UNSW SYDNEY

Community Centre

Kings Langley NSW

Energy Efficiency Training and Information Project

Commercial Buildings

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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1. Executive Summary

The 2006 Paris Agreement on climate change aims to hold the increase in global average temperatures to below 2°C above pre-industrial leveltT/9bnthes Acontxt<
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- Improvement of the lighting systems.
- Replacement of old inefficient or non-functional ceiling fans to reduce cooling loads and to reduce the energy consumption of the fans.
- Installation of mechanical ventilation with heat recovery to reduce heating loads.
- Installation of an air-to-water heat pump (AWHP) or a ground source heat pump (GSHP) could lead to a drastic reduction of final energy consumption for space heating and domestic hot water (DHW).
- Finally, the installation of a 10 kWp net metering PV system on the northern roof to cover the electricity consumption of the building.

In conclusion, a complete renovation package is suggested that includes the drastic improvement of the building envelope's thermal protection by means of insulation of external walls and roof, and replacement of the windows and glazed surfaces, the upgrading of the lighting system, the installation of ceiling fans and mechanical ventilation with heat recovery, and eventually the use of a GSHP or, if this is not possible, of AWHP. Such a package will lead to energy savings of 65.9%, resulting in an energy consumption of 57.1 kWh/m²a, compared to the baseline of 167.2 kWh/m²a. The simulation results demonstrated that almost 45.4% of the cooling load in 2030 can be cut by completely retrofitting the building. This efficiency improvement can also reduce the total electricity demand of the building by 64.5%.

3. Introduction

The selected case study building is a typical community centre built in Australia in 1982, representative of several other low-rise buildings constructed approximately in the same period. Clearly, one sample community centre building cannot completely fit all similar buildings, and each community centre has differences; however, even though the project-specific outcomes may differ, the logic and methodology presented here offer a high-quality framework to improve the energy efficiency in such buildings.

Assessing the energy performance of an old building is a complicated task. It starts with determining the building's constructional features, including the efficiency of the building envelope, lighting, HVAC equipment, etc. Considering the building's features, all calculations were based on the 'as-built' condition of the building elements (U-values, shading, air-permeability, etc.). The efficiency of the HVAC system (Coefficient of Performance (COP) and seasonal Energy Efficiency Rating (EER) were selected based on the provided information by their manufacturers, and installed lighting and plug loads were determined either by data provided by the building operators or in accordance with standards and regulations.

Additionally, two types of specific conditions that have a significant impact on the community centre building's performance must be considered:

(a) the operational parameters (hours of operation, set temperatures for heating and cooling, natural ventilation patterns, use of artificial lighting, etc.) and

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

4. Jim Southee centre in Blacktown

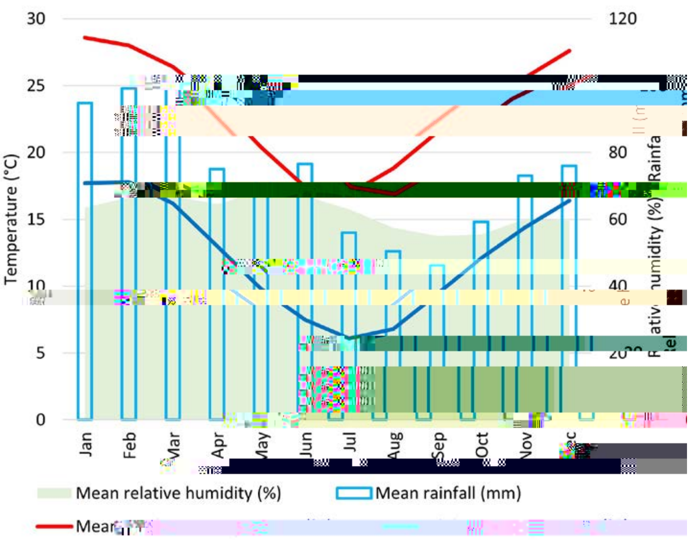

Figure 1. Climatic data for Blacktown [4].

