UNSW
SYDNEY

Hotel

Energy Efficiency Training and Information Project

Commercial Buildings

Sydney
NSW

Research group

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Acknowledgements

The research group thanks the Australian Department of Industry, Science, Energy and Resources for funding this project entitled “Energy Efficiency Training and Information”. The research group thankfully acknowledges Vass Tzavaras (Director of Engineering Australia | Frasers Hospitality Australia) for providing building documentation and data on the case study analysed in this report.

The legal entity for the contract is the University of New South Wales. ABN: 57 195 873 179. UNSW is a GST-registered organisation.

CRICOS Provider Code 00098G

Cover image:
Western view of Fraser Suites, Sydney.

Contents

1. Executive Summary

A complete renovation package ... can lead to energy savings of 57.5%

Existing buildings need to be retrofitted to adapt to global climate change, and their energy efficiency must be improved to avoid vulnerability to volatility in the energy market. Almost 80% of 2050 buildings already exist today [1], and we must prioritise improving the efficiency of existing buildings.

Tourism has been one of the fastest-growing industries in Australia, now restarting after the COVID-19 pandemic. Nowadays, hotels are delivering more facilities and provide many services to customers, resulting in higher energy consumption. More than 80% of the energy consumed in Hotels is connected to heating, ventilation, cooling, lighting, and appliances [2]. This report tackles the operational energy consumption challenge for an existing hotel, using a real-life case study to visualise the impact of each energy optimisation strategy. A high-level framework prioritising different building enhancement methods is presented in this report.

Here, a typical hotel building is considered as a case study to explore opportunities to reduce site energy. A dynamic thermal model of the hotel building is simulated with TRNSys software and then compared with the metered operational energy data. This report summarises the findings of the performed analysis on the existing conditions and provides recommendations for the improvement of the energy performance of the Fraser Suites | 488 Kent St, NSW 2000. It is a high-rise building with structural and energy performance features typical for hotels constructed in the early 2000s.

Most indoor spaces receive high levels of natural lighting close to the perimeter of the building, while areas in the building core, are dimly lit. Artificial lighting currently consists of fixtures with fluorescent or LED lamps and some controls, with a lighting power density close to the levels required by the NCC. Thus, using more efficient light sources and daylight linked controls in the common spaces would reduce the total lighting load (kW) and the annual energy (kWh) ranging from 33 to 80%.

The baseline scenario to determine possible interventions is based on the fact that electricity consumption for cooling requirements is the main problem to tackle, namely 69.2 kWh/m²a. Also, electricity consumption due to the operation of fans and pumps of the HVAC&R systems (30.2 kWh/m²a) is moderately high.

The challenge in this type of high-rise building, with a variety of different users and patterns, lies in not only improving the efficiency of the various separate systems but in improving the overall performance of the systems by interlocking them towards the optimal operation. Therefore, the following recommendations are offered:

- Improvement of the lighting systems by increasing natural lighting uniformity (saves 3.2% of electricity consumption).
- Installation of ceiling fans and introduction of night ventilation patterns in the operation of the HVAC&R system to reduce cooling loads (can decrease by 13.7% the total building electricity consumption).
- Installation of state-of-the-art building automation and controls (BAC), together with a building management system (BMS), to interlock the use of HVAC&R, domestic hot water (DHW), and lighting systems with both the weather conditions and the operational requirements (reduces 17.8% of total electricity consumption).
- Installation of water-efficient faucets, so as to reduce water consumption as such and by means of this also energy consumption for hot water. In addition, the installation of heat exchangers to recover heat from the waste water (can save 25.2% of total natural gas consumption).

- Installation of a natural gas-fired Combined Heat and Power unit, dimensioned on the base of the hot water requirements. This will not reduce final energy consumption, but it will reduce primary energy consumption, and hence the building's carbon footprint.
- Finally, the installation of a ground source heat pump (GSHP) could cut the natural gas need.

In conclusion, a complete renovation package that includes upgrading the lighting system, the installation of ceiling fans and the use of night-time ventilation patterns, linked all with the implementation of the BAC system, can lead to energy savings of 57.5%, resulting in an energy consumption of 69.3 kWh/m^{2}a, compared to the baseline of 163.1 kWh/m^{2}a. Considering the simulated portion of the building, the NABERS rating can be improved from 4.5 to 5.79 stars (estimated, the current rating of the whole building is 4.5 stars).

2. Regulations, Standards, and guidelines

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

- National Construction Code of Australia 2019 Volume One.
- 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: Nonresidential 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
- 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.

3. Introduction

The selected case study building is a typical hotel built in Australia in 2006, representative of several other high-rise hotels built approximately in the same period. Clearly, one sample hotel building cannot completely fit all similar buildings, and each hospitality facility 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 efficiency in such buildings.

Assessing the energy performance of a hotel building is a complicated task. It starts with determining the building's construction features, including the efficiency of the building envelope, the lighting, the HVAC&R equipment, etc. Considering the building's features, all calculations are based on the 'as-built' condition of the building elements (U-values, shading, air-permeability, etc.). The efficiency of the HVAC&R 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 following standards and regulations.

Additionally, two types of specific conditions that have a significant impact on the hotel 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. Fraser Suites in Sydney

4.1. Case study description

4.1.1. Climate

The case study hotel is located at 488 Kent St, Sydney, NSW 2000 (33.874S, 151.205E). The building is in the eastern part of Sydney's central business district, and it is 44 m above sea level. In Köppen's climate classification, Sydney is categorised as Cfa, meaning that it has a humid subtropical climate with mild to cool, short winters and warm, sometimes hot, prolonged summers [3]. The climate of Sydney has no extreme seasonal differences as the weather is moderated by proximity to the ocean. Rainfall is fairly evenly spread throughout the year. However, precipitation is slightly higher during the first half of the year, with an annual mean rainfall of 100.9 mm, and June has the highest rainfall (133.1 mm). Due to its geographical location, the relative humidity is distributed evenly throughout the year (61-74% in the morning and 49-64% in the afternoon). The winters are cool, with overnight minimums averaging 8°C and daily maximums climbing to only 16°C to 18°C on average. Moreover, summers are slightly warm, and the average maximum temperature reaches 26°C in January. The primary climatic information for Sydney is illustrated in Figure 1.

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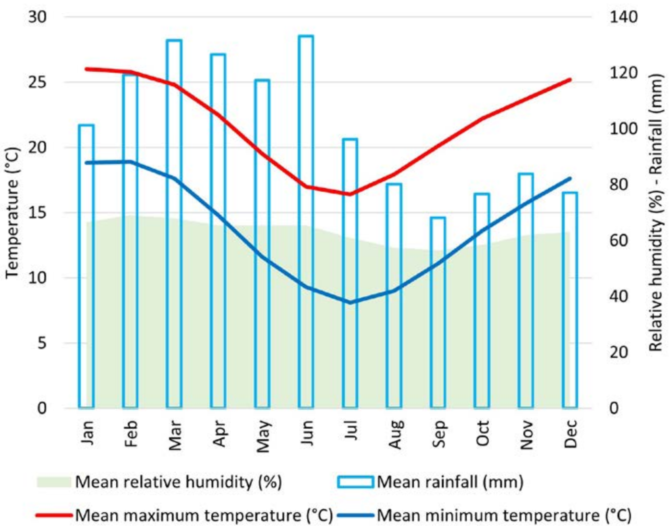

Figure 1. Climatic data of Sydney CBD [4].

