
Officeworks

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: O f ceworks store exterior

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Contents

- Installation of a more e f cient air-cooled chiller or a ground source heat pump (GSHP) could drastically reduce f nal energy consumption for cooling due to its high e f ciency.

2. Regulations, Standards, and guidelines

The regulatory documents and Standards used for the analysis and the proposals are:

3. Introduction

The selected case study building is a typical shopping centre built in Australia, exemplar of many other shopping centres constructed in the same period. In fact, the aim of selecting Underwood O f ceworks is the potential for methodology replication and f ndings expansion to other similar buildings.

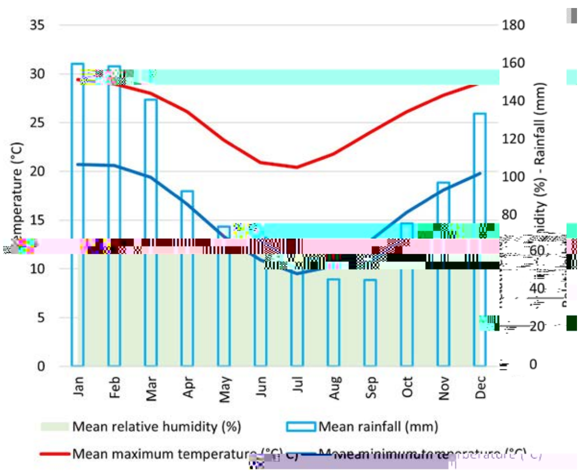
One sample shopping centre cannot wholly represent all similar buildings. Each retail centre has differences; however, even though the required procedure may differ, the logic and methodology presented here offer a high-quality framework to improve the energy e f ciency in such buildings.

Assessing the energy performance of a shopping centre is a complicated task. It starts with determining the building's construction features, including the e f ciency of the building envelope, lighting, HVAC&R equipment etc. Considering the building's features, all calculations were based on the 'as-built' condition of the building

4. Officeworks shopping centre in Underwood

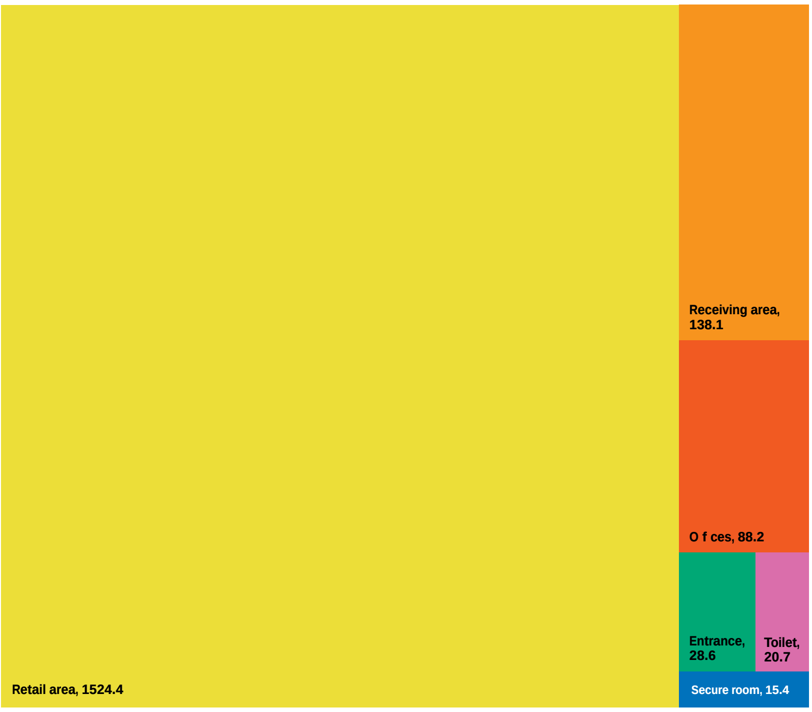
4.1. Case study description

The case study building is located at 183 Kingston Rd, Underwood, QLD 4119 (27.617S, 153.114E). The building is a part of the Zone Underwood complex (20 km south of Brisbane) and has an elevation of 28 meters above mean sea level. In Köppen's climate



This case study building is in a southern Brisbane suburb, and it was refurbished in 2009. The digital National Construction Code of Officeworks is Class 6: a shop or other building used for the sale of goods by retail or the supply of services direct to the public [5]. The shopping centre has a main retail area with a capacity of 150 people. The height of the mentioned building varies between 4.7-7 m. Figure 3 illustrates the treemap chart of the gross internal area of the case study building. The total gross floor area is 1815.4 m².

