Wa
Sou
VIC

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

Dr Riccardo Paolini – r.paolini@unsw.edu.au

Paulina Muliuolyte
Client Relationship Consultant
Unisearch Expert Opinion Services
Level 2, South Wing, Rupert Myers Building
Gate 14, Barker Street
UNSW SYDNEY NSW 2052
p.muliuolyte@unsw.edu.au
+61 2 9385 1500

Contents

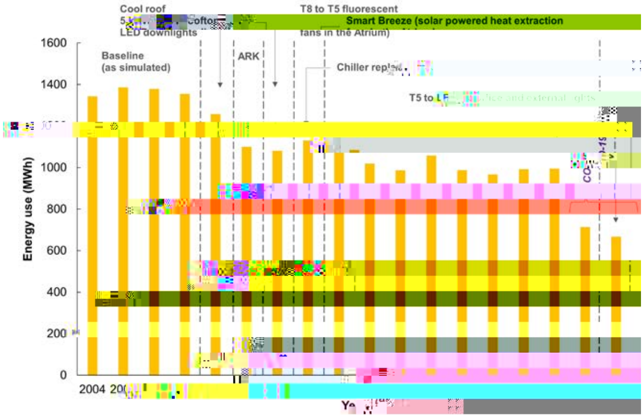
2. Regulations, Standards, and guidelines

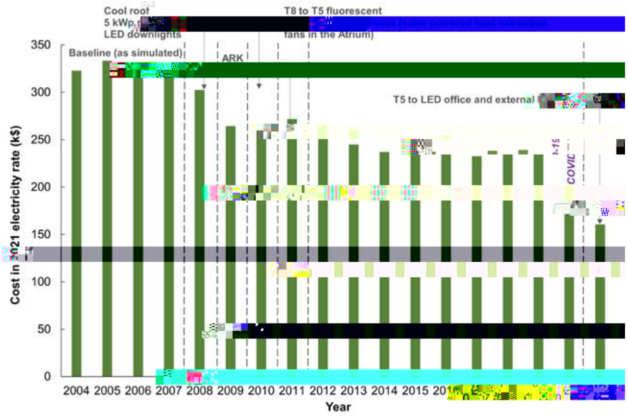
The regulatory documents and Standards used for the

3. Introduction

The selected case study building is a typical office building built in Australia in the 1990s, representative of many other buildings constructed in the same period. The aim of selecting Knox Civic Centre is the potential for methodology replication and findings expansion to other similar buildings.

The Knox Civic Centre is an exemplar case of energy retrofit, with staged interventions carried out by Council starting in 2008, delivering substantial energy savings. These interventions were performed between 2008 and 2021, and include the installation of a cool roof, a 5 kWp rooftop PV plant, energy-efficient lights and heat-extraction from the atrium (Figure 1). Considering the pre-COVID period, the energy-savings account for 27% of the energy consumption (4-year average pre-retrofit vs 4-year average retrofitted pre-COVID), or approximately $91,000 per annum with the 2021 energy costs, initially of approximately $322,000 (Figure 2).



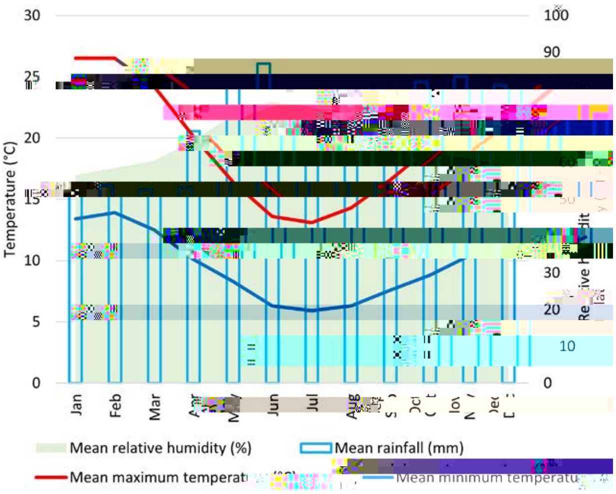


As the building serves as a case study helpful to consider opportunities for similar buildings, here we simulate the building in its pre-retrofitted state (2007) to consider the potential for energy improvements with the currently available technology. Further, it offers insight into additional opportunities for energy efficiency, beyond those already implemented, and complementing the information available thanks to metering. Also, multiple interventions on the real buildings were performed at the same time (e.g., cool roof coating, 5 kWp rooftop PV and LED downlights all in 2008), and simulations allow for the assessment of single interventions, instead. Furthermore, every year the climate conditions are different, and it

4. Knox Civic Centre in Melbourne

4.1. Case study description

The Knox Civic Centre is located at 511 Burwood Highway, Wantirna South Vic 3152 (37.871S, 145.245E). The building is in the eastern part of Melbourne, 86 m above sea level. In Köppen's climate classification, Knox's council area is categorised as Cfb, meaning that it has a temperate oceanic climate [3]. There is no significant precipitation difference between seasons. The average rainfall is 855 mm, with an average of 115 days of rain each year. Due to its geographical location, the relative humidity is distributed evenly



This case study office building was rebuilt after a fire in 1998, and here it is considered in its 2007 condition, before energy efficiency interventions (Figure 4). According to the National Construction Code, its classification is Class 6 – office building used for professional or commercial purposes [5]. The Knox civic centre provides services to 255 people at the busiest hours. The under-ceiling height of this two-story office building varies between is 2.7 m. Figure 3 illustrates the treemap chart of the gross internal area of case study buildings. The total gross floor area is 6,174 m².