4.1.2. Building description

The building was constructed in 2006. The building classification according to the National Construction Code is ‘Class 3: residential building providing long-term or transient accommodation for a number of unrelated persons’ [5]. The building has 43 floors, including 8 parking levels underground. The under-ceiling height for the residential part of Fraser Suites is 3 m. The total gross floor area is 14,586 m². Figure 2 illustrates the treemap chart of the gross internal area of the case study building.

4.1.3. NABERS rating

The hotel building was certified by NABERS Energy 4.5 star in May 2021. Based on the NABERS database, this building energy performance is categorised as “Good”. Its annual energy use is 9,980,996 kWh (38,836 kWh/room) and its annual greenhouse gas emission is 2,073,712 kg CO_2 (8,069 kg CO_2/room). Also, the NABERS Water rating of this building is 3.5 (Average) [6]. →

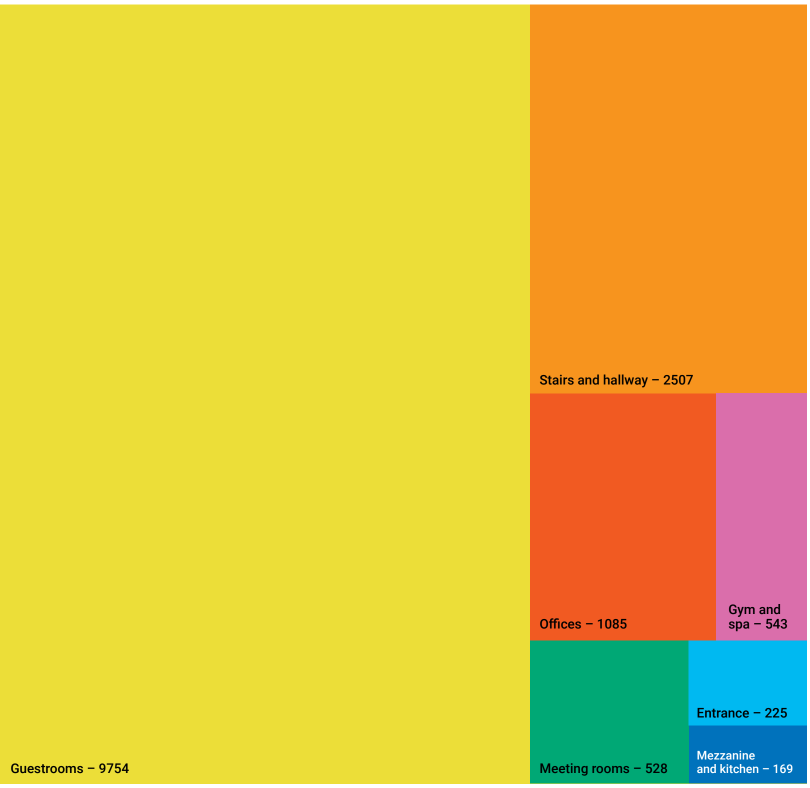

Figure 2. Gross floor divided area of case study building.

4.1.4. Energy consumption and sources

Improving energy efficiency is a practical way to reduce building's operational cost. The case study hotel uses energy as follows:

- For cooling purposes of Fraser Suites, 2 cooling towers were used together with ducted water-cooled packaged air conditioners.
- Also, 2 water heaters were used for space and domestic water heating.

Natural gas is used for heating and food preparation, while electricity is used for other purposes (lighting, appliances, etc.).

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, each modelling assumption will be briefly explained and referenced.

4.2.1. Occupancy

Currently, the Fraser Suites Sydney has 201 guestrooms, and the occupancy schedule is selected based on the national code of construction (Table 10 and Table 11) [5].

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Figure 3. Western view of Fraser Suites Sydney.

4.2.2. Geometric data

The Fraser Suites hotel is divided into 12 major zones for further energy calculation. The considered zones are presented in Table 1. It is noteworthy to mention that the building has 8 parking floors underground, and the ground floor was selected as level 9 in the original drawings.

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 in assessing 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 includes three main layers. There is a concrete block in the outer layer, mineral wool insulation in the middle, and plasterboard inside. The overall R-value of the roof is determined as 1.117 m².K/W. The solar reflectance is considered equal to 0.4. Also, using the average annual wind velocity in Sydney (2.7 m/s) [4], the convective heat transfer coefficient is calculated as 17.6 W/(m².K) [7].

4.2.3.2. Roof

The roof of the case study building consists of six layers. There are ballast gravel and waterproofing bitumen on the top layer, after that concrete and air gap in the middle, and mineral wool insulation and plasterboard inside. The overall R-value of the roof is determined as 1.368 m².K/W. The solar reflectance coefficient is considered equal to 0.25. Also, using the average annual wind velocity in Sydney (2.7 m/s) [4], the convective heat transfer coefficient is calculated as 17.6 W/(m².K) [7].

Table 1. Building geometric information.

Zone	Name	Level	Orientation	Area (m²)	Occupants
1	Entrance	9	South	224.76	24
2	Offices	10	North	542.61	27
3	Kitchen	10	South	62.77	13
4	Mezzanine	10	Central	105.92	74
5	Meeting rooms	11 and 12	South	528.38	140
6	Offices	11	North	542.61	27
7	Gym and Spa	12	North	542.61	30
8	Stairs and hallway	13 - 40	Central	2507.49	20
9	Guestrooms	13 - 40	South	2530.98	253
10	Guestrooms	13 - 40	Northwest	3443.85	344
11	Guestrooms	13 - 40	Northeast	3159	316
12	Guestrooms	41 and 42	West	620.51	62

Table 2. Building Components - Performance Descriptors – Construction – External Walls.

Material	Thickness (mm)	Conductivity (W/m.K)	Capacity (kJ/kg.K)	Density (kg/m³)	Resistance (m².K/W)	Ref.	Section and page
Concrete block	200	0.85	1	1250	-	[5]	Section J, page 388
Mineral wool insulation	30	0.042	1.03	50	-	[8]	Section 8.2, Table 4 Page 18
Plaster board	10	0.17	1	880	-	[5]	Section J, page 388

R-value: 1.117 m².K/W

Table 3. Building Components - Performance Descriptors – Construction – Roof.

Material	Thickness (mm)	Conductivity (W/m.K)	Capacity (kJ/kg.K)	Density (kg/m³)	Resistance (m².K/W)	Ref.	Section and page
Ballast Gravel	150	2.0	0.91	1700	-	[8]	Section 8.3, page 10
Water proofing	4	0.23	1	1100	-	[8]	Section 8.3, page 9
Concrete	200	0.85	1	1250	-	[5]	Section J, page 388
Air cavity	100	-	-	-	0.16	[9]	Section 5.3, page 5
Mineral wool	40	0.042	1.03	50	-	[8]	Section 8.2, Table 4 Page 18
Plaster board	10	0.17	1	880	-	[5]	Section J, page 388

R-value: 1.368 m².K/W

4.2.3.3. Windows

The current windows installed in the Fraser Suites have an aluminium thermally-broken frame, with double glazing Low-E external glass pane. The average U-value for the windows is 1.78 W/m²K, and the SHGC value is 0.66. The selected shading and glazing in the model are presented in Table 4.

4.2.4. Domestic hot water

The required hot water for the guestrooms is calculated based on Table 6, Chapter 50 of ASHRAE Handbook 2015 [11]. Therefore, considering the need for 50°C temperature increase and water heat capacity (4.19 KJ/kg.°C), 1,765 MJ is needed for daily heating domestic water.

4.2.5. Internal gains

The information regarding the thermal comfort in case hotel is provided by the Fraser Suites Facility Management (FSFM). Lighting and personal heat gain assumptions in the model are based on Australian and international standards. →

Table 4. Building Components - Performance Descriptors - Openings Shading.