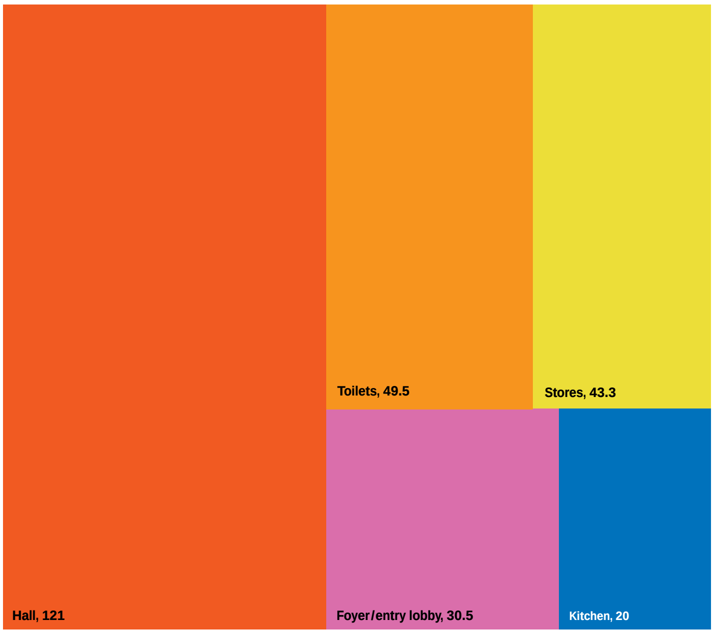

Figure 2. Gross floor divided area of case study building.

Figure 3. Northern view of Jim Southee centre.

4.1.2. Building description

This case study community centre is in a Greater Western Sydney suburb, and it was completed in 1982. In 1993, a storeroom was converted to a Kitchen in the western part of the building. According to the National Construction Code, the building classi f cation is 'Class 9b: assembly buildings in which people may gather for social, theatrical, political, religious or civil purposes' [5]. The under-ceiling height for this single-storey building varies between 2.5-5 m. The total gross f oor area is 264.3 m2. Figure 2 illustrates the treemap chart of the gross internal area of the case study building.

4.1.3. Energy consumption and sources

Improving energy e f ciency is a practical way to reduce the building's operational cost. This building does not use any renewable resources generated on-site. Electricity is used for HVAC purposes, lighting, appliances, water heating and cooking in the Jim Southee centre. ➔

4.2. Building modelling input parameters

The modelling parameters are a combination of collected data from the building inspection and Australian and international standards. In this section, each modelling assumption will be briefly explained and referenced.

4.2.1. Occupancy

Currently, the Jim Southee centre has capacity for 60 people, and the occupancy schedule is selected based on the national code of construction (Table 9)[5].

4.2.2. Geometric data

The case study building has only one floor, and Table 1 shows the purpose of each part of the building.

4.2.3. Building Components

A significant part of energy consumption is used to maintain comfort leaks through the building envelope. As a key step to assess the potential benefits of improving windows, walls, roofs and floors, the current thermal performance should be determined. Here, we assessed the thermal properties of the building envelope based on the age of 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 of the case study building can be divided into two parts. There is a brickwork wall in the lower parts of the wall and timber studs in the upper part.

The brickwork wall includes three main layers: two layers of solid bricks with an air cavity in between. The R-value of the external wall is determined as 0.633 m^2.K/W. The solar reflectance is considered equal to 0.6. Also, using the average annual wind velocity in Blacktown (3.0 m/s) [4], the convective heat transfer coefficient is calculated as 17.6 W/(m^2.K) [6].

The timber stud wall includes three main layers: timber panels as the outer layer, an air cavity, and an interior layer of timber panels, with an R-value equal to 0.850 m^2.K/W. The solar reflectance coefficient is considered equal to 0.7. Also, using the average annual wind velocity in Blacktown (3.0 m/s) [4], the convective heat transfer coefficient is calculated as 17.6 W/(m^2.K) [6]. →

4.2.3.2. Roof

The roof of the case study community centre consists of three layers. There are concrete tiles on the top layer, an air gap, and plasterboard inside, with an R-value equal to 0.545 m².K/W and a solar reflectance coefficient equal to 0.15. Also, using average annual wind velocity (3.0 m/s) [4], the convective heat transfer coefficient is calculated as 17.6 W/(m².K), respectively [6].