Based on the documents provided by Knox City Council, the performance was internally estimated equivalent to a NABERS Energy 3.5 star in 2011. Its annual energy use was

4.2. Building modelling input parameters

The modelling parameters combine collected data from the building inspection, utility bills and Australian and global standards. Each modelling assumption will be briefly explained in this section, presenting the relative references.

The case study office building has capacity for 255 people [6], and the occupancy schedule is selected based on the national code of construction [5].

Knox Civic Centre has two floors. Table 1 shows the primary purpose of each area of the building (Figure 5).

A significant part of energy consumption is to maintain comfort leaks through the building envelope. As a key step in assessing the potential benefits of improving windows, walls, roofs and floors, the current thermal performance should be determined. Surveying the case study office building, the thermal properties of the building envelope are assessed based on construction features and age. This information is used to model the building and develop a thermal model. Here, the performance descriptors of external walls, roof and windows are introduced.

The external wall of the case study building includes five main layers. There is a fibre-cement cladding on the exterior, followed by an air gap and concrete blocks, a second air gap and plasterboard on the interior. The R-value of the external walls is 0.667 m².K/W, and the solar absorbance coefficient is 0.55. Also, using the average annual wind velocity in the area (3.6 m/s) [4], the convective heat transfer coefficient is calculated as 17.6 W/(m².K) [7]. ▫

				Gross floor
Main entry	+1	274	0	274
Stairs	GF and +1	53	0	53
Atrium	GF and +1	1,076	0	1,076
Kitchen	GF and +1	45	0	45
Meeting rooms	+1	520	0	520
Workstations	GF and +1	3,822	0	3,822
Toilets	GF and +1	0	139	139
Stores and plant room	GF	0	245	245

The roof of the case study office building consists of six layers. On top, there is a field-applied reflective coating on metal sheeting, followed by an anti-con blanket and an air gap, and then mineral wool insulation and a plasterboard false ceiling. The R-value of the roof is 1.036 m².K/W, and the solar absorbance coefficient is 0.25, with a thermal emittance of 0.90, since a solar reflective coating was installed. The initial solar absorbance of the coating was 0.10, which we increased to 0.25 to take into consideration the geometry of the metal sheeting and weathering and soiling, leading to performance loss after ten years of exposure. Also, using average annual wind velocity (3.6 m/s) [4], the convective heat transfer coefficient is calculated as 17.6 W/(m².K) [7].

External windows in the case study buildings are single glazed with aluminium frame. The selected shading and glazing in the model are presented in Table 4.

The required hot water for the Knox Civic Centre is calculated based on Table 2m, NCC volume 1 page 355 [5]. Therefore, considering the need for a 50°C temperature increase and water heat capacity (4.19 KJ/kg.°C), 150 MJ heating energy is required for daily heating domestic water. ▫

The information regarding the thermal comfort in

The schedules of occupancy, lighting and appliances of the case study office building are selected based on the National Construction Code (p. 348-349 Vol 1) with some adjustments following the documentation provided by the building facility management [5].