Shading type & material	External Shading is applied to the windows on the western and eastern sides of building		
Glazing	**Value**	**Unit**	**Ref.**
Thickness	20	mm	[10]
Glazing U-value	1.78	(W/m².K)	
Glazing solar heat gain coefficient	0.66	N/A	
Window frame material	Aluminium	N/A	
Window frame ratio or width	15	%	
Glazing layout – WWR	40	%	
Glazing type	Double glazed	N/A	

Table 5. Domestic hot water.

Demand-side	Value	Unit Hot water demand	Daily hot water demand (lit)
Guestrooms	201 rooms	37.8 lit/unit	7,598
Office, meeting rooms	218 occupants	3.8 gal/person	828
Total hot water demand			8,426

Table 6. Temperature setpoints, lighting and personal heat gain.

	Zone(s)	Value	Unit	Ref.	Section
Cooling setpoint temperature	All	22	°C	FSFM	-
Heating setpoint temperature	All	20	°C	FSFM	-
Personal latent gain	1,2,5,6	55	W/person	[12]	Chapter 18.4
	3,7	185	W/person		
	4,8,9,10,11,12	45	W/person		
Personal sensible gain	1,2,5,6	75	W/person	[12]	Chapter 18.4
	3,7	110	W/person		
	4,8,9,10,11,12	70	W/person		
Lighting heat gain	1, 4	9	W/m²	[5]	Section J, page 379
	2, 5, 6, 8	4.5	W/m²		
	3, 9, 10, 11, 12	4	W/m²		
	7	3	W/m²		

The assumed heat gain for appliances in Fraser Suites is presented in Table 7. The heat rates are based on NCC volume 1, page 355 [5] and chapter 18.12 of ASHRAE Fundamental 2017 [12].

4.2.6. Ventilation and infiltration

The fresh air supplied to each zone and the infiltration are assumed based on international standards.

4.2.7. Thermal Comfort

The thermal comfort parameters have been considered as in Table 9, using the PMV method, according to the National Construction Code. →

Table 7. Building appliances heat gains.

Zone		Microwave	Refrigerator	Freezer	TV 40"	Dishwasher	Computer	Projector	Vending machine	Heat (W)
1	Entrance	0	0	0	0	0	2	0	0	260
2	Offices	1	1	0	1	1	27	1	1	5,969
3	Kitchen	1	1	1	0	1	0	0	0	2,045
4	Mezzanine	0	0	0	0	0	0	0	0	0
5	Meeting rooms	0	0	0	0	0	4	4	0	3,752
6	Offices	1	1		1	1	27	1	1	5,969
7	Gym	0	0	0	0	0	0	0	1	940
8	Stairs and hallway	0	0	0	0	0	0	0	0	0
9	Guestrooms South	54	54	0	54	54	0	0	0	23,652
10	Guestrooms Northwest	54	54	0	54	54	0	0	0	23,652
11	Guestrooms Northeast	54	54	0	54	54	0	0	0	23,652
12	Guestrooms level 41 & 42	2	2	0	2	2	0	0	0	876

Table 8. Ventilation and infiltration.

	Schedule	Value	Unit	Ref.	Section and page
Fresh air	Occupied period	10	L/s.person	[13]	Appendix A, Table A1
	Unoccupied period	5	L/s.person		
Infiltration	Occupied period	1	ACH	[14]	Section 2.7
	Unoccupied period	0.5	ACH		

Table 9. Thermal comfort parameters.

Factor	Value	Unit	Ref.	Section and page
Clothing Factor	Summer 0.6 – Winter 1	clo	[15]	Section 5, page 8
Metabolic rate	1.0	Met	[15]	Section 5, page 7
Relative air velocity	Less than 0.2	m/s	[15]	Section 5, page 11

4.2.8. Energy resources and HVAC&R systems

The total energy demand of this building is provided by electricity and natural gas. Natural gas is used for domestic water heating and space heating operation. Electricity is consumed for lighting, appliances and fans, pumps, cooling system, etc. The guestrooms have a central HVAC&R system, while the other parts of the building have separate HVAC&R systems. Based on the provided drawings and specification, and considering the age of the building, the efficiency of the water boiler is considered as 78%, and the EER of cooling units are considered as 2.0.

4.2.9. Schedules

The schedules of occupancy, lighting and appliances of the residential levels of Fraser Suites are selected based on page 348 of the Australian national construction code [5]. The occupancy, lighting and appliance schedules for common zones 1-8 (offices, entrance, meeting rooms, etc.) are considered based on pages 348-349 in NCC [5].

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Table 10. Occupancy, lighting and appliances schedules for zones 9-12.

Time	Occupancy	Artificial lighting	Appliances and equipment	Air-conditioning
00:00-01:00	0.90	0.05	0.20	On
01:00-02:00	0.90	0.05	0.20	On
02:00-03:00	0.90	0.05	0.15	On
03:00-04:00	0.90	0.05	0.15	On
04:00-05:00	0.90	0.05	0.15	On
05:00-06:00	0.80	0.25	0.15	On
06:00-07:00	0.70	0.80	0.40	On
07:00-08:00	0.60	0.50	0.80	On
08:00-09:00	0.60	0.20	0.50	On
09:00-10:00	0.30	0.20	0.30	On
10:00-11:00	0.10	0.20	0.20	Off
11:00-12:00	0.10	0.20	0.20	Off
12:00-13:00	0.10	0.20	0.20	Off
13:00-14:00	0.10	0.20	0.20	Off
14:00-15:00	0.10	0.20	0.20	Off
15:00-16:00	0.10	0.20	0.20	Off
16:00-17:00	0.20	0.20	0.20	On
17:00-18:00	0.30	0.50	0.40	On
18:00-19:00	0.40	0.50	0.40	On
19:00-20:00	0.50	0.50	0.50	On
20:00-21:00	0.60	0.50	0.60	On
21:00-22:00	0.70	0.50	0.60	On
22:00-23:00	0.90	0.50	0.40	On
23:00-00:00	0.90	0.50	0.20	On

Table 11. Occupancy, lighting and appliances schedules for zones 1-8.

Time	Occupancy	Artificial lighting	Appliances and equipment	Air-conditioning
00:00-01:00	0.0	0.15	0.25	Off
01:00-02:00	0.0	0.15	0.25	Off
02:00-03:00	0.0	0.15	0.25	Off
03:00-04:00	0.0	0.15	0.25	Off
04:00-05:00	0.0	0.15	0.25	Off
05:00-06:00	0.0	0.15	0.25	Off
06:00-07:00	0.0	0.15	0.25	Off
07:00-08:00	0.1	0.40	0.65	On
08:00-09:00	0.2	0.90	080	On
09:00-10:00	0.7	1.00	1.00	On
10:00-11:00	0.7	1.00	1.00	On
11:00-12:00	0.7	1.00	1.00	On
12:00-13:00	0.7	1.00	1.00	On
13:00-14:00	0.7	1.00	1.00	On
14:00-15:00	0.7	1.00	1.00	On
15:00-16:00	0.7	1.00	1.00	On
16:00-17:00	0.7	1.00	1.00	On
17:00-18:00	0.35	0.80	0.80	On
18:00-19:00	0.1	0.60	0.65	Off
19:00-20:00	0.05	0.60	0.55	Off
20:00-21:00	0.05	0.50	0.25	Off
21:00-22:00	0.0	0.15	0.25	Off
22:00-23:00	0.0	0.15	0.25	Off
23:00-00:00	0.0	0.15	0.25	Off

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 Fraser Suites hotel. 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 Frasers Suites in Sydney were the lighting drawings for the guestroom levels and the mechanical drawings for all the levels. Additionally, the characteristics of the LED lamps used to replace conventional incandescent and/or fluorescent lamps in the past were also provided.

