Energy Efficiency Training and Information Project

Commercial Buildings

Wagga Wagga
NSW

Research group

High Performance Architecture research cluster, School of Built Environment, Faculty of Arts, Design and Architecture, UNSW

https://www.be.unsw.edu.au/research/research-clusters-and-groups/high-performance-architecture-research-cluster

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Cover image:
43-45 Johnston Street Wagga Wagga, NSW

Contents

1. Executive Summary

a case study to explore opportunities to reduce the

Wagga (NSW) built in the late 1950s, offering consistent opportunities for improving the energy performance.

The building was internally estimated NABERS Energy 3.5 star in October 2021, with 6% of energy supplied by green power, while going through renovations and HVAC&R commissioning. Due to the nature of this project, the energy consumption was fully investigated, while the on-site energy production (with renewable resources) was not evaluated.

as a case st dy to explore opportunities to reduce the electricity consumption (site energy). A dynamic thermal model of the building is simulated with TRNSys software, similar to the characteristics of the real

Based on the results, the following recommendations are technically viable and relatively easy to implement:

- Refurbishment of the windows, with new aluminium framed, double glazed ones, of high energy

  solar loads in summer and achieve airtightness throughout the year.

- Improvement of the lighting systems by installing

- Installation of ceiling fans to reduce cooling loads.

In conclusion, a complete renovation package is suggested that includes the drastic improvement of the building envelope's thermal protection by replacing the windows and glazed surfaces, upgrading the lighting system, and installing ceiling fans. The result indicates

condition, 24.0% of required electricity can be reduced, resulting in an energy consumption of 69.1 kWh/m²a. compared to the baseline of 90.9 kWh/m²a. Using NABERS Energy reversed calculator, if the building is

from 3.75 to 4.25 stars [16].

2. Regulations, Standards, and guidelines

The regulatory documents and Standards used for the

- National Construction Code of Australia 2019 Volume One.
- AS/NZS 1680.1-2006: Interior and workplace lighting, Part 1: General principals and recommendations.
- AS/NZS 1680.2.1-2008: Interior and workplace lighting, Part 1: Specific applications. Circulation spaces and other general areas.
- AS/NZS 1680.2.2-2008: Interior and workplace lighting, Part 1: Specific applications. Office and screen-based tasks.
- ANSI/ASHRAE 62.1-2019 Ventilation for acceptable indoor air quality
- ANSI/ASHRAE 55-2020 Thermal environmental conditions for human occupancy
- ASHRAE Handbook Fundamentals 2017, Chapter 18: Non-residential cooling and heating load calculation
- ISO 17772-1-2017 Energy performance of buildings -Indoor environmental quality, Part 1: Indoor environmental input parameters for the design and assessment of energy performance of buildings
- AS 1668.2-2012 The use of ventilation and air conditioning in buildings, Part 2: Mechanical ventilation in buildings

3. Introduction

Global climate change is exposing existing buildings to conditions they were not designed to face, with a

operational cost and carbon dioxide emissions. To meet these goals, established buildings need energy

today [1], and we must prioritise the improvement of

The largest fraction of the energy consumption in an

ventilation, air conditioning and refrigeration (HVAC&R) applications, lighting, and appliances [2]. This report tackles the operational energy consumption challenge

4. Office Building in Wagga Wagga

4.1. Case study description

4.1.1. Climate

The case study building is located at 43-45 Johnston Street, Wagga Wagga NSW 2650 (-35.106S, 147.369E). Wagga Wagga is in the southern part of New South Wales and is 183 m above mean sea level. The climate is mild and generally warm and temperate. Wagga Wagga has an annual mean rainfall of 572 mm and median rainfall of 575 mm, distributed relatively equally over the entire year. Maximum temperatures in summer are warm averaging between 29 °C and 32 °C. Relative humidity, however, remains low in the summer months, with a 3 pm average of about 30%. The winters are cool to cold, with overnight minimums averaging 3°C and daily maximums climbing to only 12 °C to 14°C on average. Relative humidity is much higher in winter, with a 3 pm average of over 60% and a 9 pm average just below 90%. Frost and fog are a feature of Wagga Wagga in winter. Snow has been recorded in the area but is a very rare occurrence. The major climatic information of Wagga Wagga is illustrated in Figure 1.