Electricity is used for HVAC&R purposes, lighting, appliances, and water heating of the case study building. ➔



4.2. Building modelling input parameters

The modelling parameters are a combination of collected data from the building inspection, utility bills and Australian and global standards. In this section, The required hot water for the case study shopping centre is calculated based on Table 2m, NCC volume 1 page 355 [5]. Considering the need for a 50°C temperature increase and water heat capacity (4.19 KJ/kg.°C) and the occupancy schedule of the case study shopping centre, 37.6 MJ of heating energy is required for daily heating domestic water uses.

Demand-side	Occupancy	Unit Hot water demand	Daily hot water demand (lit)
	150	4 lit/person	600

The information regarding the thermal comfort in the studied shopping centre is provided by the Clarence property facility management (CPFM). Lighting and personal heat gain assumptions in the model are based on Australian and international standards.

	Section	Value	Unit	Ref.	Section and page
Cooling setpoint temperature	All	22	°C	[8]	Page 1396
Heating setpoint temperature	All	16	°C	CP FM	-
Personal latent gain	All	55	W/person	[9]	Chapter 18.4
Personal sensible gain	All	75	W/person	[9]	Chapter 18.4
Appliances and equipment gain		5	W/m²	[5]	
Lighting heat gain	Entrance	9	W/m²	[5]	Section J, page 355
	Retail area	14	W/m²		
	Ofces	4.5	W/m²		
	Secure room	4.5	W/m²		
	Receiving area	4.0	W/m²		
	Toilets	3.0	W/m²		

4.2.6. Ventilation and infltration

The thermal comfort parameters have been considered as in Table 7, using the PMV method, according to the National Construction Code.

	HVAC&R	Value	Unit	Ref.	Section and page
Fresh air	On	10	L/s.person	[10]	Appendix A, Table A1
	Off	5	L/s.person		
Infltration	On	1	ACH	[11]	Section 2.7
	Off	0.5	ACH		

The thermal comfort parameters have been considered as in Table 7, using the PMV method, according to the National Construction Code. ➔

Factor	Value	Unit	Ref.	Section and page
Clothing Factor	Summer 0.6 – Winter 1	clo	[12]	Section 5, page 8
Metabolic rate	1.0 0.5			