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 Australian NCC [5]. Based on the simulation findings, three scenarios were tested. These scenarios are described in Table 12.

4.3.2. Lighting analysis result

Here, the calculation of the existing lighting power density (W/m²) is detailed, and scenarios for the reduction of the energy consumption for lighting are proposed.

4.3.2.1. Natural lighting

The building has large openings in the west and east facades. The natural lighting conditions have been studied in indicative common or working spaces: the level 9 lobby, the north wing of level 10 and the south wing of level 11. The rest of the spaces on levels 10, 11 and 12 are expected to have similar natural lighting conditions to the levels and spaces simulated. The guestrooms are considered to have interior shading elements, and the view outside is necessary, so their natural lighting conditions are not analysed, and exterior shading elements are not recommended.

All the spaces studied have average Daylight Factors above 2%, as they have large windows facing west. However, the uniformity of the natural lighting levels is low, with the levels at the spaces close to the building perimeter being much higher than those at the building core.

Exterior shading of the west-facing windows of the levels hosting communal and working spaces is recommended. Shading would reduce the natural lighting levels in the spaces. However, it would increase uniformity and visual comfort for the building users.

4.3.2.2. Artificial lighting

The management of the hotel provided some information on the artificial lighting of the building. More specifically, the drawings of the guestroom levels' lighting systems, as well as the type and number of LED lamps that replaced conventional lighting a few years ago, were provided. However, the exact as-built positions of the LED lamps are not determined. ■

Table 12. Scenarios for reduced energy consumption for lighting.

Base-case scenario	The lighting power density was considered equal to the maximum density permitted by the NCC for the specific type of space.
Scenario 1	The data provided by the building management for the installed light sources were used where possible.
Scenario 2	More efficient light sources and appropriate lighting controls were used.

Table 13. Mean Daylight Factor (%) of the occupied spaces of the Fraser Suites Sydney.

Space	Average Daylight Factor (%)	Uniformity
Level 9	7.3	0.22
Level 10 – North wing	3.7	1.44
Level 11 – South wing	6.82	0.31

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, civil and mechanical engineering. The model was designed based on actual building dimensions, rotation, and shadings (adjacent building and external venetian blinds) (Figure 4). →

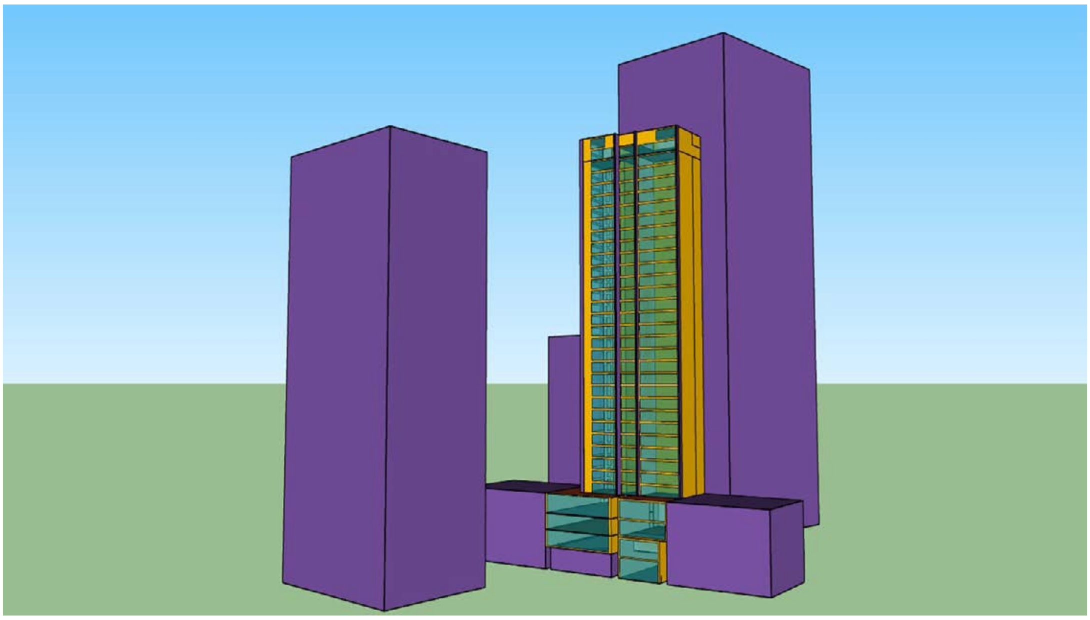

Figure 4. SketchUp model.

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 needed to simulate the thermal behaviour of the building, such as windows optical properties, heating and cooling schedules, etc. [16].

After importing the 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 defined in TRNBuild. By adding the proper climatic data (temperature, relative humidity, radiation, etc.) using the CSIRO weather database, the building model was finalised.

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 the efficiency 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 elements (U-values, shading, air-permeability, etc.), of the HVAC&R system (Coefficient of Performance and Seasonal Energy Efficiency Rating as provided by manufacturers or (for older systems) by regulations), whilst installed lighting and plug loads were determined either by data provided by the building operators or in accordance with standards and regulations.

Additionally, other specific conditions that have a significant impact on the building's performance are: (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.). 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 latter is affected by the aforementioned building's specific operational and microclimate conditions, as well as by the weather conditions of the specific period. In that sense, while the metered consumption values are real, they do not necessarily represent a base for an objective assessment. Therefore, the building has to 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 are carried out with a 1-hour time step, whilst the thermal zoning is based on the differentiation of thermal conditions. This approach not only allows a reliable and cohesive assessment for the specific building but enables using the outcomes as a pilot for further similar projects. →

5.3.1. Lighting retrofit

This section aims to develop scenarios that would enable reduced energy consumption for lighting and provide an approximation of how much energy can be saved. The base-case scenario considers the maximum lighting power density permitted by the NCC for each type of space [5]. For the cases where a range of power densities is allowed, the maximum value is considered (Table 14). On the contrary, Scenarios 1 and 2 aimed to achieve minimum energy consumption. As a result, for 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 [5].

In spaces where no information on the existing lighting equipment was retrieved, and the NCC maximum lighting power density is high, i.e., the entrance/lobby and the mezzanine floor, the assumption that the existing light sources can be replaced with LEDs achieving 2/3 of the NCC maximum permitted lighting power density was made. In spaces for which no information is available on the existing lighting equipment and where the NCC maximum lighting power density is relatively low, i.e., the kitchen and the gym, the lighting power density remains the same for all scenarios. 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 proposed scenarios resulted in a reduction of the total lighting load (kW) and the annual energy (kWh) ranging from 33 to 80% (Table 14).

The spaces that do not present a relevant potential for energy savings are the kitchen and the guestrooms, where the installed power density is relatively low, and lighting controls cannot be implemented (kitchen) or already exist (card readers in guestrooms). The schedules used are presented in Table 10 and Table 11. Also, the area used for the lighting calculations is limited in the vicinity of the windows. →

Table 14. Illumination power density and energy consumption for the base case and the proposed scenarios.