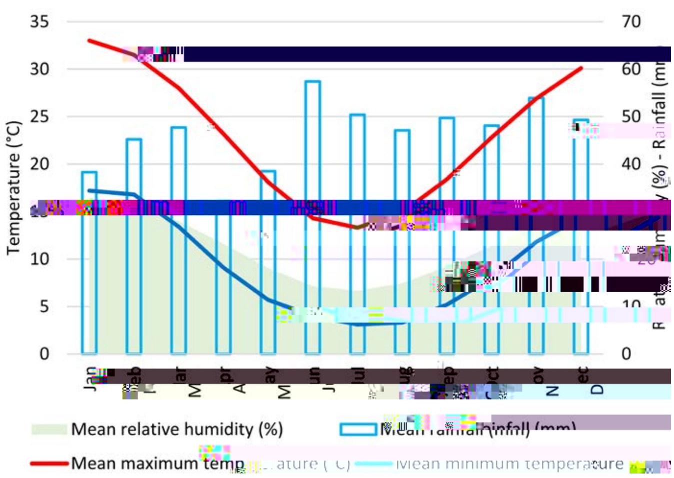

Figure 1. Climatic data of Wagga Wagga.

4.1.2. Building description

The building was constructed in 1959 (Figure 2) and

the Building Code of Australia [2].

Currently, three tenants occupy two levels of the building. NSW Fire and Rescue (Northern side) and NSW Education Standards Authority (Southern part) have leased level 1. Also, the NSW Department of Public Prosecutions occupies level 4. Figure 3 illustrates the treemap chart of the gross internal area of the case

and the net lettable area is 2178 m².

4.1.3. NABERS rating

in October 2021. Based on the NABERS database, this building energy performance is categorised between 'Average' and 'Good'. Rooftop photovoltaic panels provide 6% of the site energy needs, and the building annual greenhouse gas emissions are equal to 170,258 kg CO (183.9 kg CO /m²). Also, the NABERS Water rating of this building is 3.5 [3].

replacement of the old HVAC&R systems with newer

performed considering the new system with improved performance. ➔

Figure 2. South-western view of 43-45 Johnston Street.

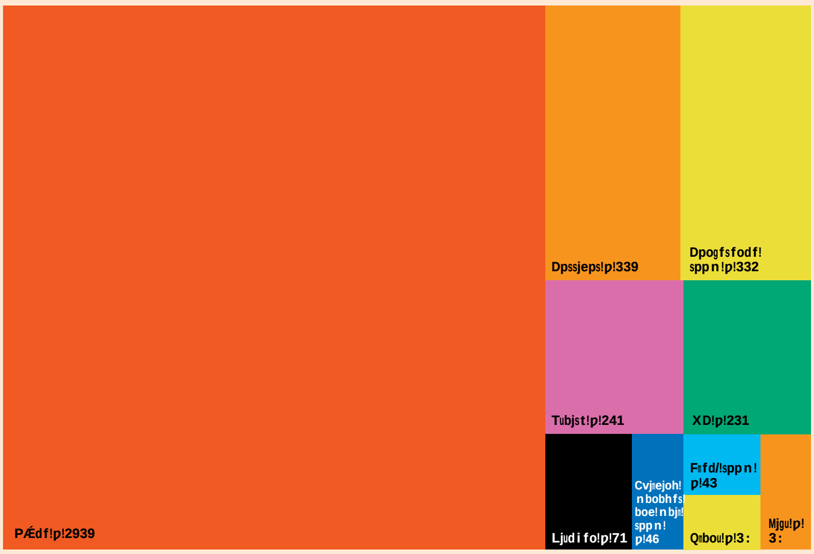

Figure 3. Gross floor divided area of case study building.

