trees (above 6.25m² per tree, soil depth above 0.7m)	410
Shrubs (below 1m tall, soil depth above 0.4m)	217
Multiple year cultivating vines (stereo climbing area, soil depth above 0.25m)	82
Herbs, flowers or high stem wild grass (below 1m tall, soil depth above 0.25m)	46
Annual vines or low-stem grass (about 25cm tall, soil depth above 0.25m)	16
Meadow	0

Figure 19. CO_2 fixation amount of various plants over a 40 year period.
Source Evaluation Manual for Green Buildings in Taiwan, *Environmental Bamboo Foundation

It can be calculated how much vegetation is needed to offset 453,901 kg of CO_2 using the table above.

It can be estimated that existing vegetation absorbs 1,886 kg of CO_2 into the atmosphere annually. These calculations assumed that vines would grow in the North façade and shrubs would be planted on the vertical gardens, winter gardens and the rooftop. This leaves 452,015 kg of CO_2 left to absorb if the building were to reach its objective of becoming carbon neutral.

If it is assumed that one medium sized tree sequestrates 16.8 kg of CO_2 per year, and that the planting grid is 10m², then this calculates to the planting of approximately 26,900 trees, which takes up around 27 hectares of land.

4.3.2 Renewable Energy

The use of renewable energy from sustainable sources such as the sun or wind can also be considered in achieving zero carbon emissions for CH_2. For example, if Melbourne City Council decided to invest in the purchase of a wind turbine which saved 453,901 kg of CO_2 through its contribution of a clean energy source, the building could achieve its target of being carbon neutral.

Based on preliminary research into wind turbine feasibilities in the Melbourne area, ie wind speeds etc, a typical 660kW wind turbine produces over 1.5 million kWh of electricity annually. This saves 2.01 million kg of carbon emissions from entering the atmosphere which would otherwise be emitted by burning brown coal in Victoria.

5 CONCLUSIONS AND RECOMMENDATIONS

Based on analysis, it has been predicted that based on the design criteria mentioned in this report, the energy consumption of an occupied CH_2 building annually is:

- 371,437 kWh of electricity (156,000 kWh comes from co-generation)
- 125,598 kWh of gas (452,153 MJ)

This equates to 453,901 kg of CO_2 released into the atmosphere.

If the carbon neutral building objective is to be achieved, it can be recommended that:

- 27 hectares of trees (26,900 trees) be planted to offset the building's carbon emissions through the carbon dioxide absorption of vegetation, or
- energy from renewable sources be provided, eg from wind turbines, which would save 453,901 kg of CO_2 from entering the atmosphere.