Space	Area	Base case		Scenario 1		Scenario 2	Maximum energy savings achieved (%)
	(m^{2})	Max illuminat. power density (W/m^{2})	Energy consumption (kWh/year)	Max illuminat. power density (W/m^{2})	Energy consumption (kWh/year)	Energy consumption (kWh/year)	
Entrance	224	9	9,812	6	6,546	6,546	33.3
Level 10 Offices	260	4.5	5,690	2.5	3,161	1,572	72.4
Level 11 Offices	260	4.5	5,690	2.5	3,161	1,572	72.4
Kitchen	63	4	1,227	4	1,227	1,227	0
Mezzanine	106	9	4,628	6	3,085	3,085	33.3
Level 11 Meeting rooms	81	4.5	1,781	2.5	990	332	81.4
Level 12 Meeting rooms	120	4.5	2,741	2.5	1523	569	79.2
Gym & Spa	115	3	1,371	3	1,371	487	64.5
Stairs & hallway (L 13-40)	910	4.5	19,879	2	8,835	8,835	55.6
Guestrooms (L 13-40)	9240	4	95,782	4	95,782	95,782	0
Guestrooms (L 41 & 42)	470	4	4,872	4	4,872	4,872	0

5.3.2. Automation and controls

Even HVAC&R systems of the highest efficiency do not run optimally if they do not consider variations in ambient air temperature and solar radiation, the presence of users in the various rooms and the thermal response of the building's envelope. In that sense, one of the most important tools to improve energy efficiency is the use of sensors, automation and control systems that interlock the use of HVAC&R, DHW and lighting systems with both weather conditions and operational requirements. The impact of Building Automation And Control Systems (BACS), along with Building Management Systems (BMS), is expressed and quantified by a series of standards, like the EN ISO 52127 and 15232. According to those standards, four energy efficiency classes (A, B, C, D) are defined to evaluate the performance of the building automation:

- A: high energy performance BACS and BMS
- B: systems with advanced BACS and BMS
- C: standard BACS
- D: non-energy-efficient BACS

Table 15 depicts typical features of the four mentioned classes. The impact of the automation level on the building's energy consumption is also quantified according to EN 15232, as shown in Table 16.

This approach allows a rough evaluation of the impact of BACS systems on the energy performance of the building in a period of a year. The impact of each function (e.g. cooling/heating and lighting) is calculated using the pertinent standards. →

Table 15. Functions and assignment to energy performance classes.

	Heating/Cooling control	Ventilation / Air conditioning control	Lighting Control	Solar protection
A	• Individual room & communication between controllers • Indoor temperature control of distribution network water temperature • Total interlock between heating & cooling control	• Demand/presence dependent airflow control at room level • Variable setpoint with load-dependent compensation of supply temperature • Room/exhaust/supply-air humidity control	Automatic • Daylight control • Occupancy detection manual on / auto off • Occupancy detection manual on / dimmed • Occupancy detection auto on / auto off • Occupancy detection auto on / dimmed	Combined light/blind/HVAC&R control
B	• Individual room control with communication between controllers • Indoor temperature control of distribution network water temperature • Partial interlock between heating & cooling control (dependent on HVAC system)	• Time-dependent airflow control at room level • Variable setpoint with outdoor temperature compensation of supply temperature control • Room/exhaust/supply-air humidity control	Automatic • Daylight control • Occupancy detection manual on / auto off • Occupancy detection manual on / dimmed • Occupancy detection auto on / auto off • Occupancy detection auto on / dimmed	Motorized operation with automatic blind control
C	• Individual room automatic control by thermostatic valves or electronic controller • Outdoor	• Time-dependent airflow control at room level • Constant setpoint of supply temperature control • Supply-air humidity limitation	Manual • Daylight control • On/off switch + additional sweeping extinction signal • Manual on/off	Motorized operation with manual blind control
D	• No automatic control • No control of distribution network water temperature • No interlock between heating and cooling control	No airflow control at room level No supply temperature control No air humidity control	Manual • Daylight control • On/off switch + additional sweeping extinction signal • Manual on/off	Manual operation of blinds

The result of the evaluation is two sets of BAC efficiency factors ($f_{BAC,hc}$ and $f_{BAC,e}$). 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

Even if the building is not of Class C (which is an assessment to be on the safe side), heating, cooling and DHW loads can be reduced by at least 25%, apart from savings achieved due to the refurbishment of building's envelope. Similarly, electrical loads can be reduced by a further 15%.

5.3.3. Ceiling fans

Ceiling fans are a simple and cost-effective method to enhance the indoor air quality in summer and also to 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.

5.3.4. Night ventilation

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.

The applicability of this option is based on the potential of a wall to prevent noise transmission. The proposed scenario will be auto night ventilation between 20:00 and 8:00 in summer with a volume flow rate of 5 ACH and is activated only when the difference between indoor and outdoor temperature is greater than 4°C. →

Table 16. Functions and assignment to energy performance classes for non-residential buildings. Standard automation is used as reference.

	BAC efficiency factors $f_{BAC,hc}$ BAC efficiency factors $f_{BAC,e}$							
	D	C	B	A	Energy saving adopting classes			
Building use	No autom.	Standard autom.	Advanced autom.	Full autom.	D→A	D→B	C→A	C→B
Offices	1.51	1	0.80	0.70	54%	47%	30%	20%
	1.10		0.93	0.87	36%	27%	30%	20%
Lecture Hall	1.24	1	0.75	0.35	60%	40%	50%	25%
	1.06		0.94	0.89	53%	29%	50%	25%
Education buildings (schools)	1.20	1	0.88	0.80	33%	27%	20%	12%
	1.07		0.93	0.86	25%	18%	20%	12%
Hospitals	1.31	1	0.91	0.86	34%	31%	14%	9%
	1.05		0.95	0.90	18%	13%	14%	9%
Hotels	1.31	1	0.85	0.68	48%	43%	32%	25%
	1.04		0.96	0.92	36%	21%	32%	15%
Restaurants	1.23	1	0.77	0.68	45%	37%	32%	23%
	1.08		0.95	0.91	35%	26%	32%	23%
Wholesale and retail	1.56	1	0.73	0.47	62%	53%	40%	27%
	1.08		0.95	0.91	44%	32%	40%	27%

5.3.5. Domestic hot water intervention

Installation of water-efficient faucets and drain water heat recovery are efficient ways to decrease energy consumption. A drain water heat recovery (DWHR) unit can capture almost 60% of that heat and return it to the shower water or the hot-water tank. Such units can also triple the heat recovery rate of a water heater by making hot water available much faster. The efficiency of the heat recovery ventilation is 80%.

5.3.6. Combined Heat and Power unit (CHP)

Hotel energy systems are characterised by high seasonal and daily fluctuations in heat and electricity consumption. Not only does the level of energy demand vary with time, but so does the relationship between the two types of energy. The degree of correlation between the two factors determines the primary energy savings potential of CHP plants and should be used to choose the proper type and sizing of the CHP unit.

The fraction of primary energy savings due to CHP installation must be computed in order to estimate the primary energy savings. A comparison between CHP and a reference system of isolated power and heat production is used to analyse the primary energy savings of CHP. In our case, we should compare the primary energy consumption for cooling (Australian primary energy conversion factor for electricity) and the primary energy consumption of the installed heating system (gas boiler) with the primary energy consumption of the coupled supply system (CHP).

5.3.7. Ground Source heat pump (GSHP)

The GSHP cycle exchanges heat between two thermal reservoirs, one at a relatively high temperature and another at a lower one. Actually, the building and the underground temperatures are assumed to be high and low-temperature reservoirs during the hot season, respectively. In winter, 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, which should be cooled [17].