4.1.4. Energy consumption and sources

The best way to decrease the operational cost of

4.2.3. Building Components

envelope. As a key step in assessing the potential

the current thermal performance should be determined.

the thermal properties of the building envelope based on age and construction. This information is used to model the building and develop a thermal model. In this section, the performance descriptors of external walls, roof and windows are introduced.

4.2.3.1. External walls

The external wall is a double brick cavity wall with R-value equal to 0.63 m².K/W.

Nbufsjbm	Uijdloftt!)nn*	Uifsnbm! Dpoevdujwjuz!)X0n/L*	Uifsnbm! Dbqbdjuz!)lK0lh/L*	Efotjuz!)lh0n³*	Uifsnbm! Sftjtubodf!)n²/L0X*	Sfg/	Tfdujpo!boe!qbhf
Brick	110	0.78	0.8	1950	0.14	[4]	Section J, page 389
Air space	50	-	-	-	0.18	[5]	Section 5.3, page 5
Brick	110	0.78	0.8	1950	0.14	[4]	Section J, page 389

R-value: 0.63 m².K/W

4.2.3.2. Roof

The roof has metal sheeting as the top layer,

medium density concrete inside, delivering an R-value of 0.54 m².K/W. →

Nbufsjbm	Uijdloftt!)nn*	Uifsnbm! Dpoevdujwjuz!)X0n/L*	Uifsnbm! Dbqbdjuz!)lK0lh/L*	Efotjuz!)lh0n³*	Uifsnbm!		

4.2.5. Ventilation and infiltration

The building's HVAC&R systems have been upgraded recently. Therefore, fresh air supplied to each zone is based on AS1668.2 [10]. Also, depending on the activity

4.2.6. Thermal comfort

The thermal comfort parameters are offered in Table 9. The thermal comfort metric used in this assessment is the PMV, in compliance with the National Construction Code.

4.2.7 Energy resources

The total energy demand of this building is provided by

for the case study building, 6% of the delivered energy is generated by 11 kWp rooftop PV (Figure 4) [3].

4.2.8 Schedules

The schedules of occupancy, lighting and appliances are selected based on those provided in the National Construction Code [4].

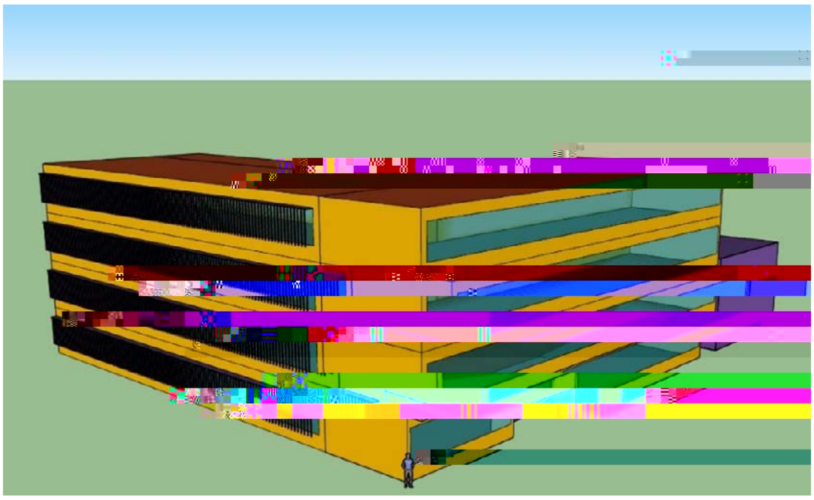

Figure 5. SketchUp model

(b) the microclimate on the building's site (shading by natural obstructions and other buildings, albedo and thermal storage of surrounding areas, existence of water surfaces, etc.).

Finally, a baseline or reference condition should be determined, against which the effectiveness of interventions can be evaluated.

This baseline condition cannot be straightforwardly derived from metered energy consumption since the

and microclimate conditions, as well as by the weather

the metered consumption values are real, they do not necessarily represent a base for an objective assessment. Therefore, the building must adopt standard reference conditions, as foreseen by national regulations and standards, which allow a good degree of replicability for the simulative calculations that allow a detailed breakdown of energy consumption by source and use and a reliable assessment of the improvements achieved by the interventions considered.