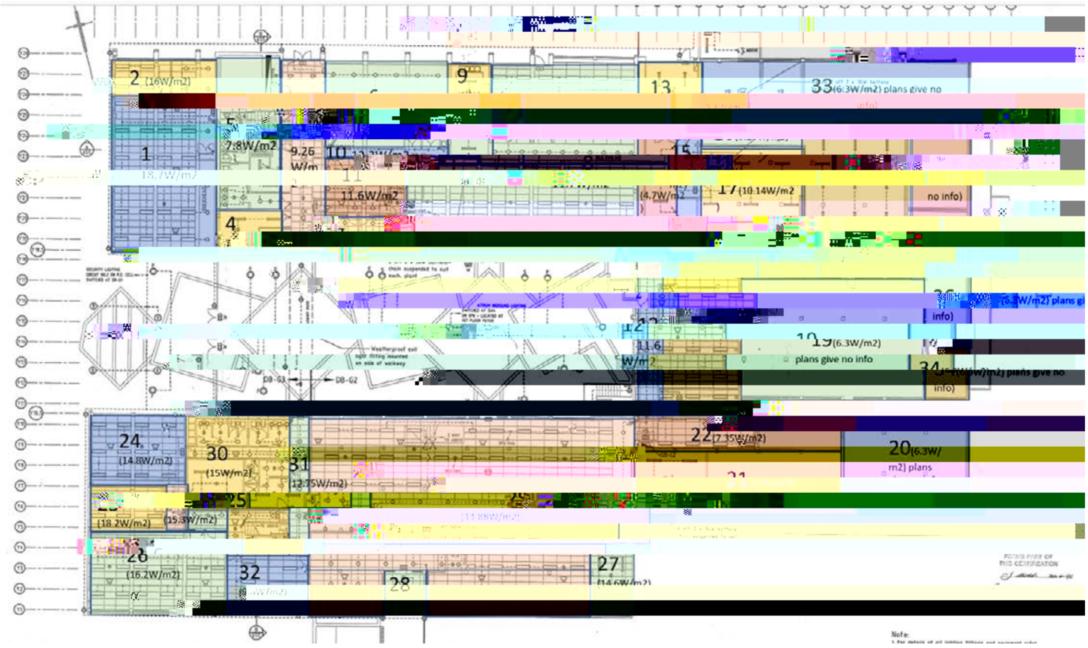
4.3. Evaluating Lighting Condition

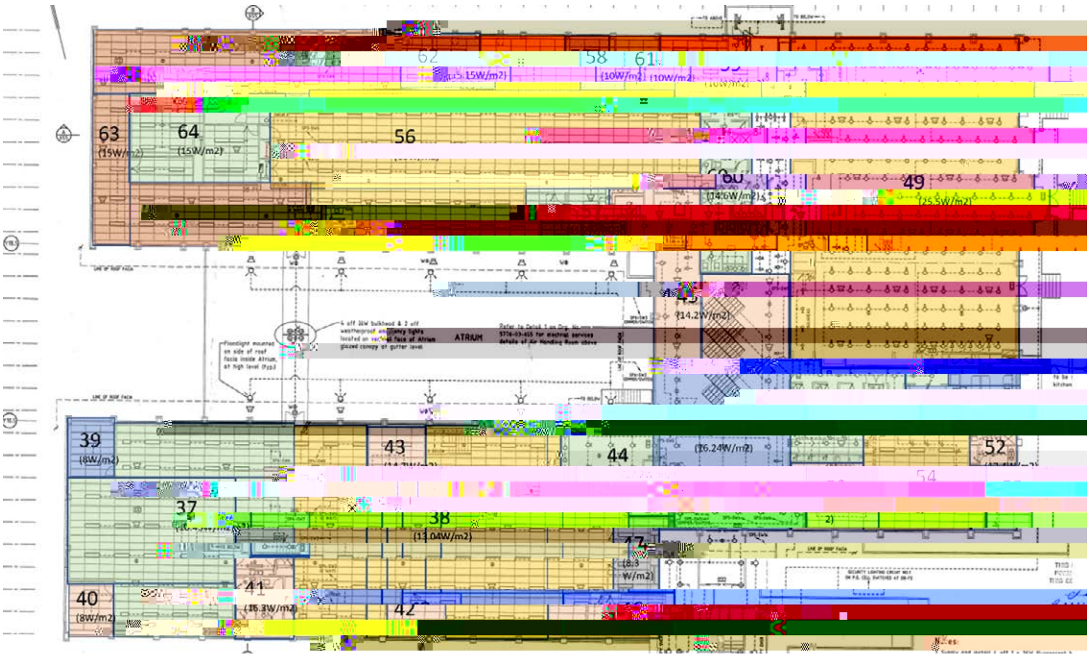
This section aims to recommend appropriate solutions for improving the natural and artificial lighting

The results are analysed in two parts:

1) The assessment of the existing natural conditions;

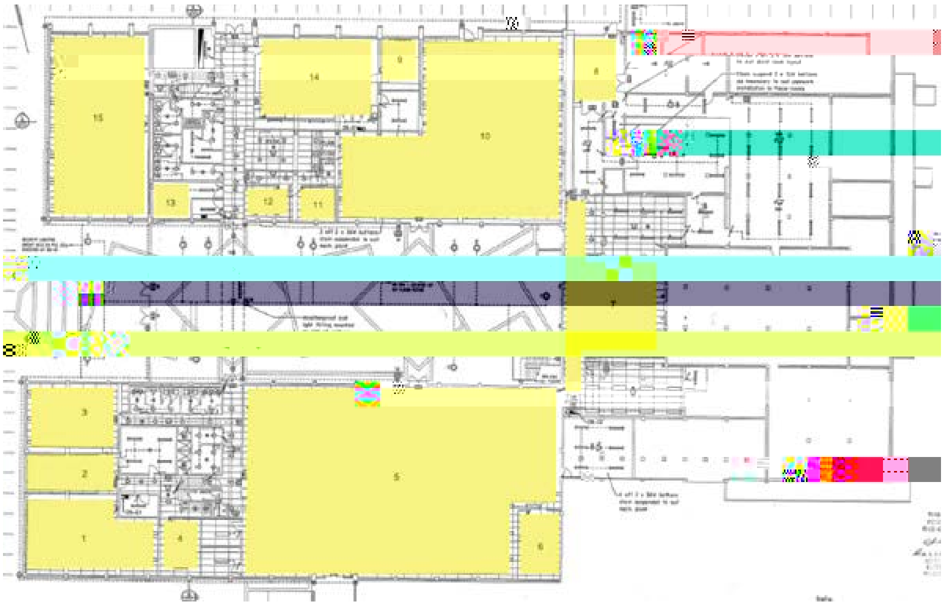
2) The calculation of the existing lighting power density (W/m²), and the proposal of scenarios to reduce the energy consumption for lighting. ▫