4.2.3.3. Windows

External windows in the case study community centre are single glazed with an aluminium frame. The selected shading and glazing in the model are presented in Table 5.

4.2.4. Domestic hot water

The needed hot water for the Jim Southee centre is calculated based on Table 2m, NCC volume 1 page 355 [5]. Therefore, considering the need for 50°C temperature increase and water heat capacity (4.19 KJ/kg.°C), and occupancy schedule of the community centre, 17.6 MJ heating energy is needed for daily heating domestic water (Table 6). ➔

4.2.5. Internal gains

The information regarding the thermal comfort in the studied community centre is provided by the Blacktown City Council (BCC), as given in Table 7. Lighting and personal heat gain assumptions in the model are based on Australian and international standards. The assumed heat gain for kitchen appliances in Jim Southee centre is presented in Table 8. The heat rates are based on NCC volume 1 page 355 [5] and chapter 18.12 of ASHRAE Fundamental 2017 [10].

4.2.9. Schedules

The schedules of occupancy, lighting and appliances of the Jim Southee Community Centre (Table 11) are selected based on pages 352-353 of the National Construction Code with some modifications due to provided documents by BCAM [5].

4.3. Evaluating Lighting Condition

The aim of this section is to recommend appropriate solutions for the improvement of the natural and artificial lighting environment and for minimising the energy consumption for lighting of the interior spaces of Jim Southee community centre. The steps taken in this regard are:

1. The analysis and simulations of the existing lighting conditions, based on information provided by the building management;

2. The assessment of the compliance of the energy performance and the lighting conditions established with relevant regulations, standards and guidelines; and

3. Research, simulation, and presentation of appropriate techniques and methods to achieve minimum energy consumption for lighting and heating loads from artificial lighting while complying with the Australian building regulations.

4.3.1. Lighting evaluation method

Proposing strategies for improving lighting conditions or reducing energy use requires a detailed analysis of the existing natural and artificial lighting conditions. The data provided for the Jim Southee centre were the architectural drawings of the building. Photographs of the interior and exterior of the building were also provided, where some lighting fixtures and interior surfaces' properties were visible. Specific information about the building's lighting system was not available. Using the provided data, the building was modelled in the software Rhinoceros, and the lighting conditions were simulated in the add-on tool Climate Studio. Climate Studio is an environmental performance analysis software with advanced lighting calculation capabilities. The simulation results were then compared to the requirements and recommendations of the A

5. Simulation approach

The simulation includes two main parts. First, the building was defned in SketchUp software and then energy modelling was conducted in TRNSys.

5.1. SketchUp

SketchUp is a 3D modelling computer program for a wide range of drawing applications such as architectural, interior design, landscape architecture, civil and mechanical engineering. The model was designed based on actual building dimensions, rotation, and shadings (adjacent building and external shadings) (Figure 4).

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, as well as everything that is required to simulate the thermal behaviour of the building, such as windows optical properties, heating and cooling schedules, etc. [10].

After importing the aged care centre buildings model into TRNSys, all building structural parameters (walls, windows, doors, etc.), schedules (occupancy, lighting, and appliances), internal loads, and HVAC systems (setpoint, ventilation, infltration, and comfort) were defned in r