In this line of approach, all operational parameters for the baseline scenario were considered in accordance with national standards, regulations, and recommendations or in accordance with ASHRAE and ISO standards. Simulations were carried out on an hourly basis, hence resulting in a high temporal analysis, whilst the thermal zoning was based on the differentiation of thermal conditions.

This approach not only allows a reliable and cohesive

the outcomes as a pilot for further similar projects.

then their combined impact will be investigated.

5.3.1. Lighting retrofit

5.3.2. Windows retrofit

The current windows installed in the Wagga Wagga

The monthly energy balance of the building and the

presented in Figure 12.

6.3. Interventions proposed

Depending on the building typology, function and condition, there is a plethora of possible interventions which can be considered. Choosing the suitable ones is a challenging problem since they must be technically

must be underlined:

- The simulations proved that the natural lighting

  are lit to lower and some to higher lighting levels,

  scenario showed that by using the LED lighting

  the recommended, a reduction of energy consumption between 37.5 and 55.3% can be achieved.

-

6.4. Weather database investigation

The climatic data provided by TRNSys is limited (only 33 cities in Australia). To compare the external weather databases (CSIRO and EnergyPlus), modelled the building was simulated in three cities representing different climatic conditions in Australia. Table 15 compares the heating and cooling load in 3 different cities and two weather databases. Also, Figure 16 illustrates the result of site energy demand in different sectors.

The comparison shows an acceptable difference between weather databases. The CSIRO database is selected for further modelling based on the following

Table 15. Weather database comparison in different climates.

#	Mpdbujpo	Tpvsdf	Mpbe!)I X i0n²/b*		Tjuf!Fofshz!)I X i0n²/b*				
			I fbujoh	Cooling	I fbujoh	Cooling	Mjhiujoh	Bqqmjbodft	Total
1	Sydney	E+	12.4	44.7	3.2	13.7	23.7	43.1	83.7
2	Darwin	E+	0	153.1	0	46.7	23.7	43.1	113.6
3	Melbourne	E+	44.8	17.8	11.5	4.5	23.7	43.1	83.8
4	Sydney	CSIRO	13.2	54.7	3.4	16.8	23.7	43.1	87.0
5	Darwin	CSIRO	0	183.3	0	56.0	23.7	43.1	122.8
6	Melbourne	CSIRO	29.0	32.3	7.5	9.9	23.7	43.1	84.2

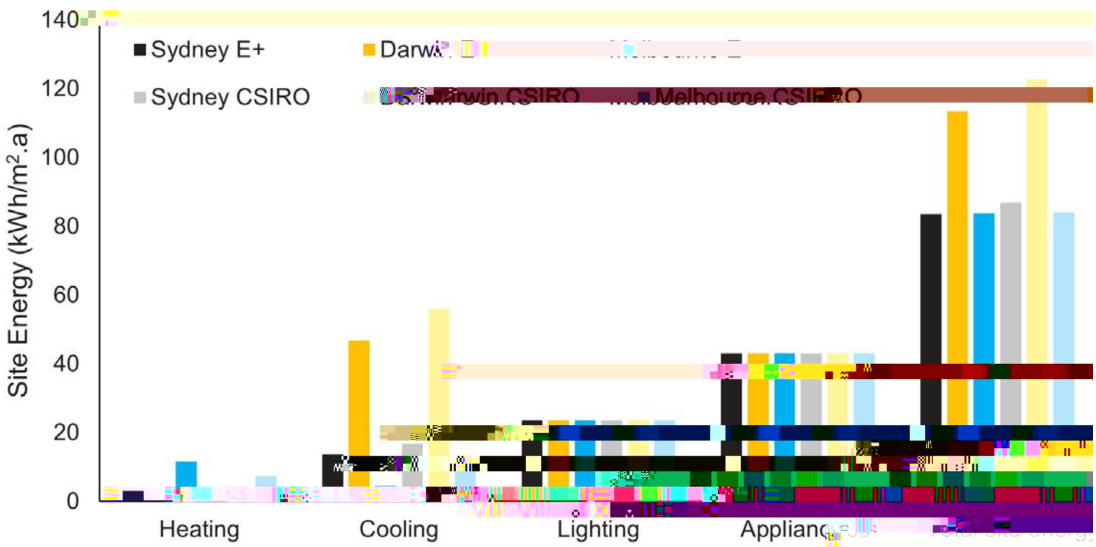

Figure 16. Site energy demand in different cities.