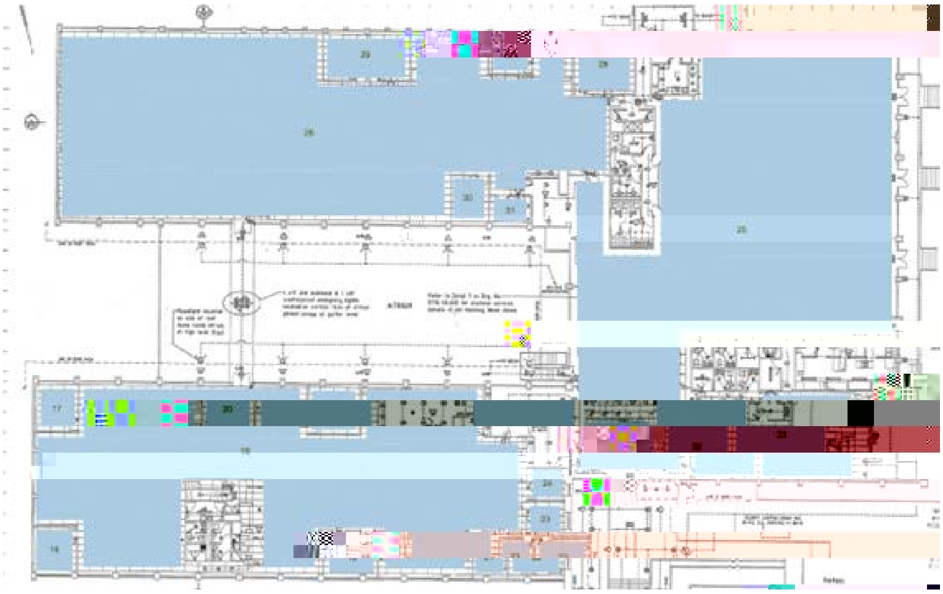




The building has many openings in the south and north facades, as well as on the “interior” elevations facing the atrium. The east façade includes translucent glazing on Level 1. The continuously occupied spaces close to the ground level perimeter receive adequate daylight, and many have Daylight Factors above 2%. There are spaces with small areas and full-height windows with high Daylight Factors (e.g., spaces 6, 11-13, 16, 22, 34), where the lighting levels and the thermal loads should be reduced. The spaces where the daylight availability should be higher are the deep spaces like spaces 2 and 8, or very large spaces, such as spaces 5, 10 and 28. The spaces behind the North façade could benefit from exterior shading, which could have the form of rollers/ blinds or louvres.

Spatial Daylight Autonomy (sDA) is the percentage of the regularly occupied floor area that is “daylit.” In this context, “daylit” locations are those meeting target illuminance levels (300 lux) using daylight alone for at least 50% of occupied hours. Such locations are said to be 50% daylight autonomous. The sDA calculations are based on annual, climate-based simulations. The sDA


15
14
9
10
8
13
12
11
3
2
1
4
5
6



5.2. TRNSys

The TRNSys software tool is used to simulate the behaviour of transient systems. TRNSYS has an extensive library of components, which can help model the performance of all parts of the system. TRNBuild is the tool used to enter input data for multizone buildings. It allows specifying all the building structure details and everything required to simulate the thermal behaviour of the building, such as windows optical properties, heating and cooling schedules, etc. [15].

After importing the case study building model into TRNSys, all building structural parameters (walls, windows, doors, etc.), schedules (occupancy, lighting, and appliances), internal loads, and HVAC&R systems (setpoint, ventilation, infiltration, and comfort) were

5.3.1. Lighting retrofit

The aim of the next step of the study was to develop scenarios that would enable reduced energy consumption for lighting and would provide an approximation of how much energy can be saved. Based on the provided information about the installed lighting sources, a base case scenario is developed. As the use of each of the spaces is not known, the maximum permitted lighting power density of office use by the NCC, i.e., 4.50W/m², was used for Scenario 1.

For Scenario 2, the power density of Scenario 1 was used and combined with continuous dimming of the light sources depending on daylight availability. The energy consumption for each of the scenarios is provided in Table 13. The proposed scenarios resulted in a reduction of the total lighting load (kW) and the annual energy (kWh) ranging from 28 to 95% (Table 13).

5.3.2. Windows retrofit and wall insulation

The windows now installed in the Knox Civic Centre are single glazed with aluminium frame. The thermal break (insulation within a window) is a constant barrier between the inside and outside window frames that avoid conductive thermal energy loss. This barrier securely bonds the interior and exterior metal frames of the window. This thermal break creates thermal energy loss resistance and, combined with double-pane glazing, keeps the interior space of the window at a more comfortable temperature. The proposed window is thermally-broken aluminium framed, double glazed, with Low-E external glass pane, with an average U-value of 1.78 W/m²K, an SHGC value of 0.66 and Air-tightness values of Class 3 with less than 2.5 L/s.m² at 100 Pa. The latter reduces the infiltration rate of the building to 0.30 1/h. Application of 80 mm of mineral wool covered with plasterboard on external walls, leading to a total thickness of 0.29 m and a total R-value of 2.67 m²K/W.

Insulation is a cost-effective way to save energy and improve the indoor environment. Roof insulation refers to the addition of a layer of Mineral wool (thickness of 8 cm) between the ceiling and the external roof, leading to an average R-value of 3.04 m²K/W. ▫

Ceiling fans are a simple and cost-effective method to enhance the indoor air quality in summer and receive points in energy rating stars. They provide additional air movement by increasing the relative air velocity resulting in the apparent temperature felt on exposed skin being 3°C colder than the actual air temperature, thereby reducing the need for additional cooling. The proposed scenario will be modelled by increasing the cooling setpoint temperature to 26°C.

Intensive ventilation through windows during the night is a cost-saving and energy-efficient method of cooling buildings in summer. It uses the natural pressure differences between at least two openings (e.g., windows, doors) of a building to the outside for air exchange. Such a pressure gradient already exists in weak winds.