4.3. Evaluating Lighting Condition

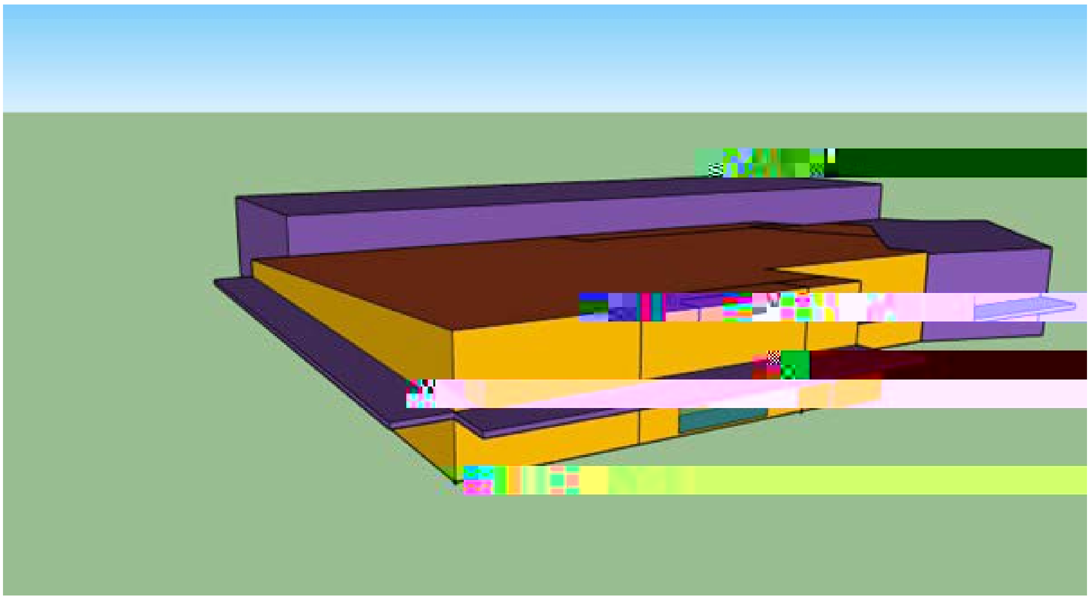
This section aims to recommend appropriate solutions for improving the natural and arti f cial lighting foa ẅ rti f cial ȅighti ĕ s rti f cial lighti˜ ƙ è ṅ я Ч

5. Simulation approach

The simulation includes two main parts. First, the building was defined 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, and civil and mechanical engineering. The model was designed based on actual building dimensions, rotation, and shadings (adjacent building and external shadings). The case study building is defined in the SketchUp model because of the importance of load determination (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 and everything required to simulate the thermal behaviour of the building, such as windows' optical

Installation of a state-of-the-art air-cooled chiller with a coe f cient of performance COP=3.5, which takes into account the distribution and terminal units losses. Here, by state-of-the-art chiller, we refer to top-tier technology available on the market, with high e f ciency and f exible con f guration, to adapt to the project-speci f c requirements.

The GSHP cycle exchanges heat between two thermal reservoirs, one at a relatively high temperature and another at a lower one. The building and the underground temperatures are assumed to be high and low-temperature reservoirs during the hot season, respectively. In the winter period, the building is regarded as a high-temperature reservoir, and the underground is the low-temperature one. Each GSHP system consists of many components. The evaporator, compressor, condenser, and expansion valve are the main components of every GSHP system. Heat gained from the underground is released into the building by means of the condenser in cold seasons, while in summer, the evaporator extracts heat from the area, cooling the indoor air [14].

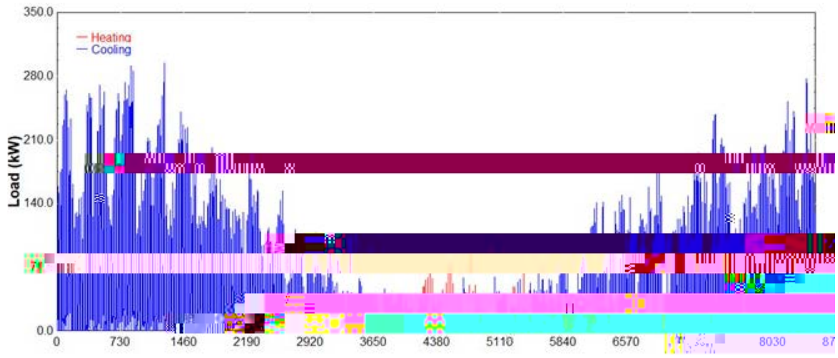
The GSHP considered in retro f tting of case study retail store meets space cooling demands of the building, and it has an average EER=4.8.