6.5. Future climate simulation

In this section, the modelled building is simulated with future weather data developed by CSIRO with climate change prediction models. Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases are called Representative Concentration Pathways (RCPs) [17]. The word representative indicates that each RCP provides one of radiative forcing characteristic. The term pathway denotes that not only the long-term concentration levels are of interest, but also the path taken over time to reach that outcome is important. RCP4.5 is selected as the future pathway to compare different cities. RCP4.5 is an intermediate condition in which radiative forcing is stabilised at approximately 4.5 W/m² after 2100.

Table 16 demonstrates the result of modelling the case study building with future CSIRO weather prediction models. The result indicates that in all RCP models, the cooling site energy will rise between 6.0%-23.5% by 2030. →

Table 16. Future CSIRO weather prediction model results.

		I fbujoh!tjuf! fofshz!	Dppmjoh!tjuf! fofshz!	Mjhiujoh!! tjuf!fofshz!	Bqqmjbodft!tjuf! fofshz!	Upubm!tjuf! fmfdusjdjuz!efnboe	Jodsfbtf!jo!upubm! dppmjoh!tjuf!fofshz!	Jodsfbtf!jo!upubm! ifbujoh!tjuf!fofshz!	Jodsfbtf!jo!upubm! fmfdusjdjuz!tjuf!fofshz!
Mpdbujpo	Qfsjpe	)IXi0n±*					&		
Adelaide	Present	5.4	15.2	20.0	43.1	83.7	-	-	-
	2030	4.4	17.6	20.0	43.1	85.1	15.8	-18.5	1.7
Brisbane	Present	1.2	26.5	20.0	43.1	90.8	-	-	-
	2030	0.8	29.2	20.0	43.1	93.1	10.2	-33.3	2.5
Canberra	Present	9.5	18.8	20.0	43.1	91.4	-	-	-
	2030	7.9	21.3	20.0	43.1	92.4	13.3	1.1	-16.8
Darwin	Present	0.0	55.2	20.0	43.1	118.3	-	-	-
	2030	0.0	58.5	20.0	43.1	121.6	6.0	0.0	2.8
Melbourne	Present	9.7	8.1	20.0	43.1	80.9	-	-	-
	2030	8.2	10.0	20.0	43.1	81.3	23.5	-15.5	0.5
Perth	Present	3.7	21.5	20.0	43.1	88.3	-	-	-
	2030	2.8	24.4	20.0	43.1	90.3	13.5	-24.3	2.3
Sydney	Present	2.8	17.5	20.0	43.1	83.4	-	-	-
	2030	2.1	19.6	20.0	43.1	84.8	12.0	-25.0	1.7
Hobart	Present	12.4	4.5	20.0	43.1	80.0	-	-	-
	2030	11.2	5.5	20.0	43.1	79.8	22.2	-9.7	-0.3

Table 17. The comparison between the base case and fully retrofitted scenario.

		Tqbdf!ifbujoh	Tqbdf!dppmjoh	Mjhiujoh!! tjuf!fofshz!	Bqqmjbodft!! tjuf!fofshz!	Upubm!tjuf! fmfdusjdjuz!efnboe	Jodsfbtf!jo!upubm! dppmjoh!tjuf!fofshz!	Jodsfbtf!jo!upubm! ifbujoh!tjuf!fofshz!	Jodsfbtf!jo!upubm! fmfdusjdjuz!tjuf!fofshz!
Mpdbujpo	Qfsjpe	)IXi0n±*					&		
Canberra Base case	Present	9.5	18.8	20.0	43.1	91.4	-	-	-
	2030	7.9	21.3	20.0	43.1	92.4	13.3	1.1	-16.8
Canberra	Present	4.7	11.3	10.3	43.1	69.4	-	-	-
	2030	3.8	12.9	10.3	43.1	70.1	14.2	1.0	-19.1