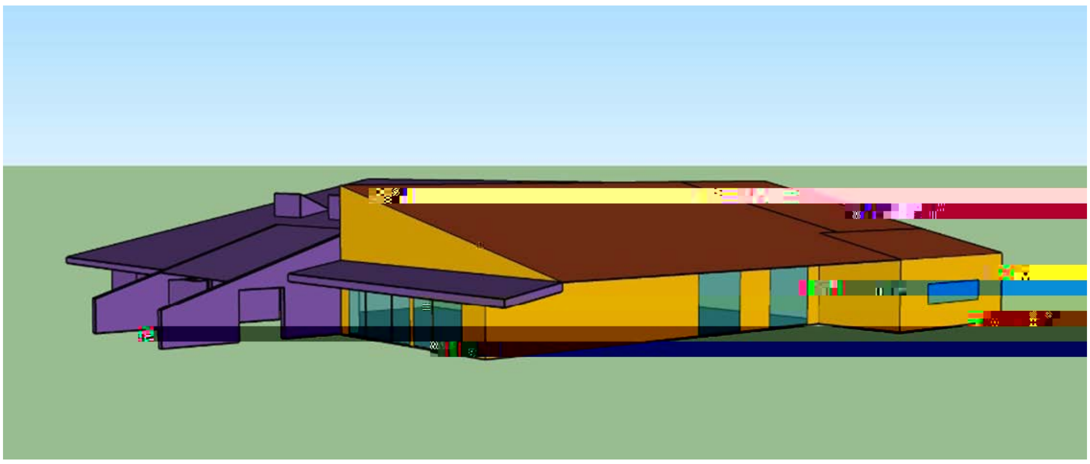

Figure 4. SketchUp model.

5.3. Retrofit approaches

Evaluating the energy performance of a building is a complicated task. It initiates with determining the building's constructional characteristics, including

5.3.2. Roof insulation

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 120 mm) under the existing roof, leading to an average total thickness of 243 mm and an average R-value of 3.73 m^2K/W. The average installed cost is estimated at 52 AUD/m^2.

6. Results

6.1. Base building modelling

The result of the Jim Southee centre simulation in Blacktown is presented in this section. The hourly energy demand for heating and cooling (sensible and latent) is illustrated in Figure 5. Also, the monthly energy demand is presented in Figure 6. →

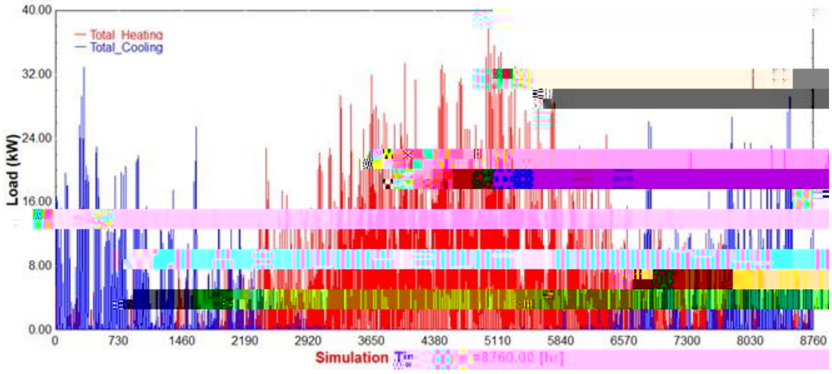

Figure 5. Hourly energy demand for HVAC purposes.

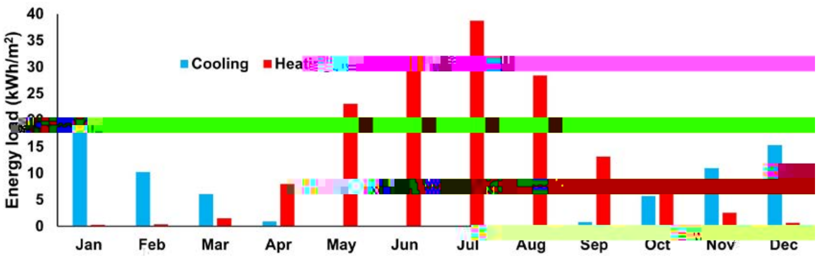

Figure 6. Monthly energy demand for HVAC purposes.

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 infltration;
- 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_{WGAIN} represents gains by convection and radiation through walls, roof and foor;
- q_{SOL} is absorbed solar gains on all inside surfaces;
- q_{HEAT} is the power of ideal heating;
- q_{COOL} is the power of ideal cooling.

Therefore, the ratio of each parameter in total energy gain can be decided for heating and cooling seasons (Figure 7 and Figure 9). Also, the amount of heating and cooling energy is illustrated in Figure 8 and Figure 10.

Figure 8. Whole building energy gain for heating and cooling load – heating season (May-September).

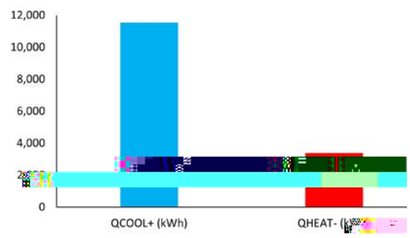

Figure 10. Whole building energy gain for heating and cooling load - cooling season (October-April).