The GSHP considered in retrofitting Fraser Suites Sydney meets space heating, cooling and DHW demands, and it has an average COP=3 and EER=2.8, including losses of the distribution network and terminal units. ■

6. Results

6.1. Base building modelling

The results of the energy simulations of the Fraser Suites in Sydney are 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. ➔

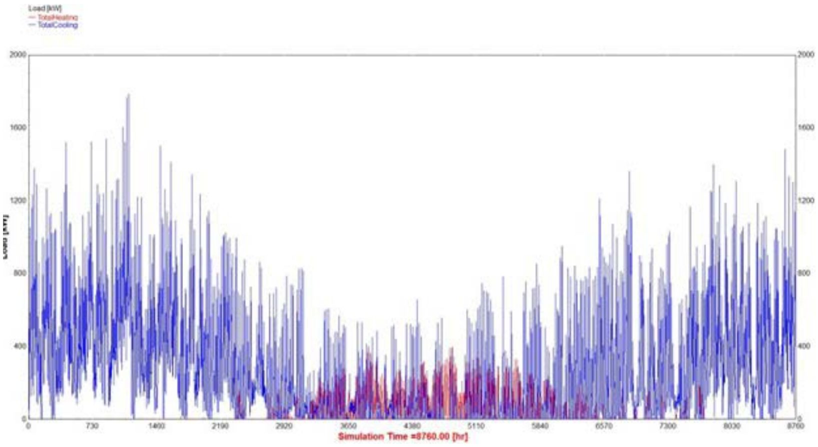

Figure 5. Hourly energy demand for HVAC&R purposes.

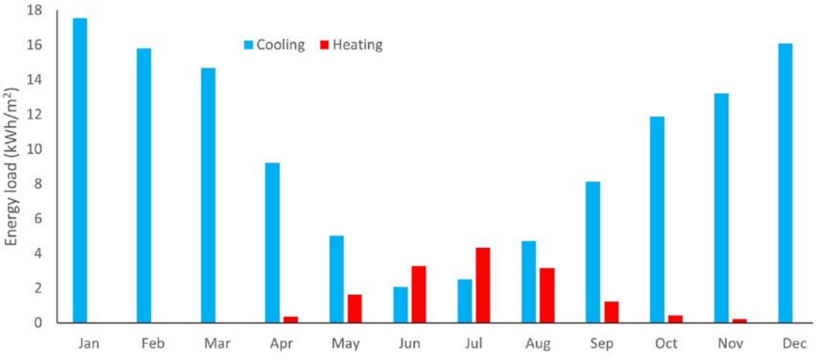

Figure 6. Monthly energy demand for HVAC purposes.

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 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 (Figure 7 and Figure 9). Also, the amount of heating and cooling energy is illustrated in Figures 8 and 10. ➔

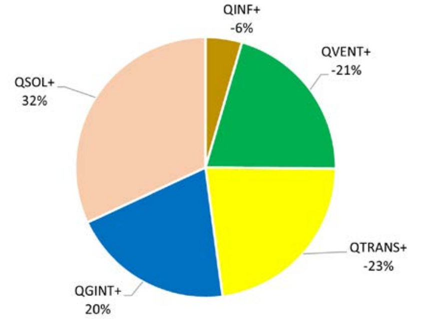

Figure 7. Whole building energy gain – heating season (May - September).

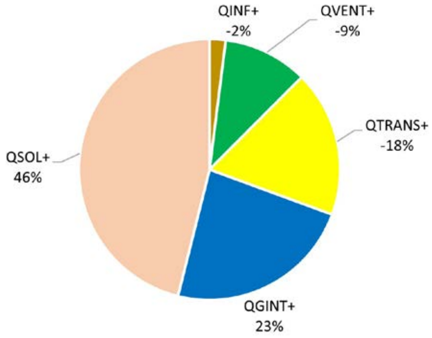

Figure 9. Whole building energy gain – cooling season (October - April).

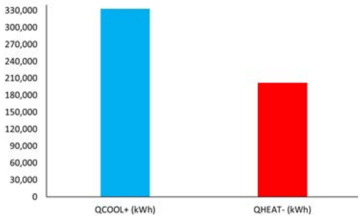

Figure 8. Whole building energy gain for heating and cooling load – heating season (May-September).

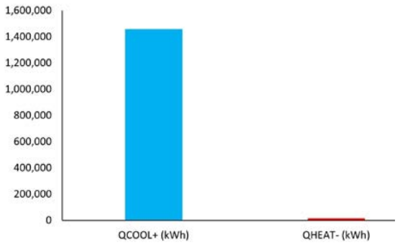

Figure 10. Whole building energy gain for heating and cooling load - cooling season (October-April).

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

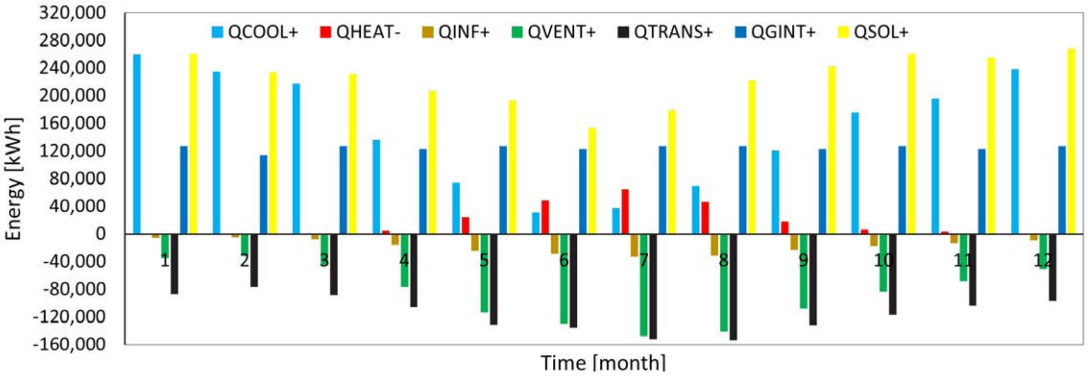

Figure 11. Monthly building energy gain.

6.2. Retrofit scenarios

The investigated retrofit cases in this report are presented in Table 17. ➔

Table 17. Retrofit scenarios.

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: Power density of lighting scenario 1 combined with continuous dimming of the light sources depending on daylight availability in: Level 10 and 11 offices, Level 11 and 12 Meeting rooms and in the gym.
Case C	Case B + 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 D	Case C + Installation of ceiling fans: Ceiling fans are modelled by increasing the cooling setpoint temperature to 26°C.
Case E	Case D + night ventilation++ window shading: Night ventilation takes place between 20:00 and 8:00, with an additional flow rate of 4 ACH. It 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 the indoor temperature is greater than the heating setpoint. Window shading is modelled by applying a shading factor of 0.7 during the cooling period (October-April).
Case F	Case E + DHW interventions: Installation of water-efficient faucets and water heat recovery systems.
Case G	Case F + CHP: Installation of a CHP designed mainly for the DHW preparation and in parallel electricity production.
Case H	Case I + GSHP: The GSHP meets space heating, cooling and DHW demands, and it has an average COP=3 and EER=2.8, including losses of the distribution network and terminal units.

Between the presented scenarios, Case H has the most retrofitting steps. Table 18 shows the influence of different retrofitting cases on heating and cooling loads. Also, Table 19 demonstrates the impact of different retrofit scenarios on electricity and natural gas consumption in the case study hotel. The result indicates that by improving the building condition, 53.1% of the required electricity can be reduced without any need for natural gas. A more detailed illustration of the retrofitting impact is presented in Figures 12-14. →

Table 18. Simulation results – heating and cooling loads.