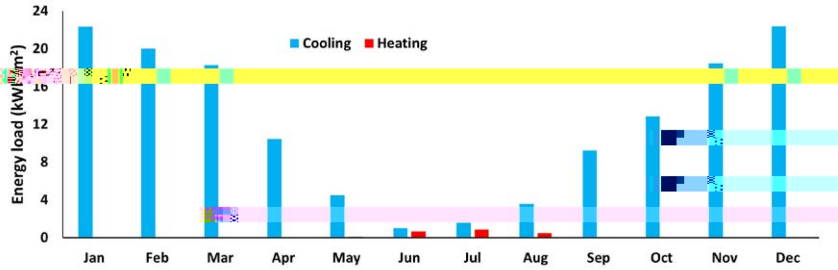
Building use	BAC e f ciency factors f							

6. Results

6.1. Base building modelling

The result of the Of ceworks retail store simulation in Underwood is presented in this section. 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. →



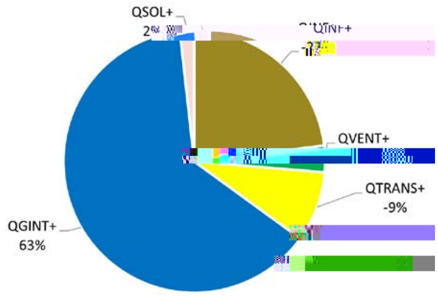


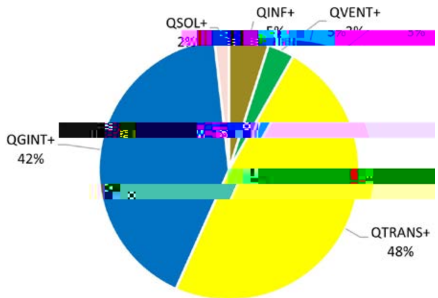
TRNSys calculates thermal loads through an energy balance that affects the air temperature inside the building:

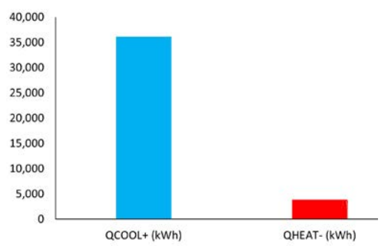
$q_{BAL} = q_{DQAIRdt} + q_{HEAT} - q_{COOL} + q_{INF} + q_{VENT} + q_{TRANS} + q_{GINT} + q_{WGAIN} + q_{SOL}$

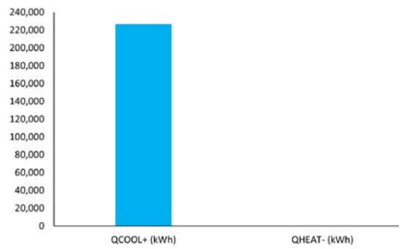
- q_{BAL}: the energy balance for a zone and should always be close to 0;
- $q_{DQAIRdt}$ is the change of internal energy of the zone (calculated using the combined capacitances of the building and the air within it);
- q_{INF} is the gains by infiltration;
- q_{VENT} is the gains by ventilation;
- q_{TRANS} is transmission into the surface from an inner surface node;
- qG_{INT} is internal gains by convection and radiation;
- q_{WGAIN} represents gains by convection and radiation through walls, roof and floor;
- 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.

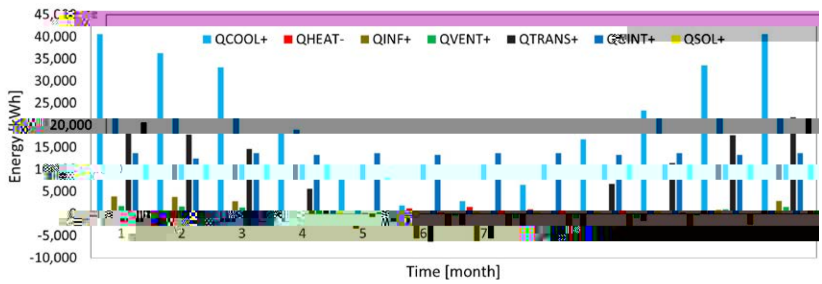
Therefore, the ratio of each parameter in total energy gain can be decided for heating and cooling seasons (Figures 7 and 9). Also, the amount of heating and cooling energy is illustrated in Figures 8 and 10). The monthly energy gain of the shopping centre building and the influence of each factor on the total energy demand is presented in Figure 11. ➔