The monthly energy gain of the community centre building and the influence of each factor in the total energy demand is presented in Figure 11.

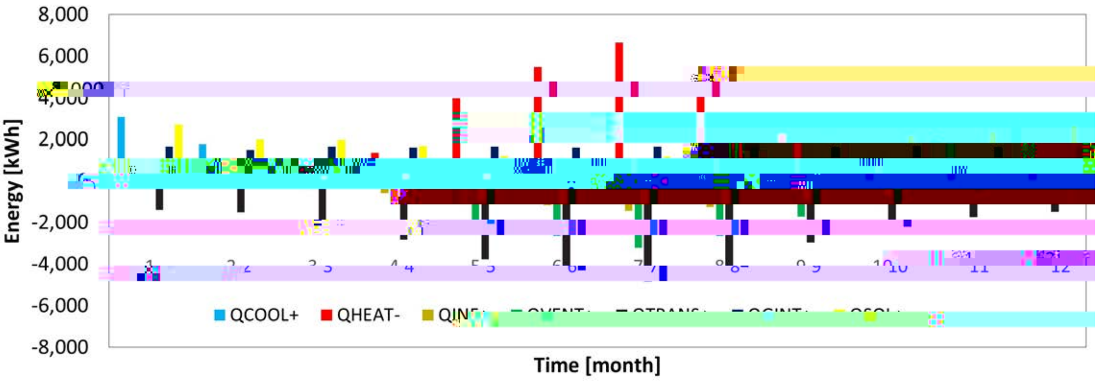

Figure 11. Monthly building energy gain.

6.2. Retrofit scenarios

The investigated retrofit cases in this report are presented in Table 13. ➔

Table 15. Retrofit cases.

Cases	Description
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	**Baseline + lighting scenario 1:** Illumination power density 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.
Case B	**Baseline + lighting scenario 2:** The power density of lighting scenario 1 was used and combined with continuous dimming of the light sources depending on daylight availability.
Case C	**Case B + roof insulation:** Refurbishment of the roof, fitting 12cm of mineral wool under the existing roof, leading to a total R-value of 3.73 W/m²K.
Case D	Application of 9cm of mineral wool covered with plasterboard on external brick walls and 8cm of mineral wool covered with plasterboard on external timber stud walls, leading to a total R-value of 2.94 m²K/W. New windows are aluminium framed, with a thermal break in the frame, double glazed, with an average U-value of 1.53 W/m²K, an SHGC value of 0.7.
Case E	**Case D + Installation of AWHP, replacing ceiling fans and MVHR:** Installation of one Air-to-water heat pump with fan coils with a coefficient of performance COP=3.5 and energy-efficient rating EER=3.8, including distribution and terminal units losses. The heat pump is also used for DHW preparation with COP=2.6, including storage and distribution losses. The efficiency of the MVHR system is 80%. Replaced ceiling fans are modelled by increasing the cooling setpoint temperature to 26°C.
Case F	**Case D + Installation of GSHP, replacing ceiling fans and MVHR:** Installation of one ground source heat pump with fan coils, with a coefficient of performance COP=4.8 and energy-efficient rating EER=5, including distribution and terminal units losses. The heat pump is also used for DHW preparation with COP=3.2, including storage and distribution losses. The efficiency of the MVHR system is 80%. Replaced ceiling fans are modelled by increasing the cooling setpoint temperature to 26°C.
Case G	**Case F + cool roof tiles:** New coating tiles with albedo 0.75 (i.e., solar absorbance 0.25). It can be achieved either with the installation of new white concrete tiles or the painting of the existing ones with a solar reflective coating.
*	**PV system.:** Installation of a 10 kWp net metering PV system on the northern roof to cover the electricity consumption of the building.