	Heating loads	Cooling loads	Heating + Cooling	Heating loads	Cooling loads	Heating + Cooling
Unit	kWh/(m^{2}a)			difference (%)		
Baseline	14.7	145.4	160.1	-	-	-
Case A (Baseline + lighting scenario 1)	15.0	143.1	158.1	2%	-2%	-1%
Case B (Baseline + lighting scenario 2)	15.1	142.5	157.5	2%	-2%	-2%
Case C (Case B + automation & controls)	15.1	142.5	157.5	2%	-2%	-2%
Case D (Case C + ceiling fans)	14.4	90.7	105.2	-2%	-38%	-34%
Case E (Case D + night ventilation + window shading)	15.9	40.6	56.5	8%	-72%	-65%
Case F (Case E + DHW interventions)	15.9	40.6	56.5	8%	-72%	-65%
Case G (Case F +CHP)	15.9	40.6	56.5	8%	-72%	-65%
Case H (Case G +GSHP)	15.9	40.6	56.5	8%	-72%	-65%

Table 19. Simulation results - Site energy.

	Heating	Cooling	Lighting	DHW	Appliances	Pumps & Fans	Total	Total difference	Total difference	Total gas	Total electricity
Unit	kWh/(m^{2}a)								%	kWh/(m^{2}a)	
Baseline	7.0	69.2	21.4	15.5	19.9	30.2	163.1	0.0	0%	15.5	147.7
Case A (Baseline + lighting scenario 1)	7.1	68.1	17.8	15.5	19.9	30.0	158.4	-4.7	-2.9%	15.5	142.9
Case B (Baseline + lighting scenario 2)	7.2	67.8	16.9	15.5	19.9	29.9	157.2	-5.9	-3.6%	15.5	141.8
Case C (Case B + automation & controls)	4.9	46.1	16.9	15.5	19.9	24.9	128.2	-34.9	-21.4%	15.5	112.7
Case D (Case C + ceiling fans)	4.7	29.4	16.9	15.5	19.9	21.3	107.7	-55.4	-34.0%	15.5	92.2
Case E (Case D + night ventilation + window shading)	5.1	13.1	16.9	15.5	19.9	18.0	88.6	-74.5	-45.7%	15.5	73.1
Case F (Case E + DHW interventions)	5.1	13.1	16.9	11.6	19.9	17.7	84.4	-78.7	-48.2%	11.6	72.8
Case G (Case F +CHP)	5.1	13.1	16.9	11.6	19.9	17.7	84.4	-78.7	-48.2%	11.6	72.8
Case H (Case G +GSHP)	3.6	9.9	16.9	3.0	19.9	16.0	69.3	-93.8	-57.5%	0.0	69.3

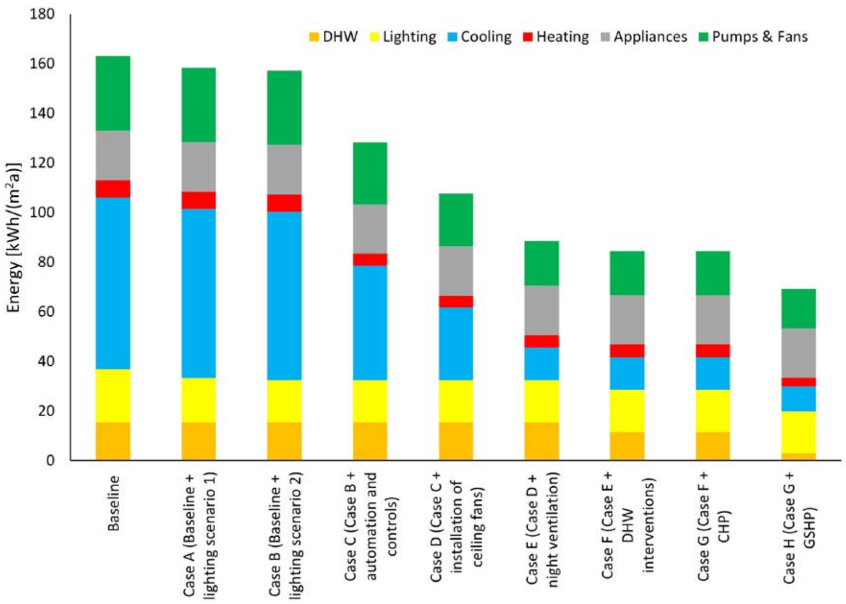

Figure 12. Site energy of the retrofit scenarios.

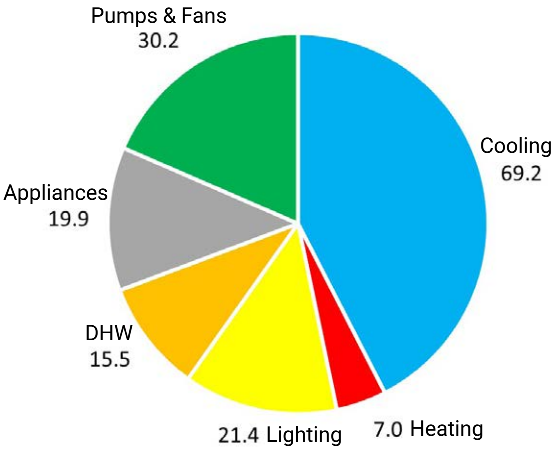

Figure 13. Share of site energy for the baseline (kWh/m²a).

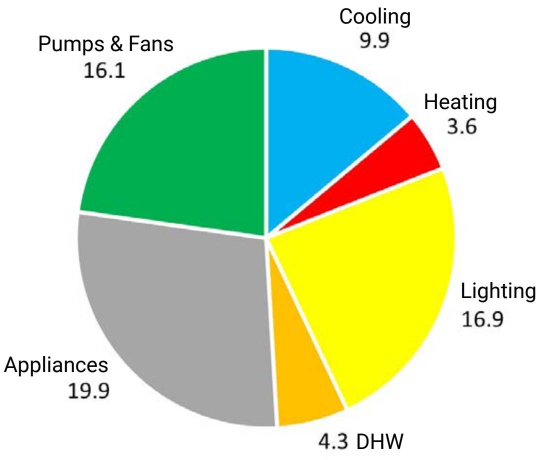

Figure 14. Share of Site energy for retrofit scenario – case H (kWh/m²a).

6.3. Future climate simulation

In this section, the case study hotel building 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)[18]. The word representative indicates that each RCP provides one of many possible scenarios that would lead to a specific 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/m^2 after 2100.

Table 20 presents the energy load and final energy demand by the hotel building in 8 representative cities, where the cooling site energy will rise between 6.4-31.8% by 2030. This considerable amount of energy demand for cooling would cause up to a 17.0% rise in total electricity demand in representative cities by 2030.

To evaluate the impact of retrofitting the case study hotel building, the base case and highly retrofitted scenario (Case H) are simulated in Sydney. As presented in Table 21, the total base case site energy will rise sharply until 2030. This is because of the climate change impact, which causes a considerable increase in the cooling demand. The simulation result demonstrated that the total hotel electricity demand will rise by 9.1%. Also, the result shows that almost 84.5% 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 56.4%. ➔

Table 20. Current and future energy demand of the case study hotel building based on CSIRO weather database.