Night ventilation takes place between 20:00 and 8:00 with an additional flow rate of 4 ACH and is activated during the cooling period and only when the difference between indoor and outdoor temperature is greater than 3 K, the outdoor temperature is greater than 15°C, and indoor temperature is greater than the heating setpoint. Window shading is modelled by applying a shading

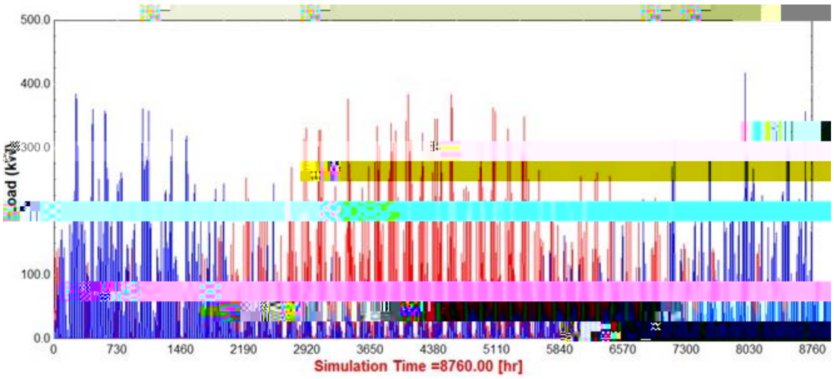
The result of the evaluation is two sets of BAC efficiency factors (fBAC,hc and fBAC,e). The first one estimates the energy for heating and cooling, and the second one the electric energy for lighting and auxiliary factors. Fraser suites Sydney is between Class D and C and can fairly easily be upgraded to Class B by installing:

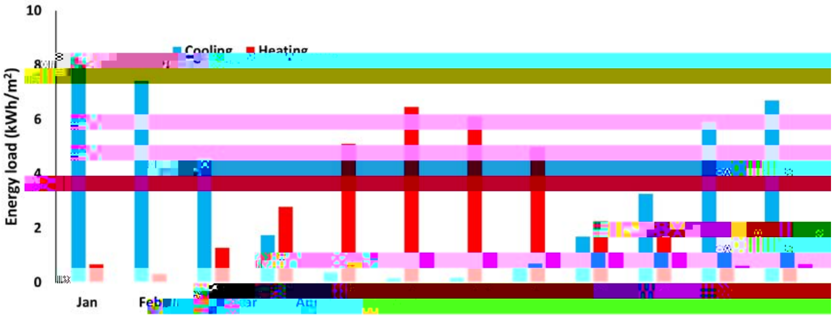
- Individual room controls with communication between them and the chillers/boilers and air handling units
- Time-dependent controls of ventilation
- Variable control of setback temperatures
- Humidity control of the ventilation and
- Lighting controls

6. Results

6.1. Base building modelling

The results of the Knox Civic Centre simulation are presented in this section. The hourly energy demand for heating and cooling (sensible and latent) is illustrated in Figure 11. Also, the monthly energy demand is presented in Figure 12.





TRNSys calculates thermal loads through an energy balance that affects the air temperature inside the building:

$q_{BAL} = q_{DQAIRdt} + q_{HEAT} - q_{COOL} + q_{INF} + q_{VENT} + q_{TRANS} + q_{GINT} + q_{WGAIN} + q_{SOL}$

q_{BAL}: the energy balance for a zone and should always be close to 0;

$q_{DQAIRdt}$ is the change of internal energy of the zone (calculated using the combined capacitances of the building and the air within it);

q_{INF} is the gains by infiltration;

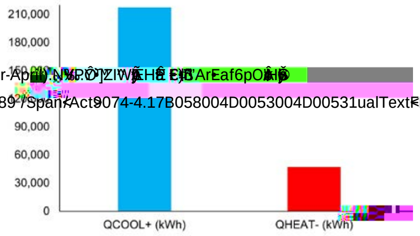
q_{VENT} is the gains by ventilation;

q_{TRANS} is transmission into the surface from an inner surface node;

qG_{INT} is internal gains by convection and radiation;

$q_{WGAINA/ActualText}$EFF0009BDEMC MC 30050.014 Tc 0.014 Tw 6 0 0 6 66.5158 307.6665 Tm[(I)-14 (NT)]TJ/C20 1 710.1 ober-April).N%.O]ZIWEHE E)B'ArEaf6pOAHp

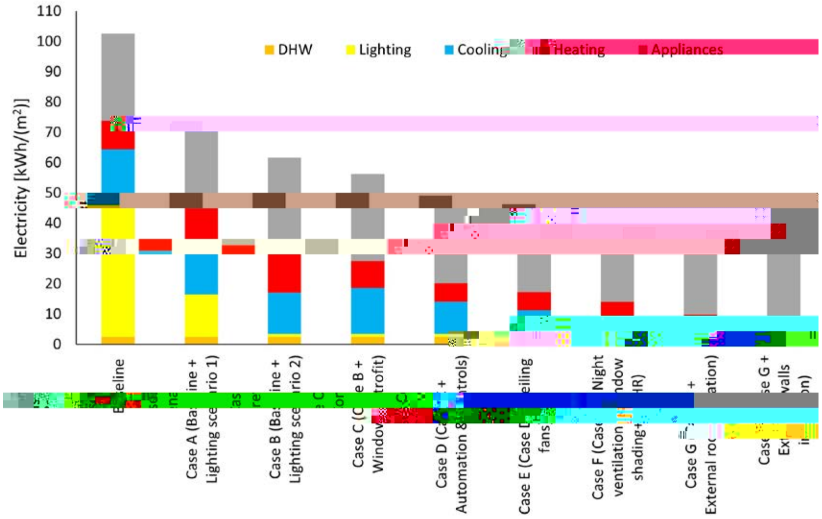
A/Actual9.944 -1.729C0009>4.944 -1.72589003TjEMC M6052004820.7 ctua0052001F}TJ/TT589001TjEMC M8Td40045005200489 /Span<Act9074-4.17B058004D0053004D00531ualText<EFF0009Tc 0