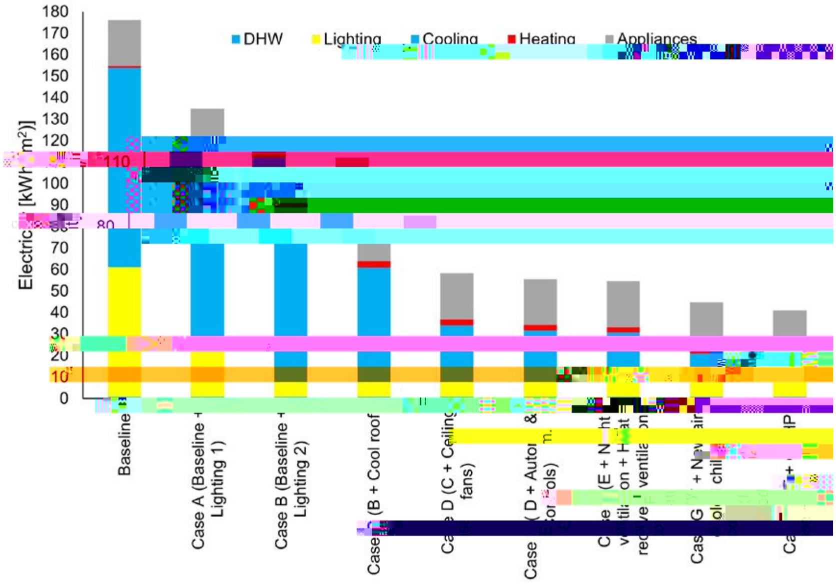


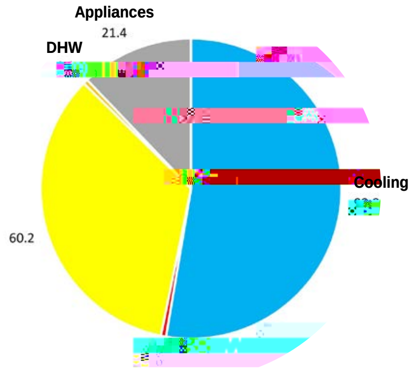
6.2. Retrofit scenarios

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

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. Cooling setpoint and setback temperatures are set according to the NCC. There is no heating system, so extremely low setpoint and setback temperatures are set for heating.
Case A	**Baseline + lighting scenario 1:** 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	**Baseline + lighting scenario 2:** The power density of lighting scenario 1 was combined with continuous dimming of the light sources depending on daylight availability.
Case C	**Case B + cool roof solution:** New cool roof coating with albedo 0.8 (i.e., solar absorbance 0.20) and thermal emittance 0.90. A field-applied solar-reflective coating can be sprayed onto the metal sheeting.
Case D	**Case C + Installation of ceiling fans:** Ceiling fans are modelled by increasing the cooling setpoint temperature to 25°C.
Case E	**Case D + Automation and Controls:** 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 F	**Case E + night ventilation + heat recovery ventilation:** 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°C, the outdoor temperature is greater than 15°C and indoor temperature is greater than 18°C. The efficiency of the heat recovery ventilation is 30%.
Case G	**Case F + New air-cooled chiller:**
Case G	

	Heating loads	Cooling loads	Heating + Cooling	Heating loads	Cooling loads	Heating + Cooling
Unit		kWh/(m²a)			difference (%)	
Case A (Baseline + lighting scenario 1)	2.1	185.6	187.8	-	-	-
Case B (Baseline + lighting scenario 2)	3.0	170.7	173.7	40%	-8%	-7%
Case C (Case B + cool roof tiles)	3.6	163.0	166.6	68%	-12%	-11%
Case D (Case C + ceiling fans)	6.4	197%	-43%	-40%		


DHW
Lighting
Cooling
Heating
Appliances
Electricity [kWh/m2)]
Baseline
Case A (Baseline + Lighting 1)
Case B (Baseline + Lighting 2)
Case C (B + Cool roof)
Case D (C + Ceiling fans)