6.6. Concluding remarks

built in Wagga Wagga at the end of the 1950s was investigated. The building currently has performance equivalent to 3.5-star NABERS for energy (internal assessment); thus, there is a considerable margin for improvement. With the replacement of new high-

recovery and ceiling fans, and then insulation of the

is cooling-dominated, meaning that it needs more energy for cooling than for heating, already with the current

need, and it reduces the heat released by the lighting

cooling load. Then, the night ventilation allows for heat dissipation during the night by exploiting the thermal mass in the building and reducing the number of hours required for cooling. Then, the improvement of the roof insulation offers further savings.

The total savings account for 21.8 kWh/m² per annum or 24% of electricity consumption. The replacement can deliver further savings of appliances – which represent 62% of the site energy in the most comprehensive

reducing the plug loads. This is not considered in this study as it is not part of the building but of its use. Therefore, the on-site renewable energy production with rooftop PV can cover a larger fraction of the building's electricity consumption since the energy needs would be greatly reduced.

In future climates, the building electricity consumption for heating will be further reduced, becoming almost negligible, with an increasing cooling energy need, which then becomes the priority.

Using NABERS Energy reversed calculator, if the

can increase from 3.75 to 4.25 stars [16].

References

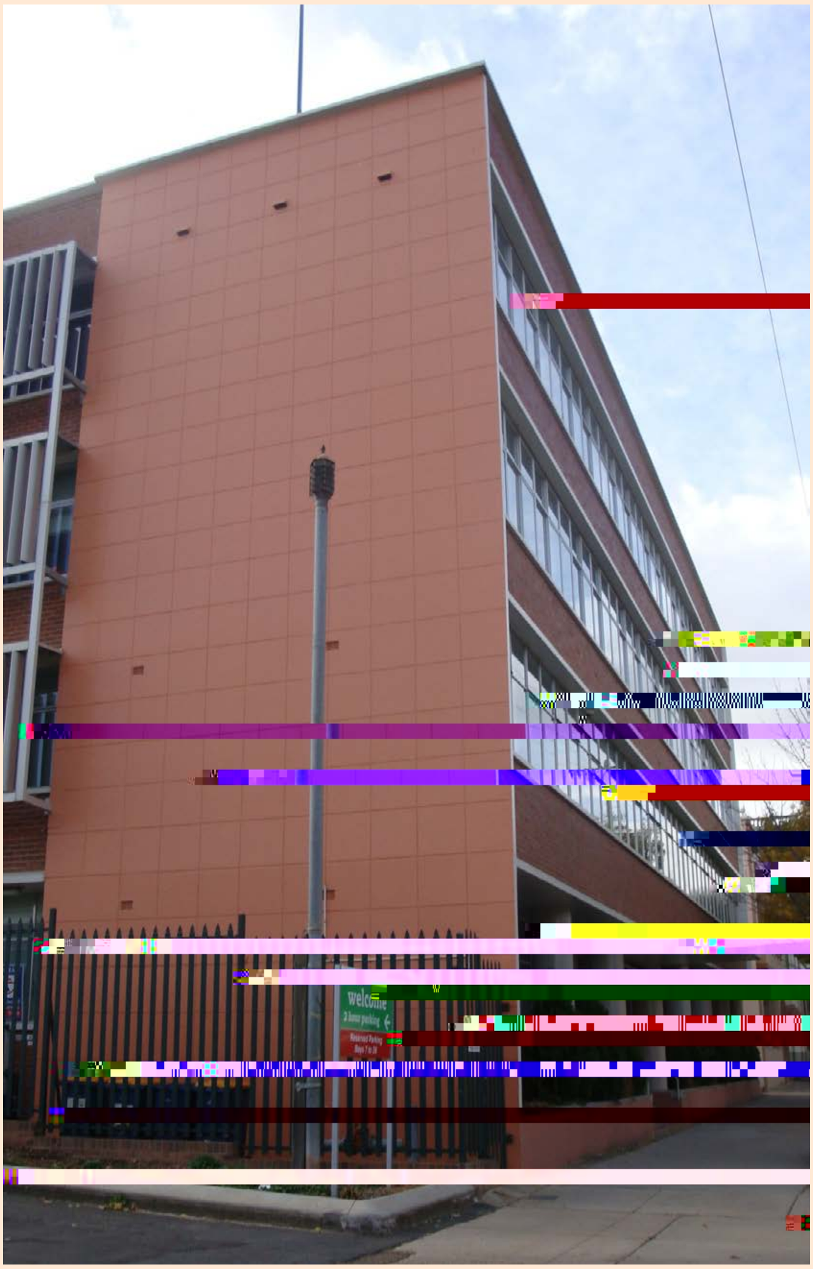

Fig. A2. Exterior Facade – South-West

Fig. A3. Exterior Facade – West

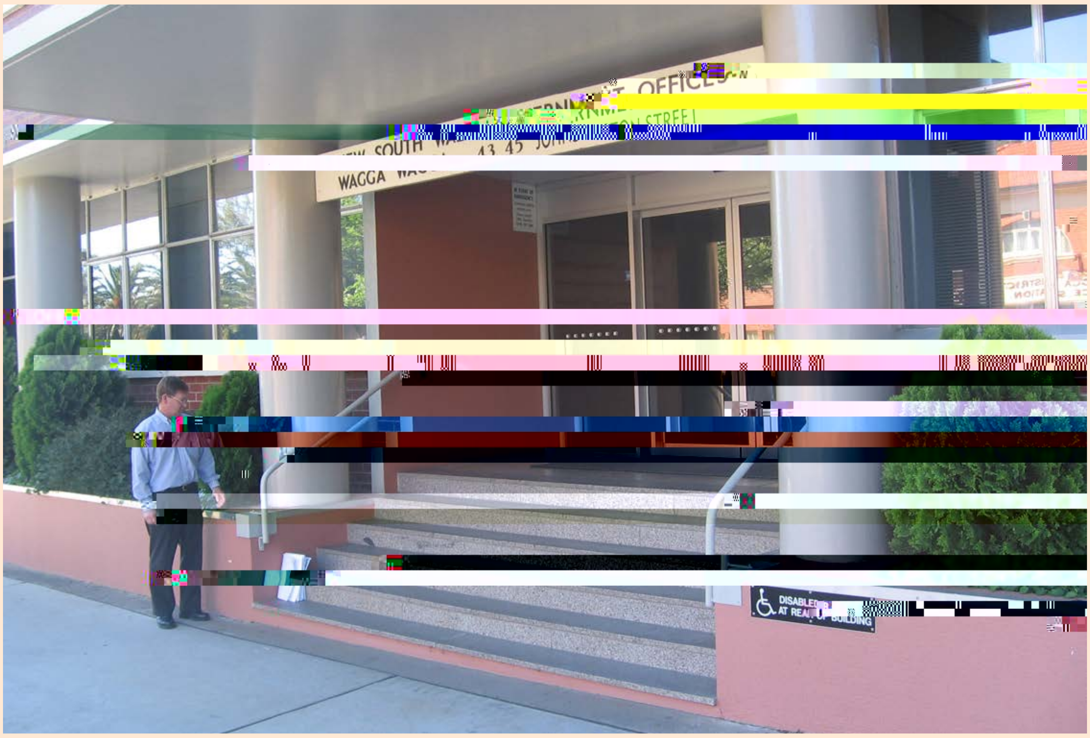

Fig. A4. Main Entrance - South

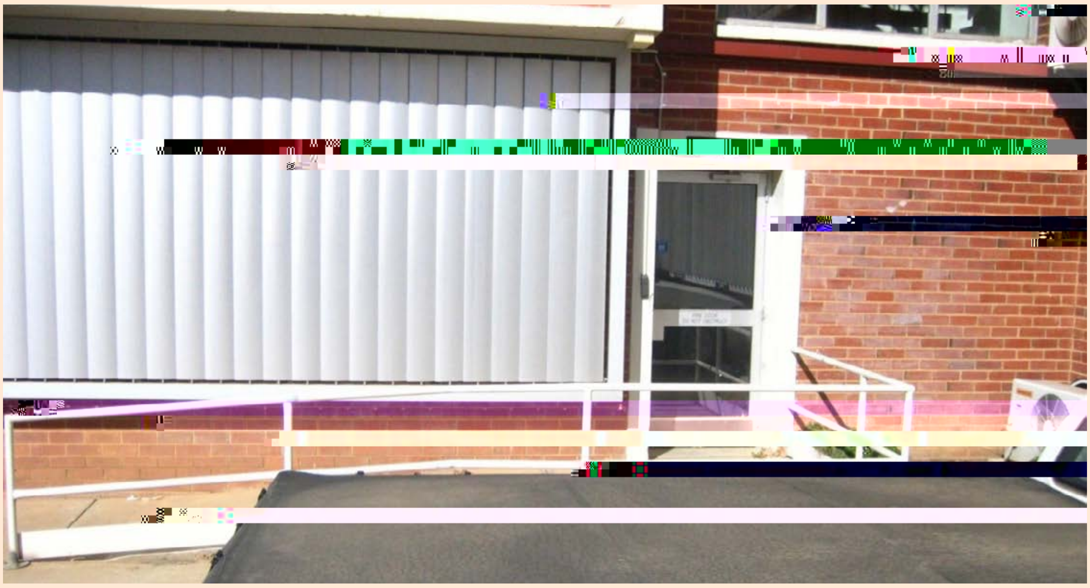

Fig. A5. Side Entrance – East.

Fig. A6. Parking entrance

Attachment 2