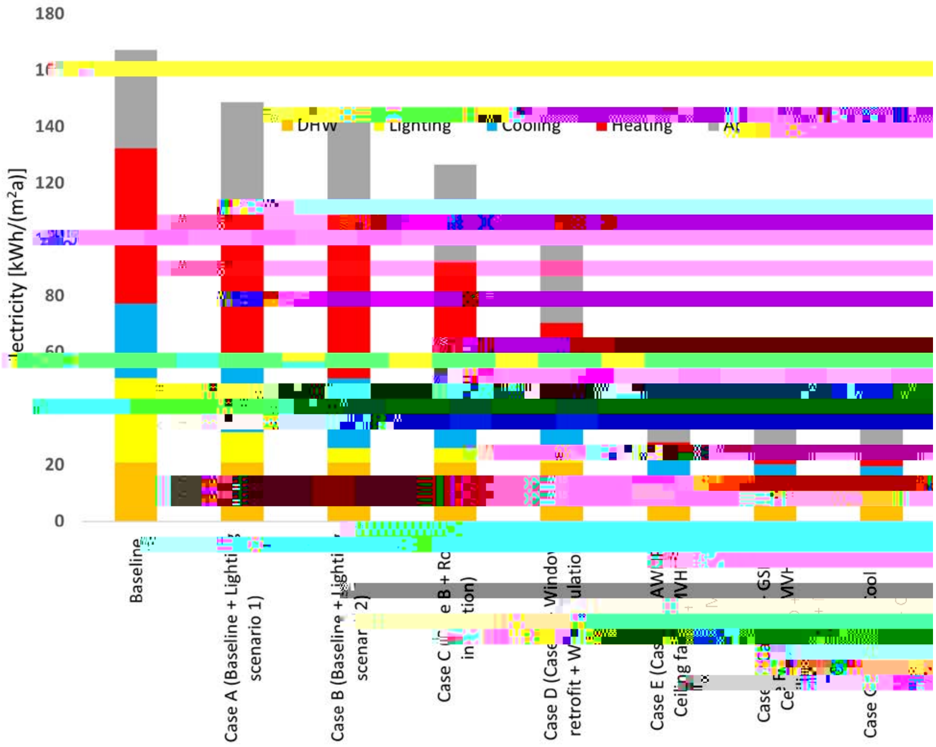

Figure 12. Site energy of the retrofit scenarios.

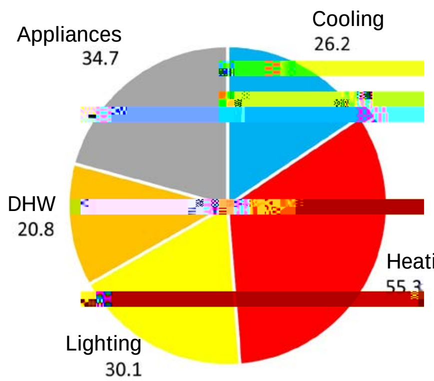

Figure 13. Share of site energy for the baseline (kWh/m²a).

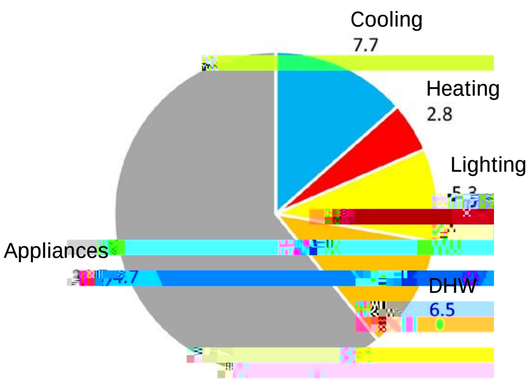

Figure 14. Share of Site energy for retrofit scenario – case F (kWh/m²a).

will rise sharply by 2030. This is because of the climate change impact, which causes a considerable increase in the cooling demand. The simulation results demonstrated that almost 45.4% of the cooling load in 2030 can be cut by completely retrofitting the building. This efficiency improvement can also reduce the total electricity demand of the building by 64.5%.

6.4. Discussion and recommendations

The Jim Southee community centre building energy performance was simulated to elaborate the baseline conditions based on the building's construction and operational features and according to the foresight of respective standards and regulations. The results show a relatively high heating and cooling energy consumption. Furthermore, the electricity consumption of appliances, DHW system, and lighting are significant,

References

1. UK Green Building Council, *Climate Change*, in https://www.ukgbc.org/climate-change/ [accessed 7 August 2021].

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Attachment 1

A□achment 2

Fig. A2. Interior view.

Fig. A3. Interior view.

Fig. A4. Kitchen - appliances.

Fig. A5. Kitchen – appliances and hood.