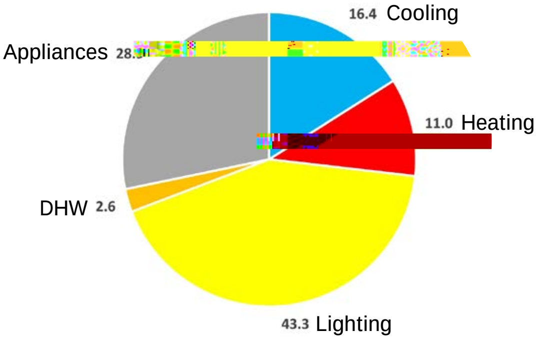


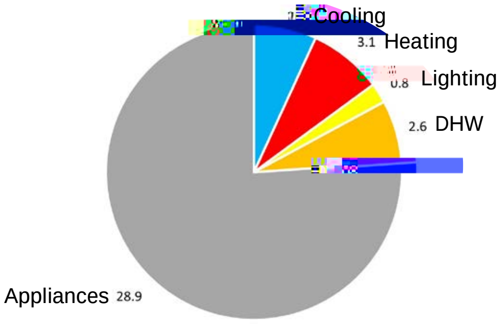
6.2. Retrofit scenarios

The investigated retrofit cases in this report are presented in Table 16.

Baseline	The base-case scenario considers the maximum lighting power density permitted by the NCC for each type of space. For the cases where a range of power densities is allowed by NCC, the maximum value is considered. Heating and cooling setpoint and setback temperatures are set according to the NCC.
Case A	The illumination power density was decreased in many spaces, either using the information for the actual lighting systems of the building or by adopting the minimum power density as required by the NCC. No controls.
Case B	The power density of lighting scenario 1 was used and combined with continuous dimming of the light sources depending on daylight availability in.
Case C	**Case B + windows retrofit:** New windows are aluminium framed, with a thermal break in the frame, double glazed, with Low-E external glass pane, with an average U value of 1.78 W/m²K, a glazing g-value of 0.66 and Air-tightness values of Class 3 with less than 2.5l/s.m² at 100 Pa. The latter reduces the infiltration rate of the building to 0.30 1/h.
Case D	The baseline class of automation is estimated according to EN15232, and then the new class and energy efficiency are estimated according to the potential improvements. Class C is the estimated class for the baseline, and it is considered that class A is reached after the improvements.
Case E	Ceiling fans are modelled by increasing the cooling setpoint temperature to 26°C.
Case F Case D	Night ventilation takes place between 20:00 and 8:00 with an additional flow rate of 4 AÓ :] 8 Ó i


110
100
90
80
70
60
50
40
30
20
10
0
Electricity [kWh/(m²)]
DHW
Lighting
Cooling
Heating
Appliances
Baseline
Case A (Baseline + Lighting scenario 1)
Case B (Baseline + Lighting scenario 2)
Case C (Case B + Window retrofit)
Case D (Case C + Automation & controls)
Case E (Case D + ceiling fans
Case F (Case Night ventilation window shading+HR)
Case G + External roof ation)
Case G + Ex walls in on)