The following tables include analytic results of the simulated and recommended lighting levels, lighting uniformity and Illumination power density.

Notes

- The Illumination power density (W/m²) for the storerooms and the toilets has been set equal to the recommended by the NCC values.
- The range of the recommended Illumination power density (W/m²) is according to the NCC provision
- The number of the scenarios for each space depend on its use and characteristics, e.g., availability of natu01B-d[6i02trn1 Td[the th.ht.37s14Wlc.d the toilets has been set equal to the recommended by the NCC values.

The properties of the LED lighting

Attachment 3

report, a brief comparison between the actual electricity

on the monthly energy bills) and simulation result is provided in the below graph.

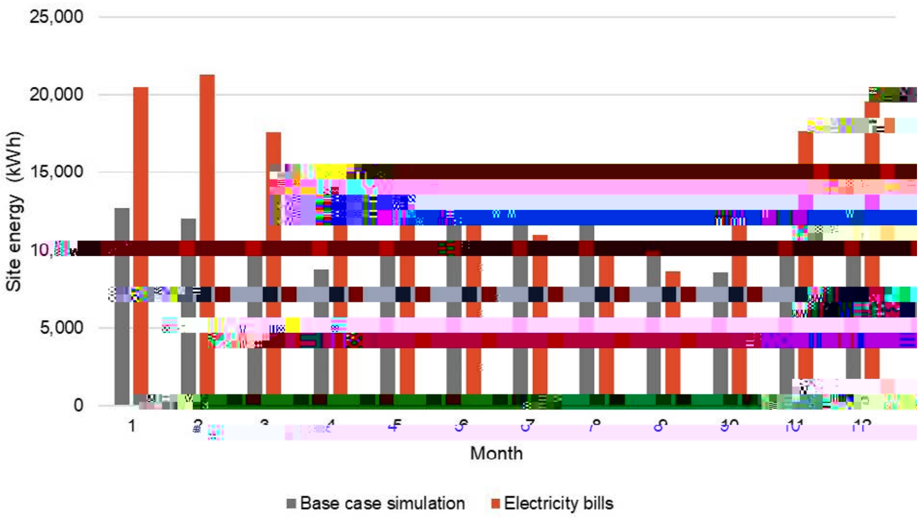

Fig. A12. Comparison between simulation and electricity bills.

The annual energy consumption result of the simulation is 19% less than the bills data. The reason behind

building in the past year.