Appliances
21.4
DHW
Cooling
60.2

2

2

6.3. Future climate simulation

In this section, the case study shopping centre is simulated in 8 representative cities in Australia. CSIRO has current and future weather models. Therefore, this database is selected to investigate the impact of geographical locations and climate change on the case study building energy demand. 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) [15]. The word representative indicates that each RCP provides one of

		Water heating	Heating site energy	Space cooling	Cooling site energy	Lighting site energy	Appliances site energy	Total site electricity demand	Increase in total cooling site energy	Increase in total heating site energy	Increase in total electricity site energy
Location	Period	(kWh/m²)							%		
Adelaide	Present	2.6	6.6	55.9	23.3	43.3	28.9	104.7	-	-	-
	2030	2.6	5.4	62.2	25.9	43.3	28.9	106.1	11.2	-18.2	1.3
Brisbane	Present	2.6	1.8	95.0	39.6	43.3	28.9	116.2	-	-	-
	2030	2.6	1.4	104.6	43.6	43.3	28.9	119.8	10.1	-22.2	3.1
Canberra	Present	2.6	14.5	46.1	19.2	43.3	28.9	108.5	-	-	-
	2030	2.6	12.6	49.4	20.6	43.3	28.9	108.0	7.3	-13.1	-0.5
Darwin	Present	2.6	0.0	194.2	80.9	43.3	28.9	155.7	-	-	-
	2030	2.6	0.0	207.1	86.3	43.3	28.9	161.1	6.7	-	3.5
Melbourne	Present	2.6	11.0	39.4	16.4	43.3	28.9	102.2	-	-	-
	2030	2.6	9.3	44.4	18.5	43.3	28.9	102.6	12.8	-15.5	0.4
Perth	Present	2.6	4.7	73.0	30.4	43.3	28.9	109.9	-	-	-
	2030	2.6	3.8	80.9	33.7	43.3	28.9	112.3	10.9	-19.1	2.2
Sydney	Present	2.6	3.6	61.2	25.5	43.3	28.9	103.9	-	-	-
	2030	2.6	3.0	67.9	28.3	43.3	28.9	106.1	11.0	-16.7	2.1
Hobart	Present	2.6	14.3	26.2	10.9	43.3	28.9	100.0	-	-	-
	2030	2.6	13.0	28.1	11.7	43.3	28.9	99.5	7.3	-9.1	-0.5

centre's total electricity demand would rise by 6.4%. Also, the results show that the cooling load in 2030 can be reduced by 89.2%, in the case of a complete refurbishment of the Officeworks shopping centre. The resulting reduction in the total electricity demand of the building is 77.5%.

		Water heating	Heating site energy	Space cooling	Cooling site energy	Lighting site energy	Appliances site energy	Total site electricity demand	Cooling site energy increase	Heating site energy increase	Total site electricity increase
Location	Period	(kWh/m²)							%		
Melbourne Base case	Present	2.6	11.0	41.0	16.4	43.3	28.9	102.2	-	-	-
	2030	2.6	9.3	46.3	18.5	43.3	28.9	102.6	-12.5%	12.8%	0.4%
Melbourne retrofitted	Present	2.6	3.1	9.3	2.6	0.8	28.9	38.0	-	-	-
	2030	2.6	2.5	10.9	3.1	0.8	28.9	37.8	-10.5%	19.2%	-0.6%

6.4. Discussion and recommendations

We established a baseline for energy consumption, and then we undertook a simulation based on various energy efficiency upgrades. The findings suggest that, in particular, cooling but also lighting energy usage are relatively high. The following suggestions are made to reduce energy consumption:

- The simulations proved that with more efficient artificial light sources, the energy consumption could be reduced by up to 60%. The building does not have windows; thus, there currently is no daylight availability. However, the addition of skylights or light pipes could reduce the lighting energy consumption of the main retail space by 90% approximately.
- The addition of glazed areas on the building roof would have an important effect on the lighting of the space and the reduction of the energy consumption for artificial lighting. It should, however, be stressed that the impact on the thermal comfort and the energy consumption for cooling has not been considered. Also, the cost of adding skylights or light pipes as modifications would be high.
- Installation of cool roof coating with low solar absorbance will lead to a reduction in cooling loads.
- Installing cutting-edge Building Automation and Controls, as well as a Building Management System, to coordinate the use of HVAC&R with both weather and operating requirements.
- Installation of ceiling fans or replacement of the old ones to reduce cooling demands.
- Installation of mechanical ventilation with heat recovery so as to reduce heating loads.
- Implementing night ventilation patterns in the HVAC&R system's operation during the cooling season to reduce cooling demands.
- Installation of an efficient air-cooled chiller or a ground source heat pump (GSHP) to reduce final energy consumption.

In conclusion, a complete renovation package that includes replacement of the building's windows and glazed surfaces, insulation of the external walls and roof, combined with an upgrading of the lighting system, the installation of ceiling fans and the use of night-time ventilation, mechanical ventilation with heat recovery and window shading patterns, linked all with the implementation of a state-of-the-art BAC system, can lead to energy savings of 62.9%, resulting in an energy consumption of 38.0 kWh/m²a, compared to the baseline of 102.2 kWh/m²a. →

In the last retrofit scenario, the cooling site energy is still close to 10 kWh/m^2a, which can be easily covered with onsite renewables. Further savings could be achieved with a solar-reflective coating of the walls, which can be achieved with near-infrared reflective paints without compromising the colour selected by the client. However, this was not considered at this stage as the difference between a conventional blue and a solar-reflective blue is contained, and a small difference in the hue might be involved. Also, further savings can be achieved by further increasing the cooling setpoint to 26°C, which was not considered in this case given the building size and number of required ceiling fans with respect to the occupants. Skylights could deliver further savings in electricity for artificial lighting, but in the case of a retrofit, they would require penetrations through the roof sheeting. Finally, a further measure relates to minimising gaps in the building envelope and more efficient automation and control of the entrance door. In this case, these were not assessed as "low-hanging fruits" as they would require very project-specific cost estimations, which are beyond the scope of this research that uses the case study buildings as generally representative of a building class.

In conclusion, a complete renovation package that includes replacement of the building's windows and glazed surfaces, insulation of the external walls and roof, combined with an upgrading of the lighting system, the installation of ceiling fans and the use of night-time ventilation, mechanical ventilation with heat recovery and window shading patterns, linked all with the implementation of a state-of-the-art BAC system, can lead to energy savings of 62.9%, resulting in an energy consumption of 38.0 kWh/m^2a, compared to the baseline of 102.2 kWh/m^2a.

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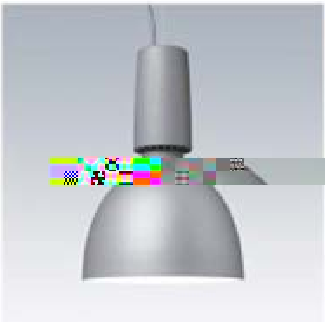
Attachment 1

This attachement contains information about luminaire product used for the main retail space.



Luminaires

Manufacturer	Thorn
Article number	96632195
Product name	GLAC2 L LED3 5000-830 BC E3 GY AL GY
Product group	Anbau- und Pendelleuchten - CLARIS (Pendel)
Mounting type	Pendant
Mounting place	Ceiling
Test mark	CE

Description

A modern and efficient LED pendant lumi[illegible] test, emergency lighting circuit. Housing: die-cast aluminium with satin grey finish. Reflector: grey aluminium with easy bayonet mount connection to housing. Class I electrical, IP20. Suspended via adjustable quick-lock 2.5m single wire [illegible] retardant silicone cable, 8 x 0.75mm². Complete with 3000K LED.

-

Dimensions: Ø348 148 x 485 mm
Total power: 43 W
Weight: 5.1 kg

Model / Variant / Configuration

Number / Name	—

Attachment 2