16.4 Cooling
Appliances 28.
11.0 Heating
DHW 2.6
43.3 Lighting


Cooling
3.1 Heating
0.8 Lighting
2.6 DHW
Appliances 28.9

2

2

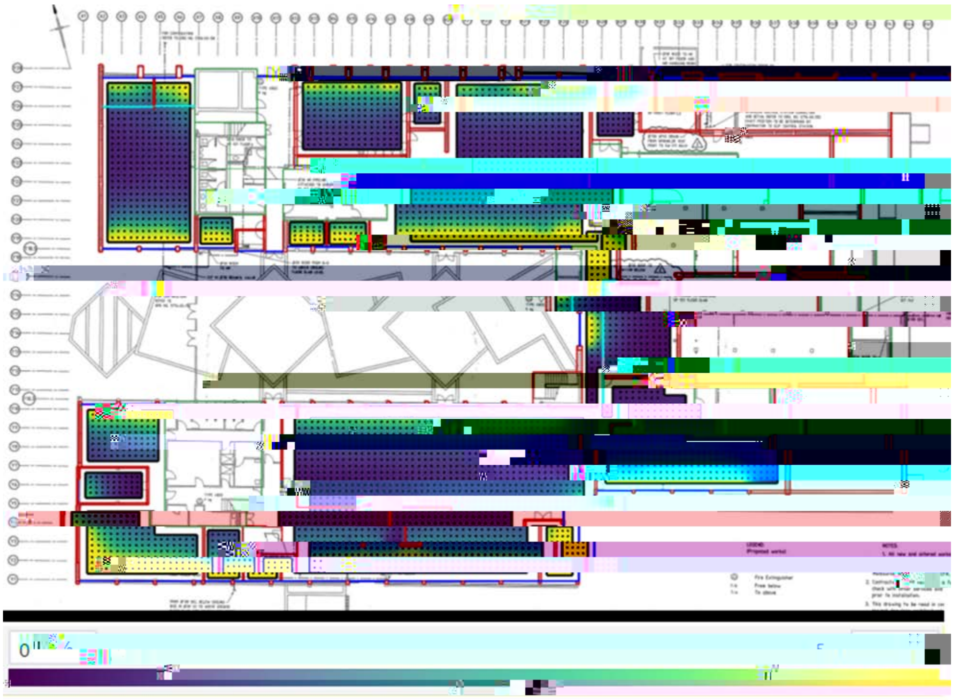
6.4. Discussion and recommendations

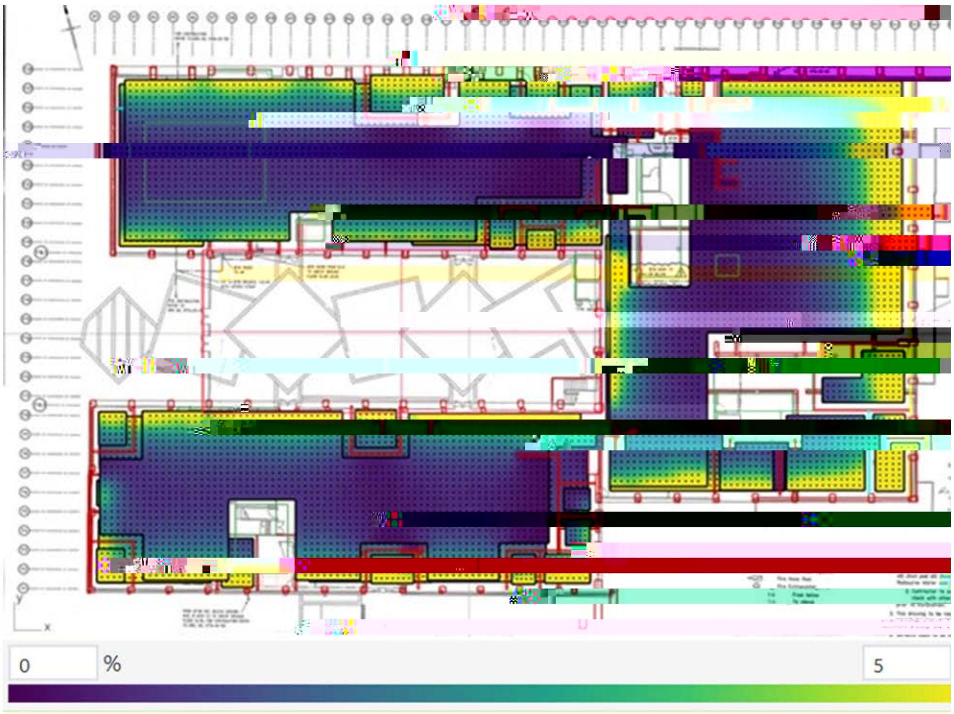
We established a baseline for energy consumption and then we undertook a simulation based on various

References

Attachment 1

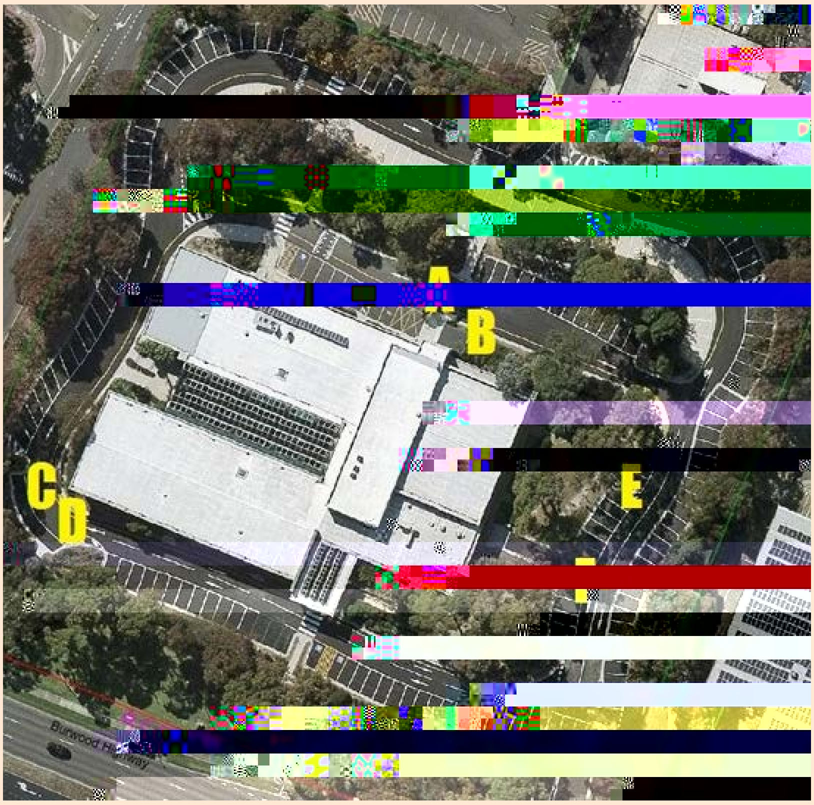
The following figures show daylight factor distribution in Knox Civic Centre.

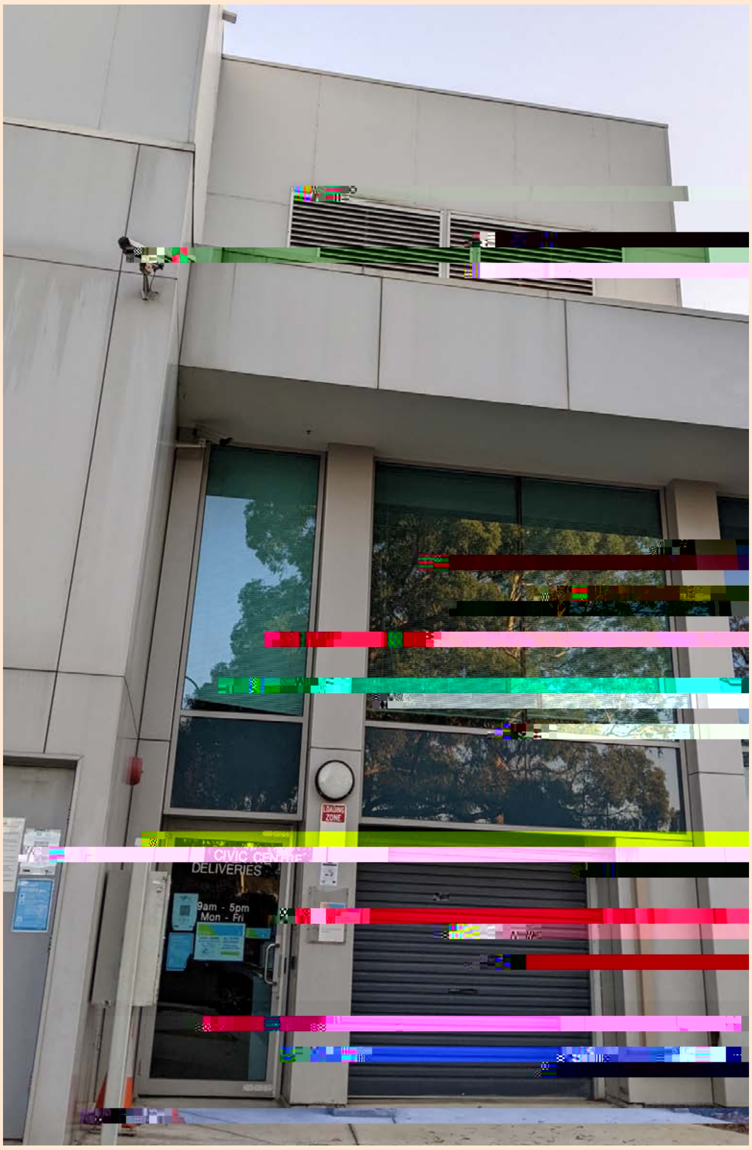


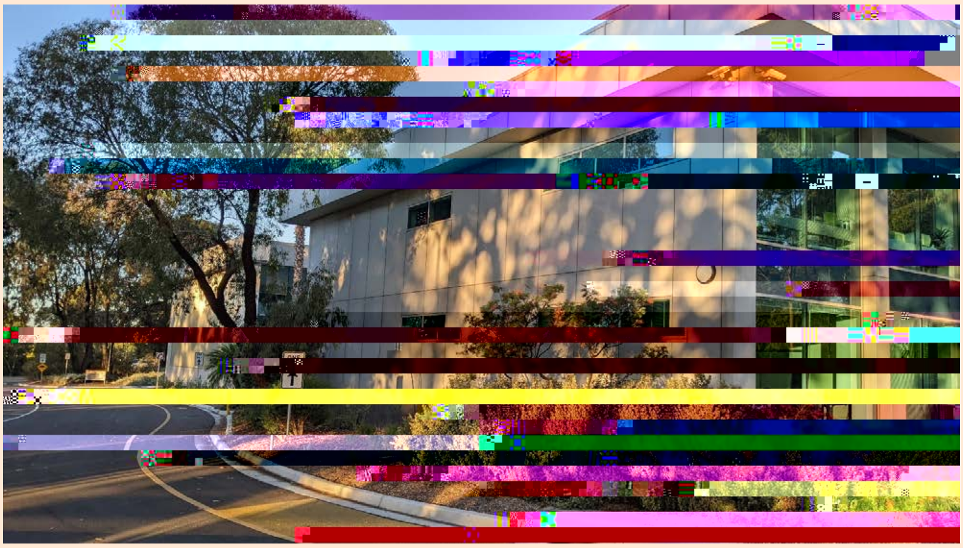

0
%
5

Attachment 2

This section demonstrates all the input information used for Energy modelling of 511 Burwood Highway, Wantirna South, VIC. The data was provided by Knox City Council, including, site photos floor plans, and elevations.




CIVIC CENTRE
DELIVERIES
9am - 5pm
Mon - Fri
LOADING ZONE



Fi36FiEnergy Efficiency Training and Information Project   reCommercia