Location	Period	Water heating	Heating site energy	Cooling site energy	Lighting site energy	Appliances site energy	Pumps & fans	Total site electricity demand	Natural gas demand	Increase in total cooling site energy	Increase in total heating site energy	Increase in total electricity site energy
		(kWh/m^2)								%		
Adelaide	Present	15.5	12.8	60.4	21.4	19.9	28.3	142.8	15.5	-	-	-
	2030	15.5	10.6	66.9	21.4	19.9	29.2	148.0	26.1	10.8	-17.2	3.6
Brisbane	Present	15.5	4.7	89.0	21.4	19.9	36.5	171.5	20.2	-	-	-
	2030	15.5	3.7	117.3	21.4	19.9	38.4	200.7	19.2	31.8	-21.3	17.0
Canberra	Present	15.5	31.0	43.8	21.4	19.9	28.7	144.8	46.5	-	-	-
	2030	15.5	27.4	48.3	21.4	19.9	28.9	145.9	42.9	10.3	-11.6	0.8
Darwin	Present	15.5	0.0	221.9	21.4	19.9	59.6	322.8	15.5	-	-	-
	2030	15.5	0.0	236.1	21.4	19.9	62.6	340.0	15.5	6.4	0.0	5.3
Melbourne	Present	15.5	22.3	39.4	21.4	19.9	25.9	128.9	37.8	-	-	-
	2030	15.5	18.9	45.0	21.4	19.9	26.4	131.6	34.4	14.2	-15.2	2.1
Perth	Present	15.5	10.6	76.3	21.4	19.9	31.2	159.4	26.1	-	-	-
	2030	15.5	8.6	84.8	21.4	19.9	32.6	167.3	24.1	11.1	-18.9	5.0
Sydney	Present	15.5	7.0	69.2	21.4	19.9	30.2	147.7	22.5	-	-	-
	2030	15.5	5.0	78.0	21.4	19.9	31.6	155.9	20.5	12.7	-28.6	5.6
Hobart	Present	15.5	27.1	25.0	21.4	19.9	23.9	117.3	42.6	-	-	-
	2030	15.5	24.5	27.6	21.4	19.9	23.9	117.3	40.0	10.4	-9.6	0.0

Table 21. The comparison between the base case and fully retrofitted scenario.

Location	Period	Water heating	Space heating	Space cooling	Cooling site energy	Lighting site energy	Appliances site energy	Pumps & fans	Total site electricity demand	Natural gas demand	Cooling site energy increase	Heating site energy increase	Total site electricity increase
		(kWh/m^2)									%		
Sydney Base case	Present	15.5	7.0	145.4	69.2	21.4	19.9	30.2	147.7	15.5			
	2030	15.5	5.0	163.8	78.0	21.4	19.9	31.6	162.4	15.5	12.7	9.1	-8.9
Sydney retrofitted	Present	3.0	3.6	40.6	9.9	16.9	19.9	16.0	69.3	0			
	2030	3.0	2.6	49.7	12.1	16.9	19.9	16.9	70.8	0	22.2	2.2	-15.2

6.4. Discussion and recommendations

We established a baseline for energy consumption, and then we undertook a simulation based on various energy efficiency upgrades, with assumptions in accordance with the relevant standards and regulations. The results show relatively high cooling energy consumption. Furthermore, the electricity consumption of appliances, fans and pumps of the HVAC&R and DHW systems and lighting, as well as the energy required for the hot water production, are significant, too. The following efficiency measures are suggested:

- The simulations proved that the natural lighting levels in the building are high, but the glazed areas are not appropriately shaded.
- The artificial lighting analysis showed that the replacement of inefficient light sources and the use of daylight linked controls can result in a reduction of the total lighting load (kW) and the annual energy (kWh) ranging from 33 to 80%.
- Installation of ceiling fans to reduce cooling loads.
- Installation of water-efficient faucets to reduce water consumption as well as the energy consumption for hot water and electricity for the pumps. In addition, the installation of shower drains water heat recovery systems to make use of the waste heat during showers.
- Another option would be the installation of a natural gas-fired Combined Heat and Power unit, dimensioned on the base of the hot water requirements. This will not reduce final energy consumption, but it will reduce primary energy consumption, and hence the building’s carbon footprint.
- Installation of state-of-the-art Building Automation and Controls, together with a Building Management System, to interlock the use of HVAC&R, DHW and lighting systems with both the weather conditions and operational requirements.

In conclusion, a complete renovation package that includes upgrading of the lighting system, and the installation of ceiling fans, linked all with the implementation of a state-of-the-art BAC system, can lead to energy savings of 57.5%, resulting in an energy consumption of 69.3 kWh/m^{2}a, compared to the baseline of 163.1 kWh/m^{2}a. Considering the simulated portion of the building, the NABERS energy rating can be improved from 4.5 to 5.79 stars (estimated). ■

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Attachment 1

The following figure shows daylight factor distribution in Fraser Suites Sydney.

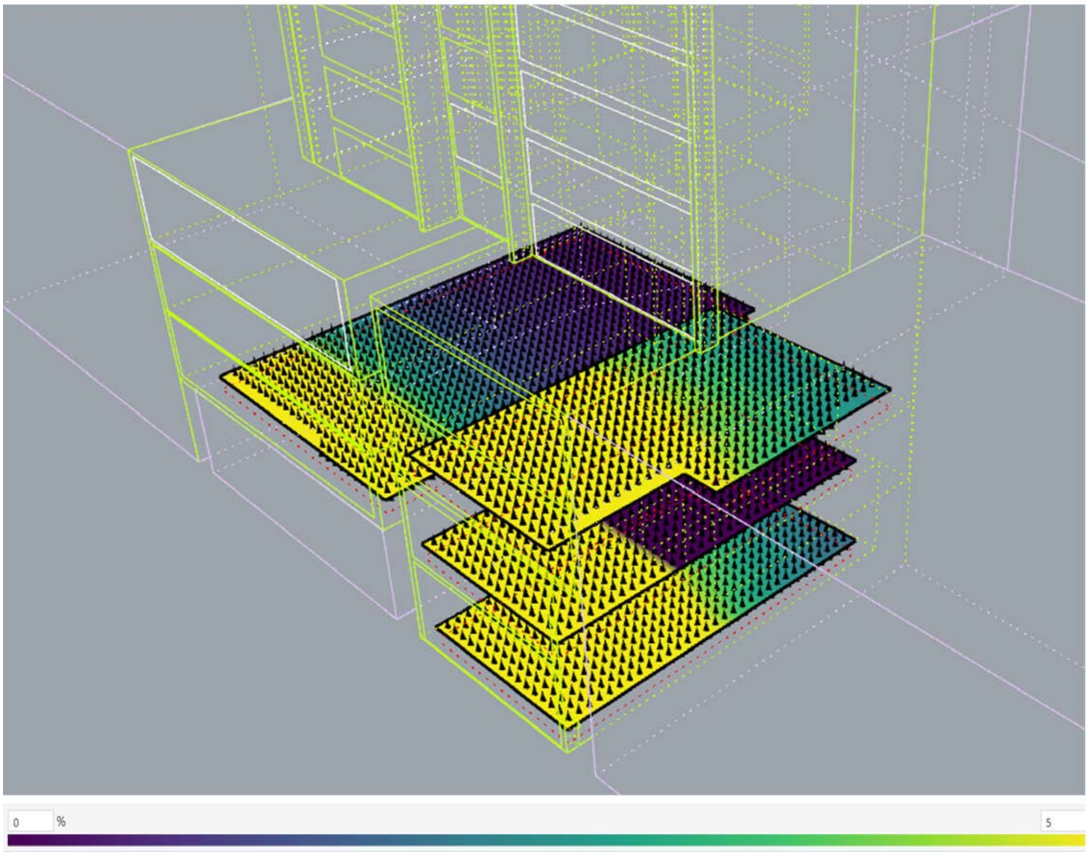

Fig. A1. Distribution of Average Daylight Factor in levels 9-11.

Attachment 2

This section demonstrates all the input information used for Energy modelling of 488 Kent St, Sydney. The data was provided by Hotel facility management and including, site photos floor plans, elevations, etc.

Fig. A2. Exterior view of the building.

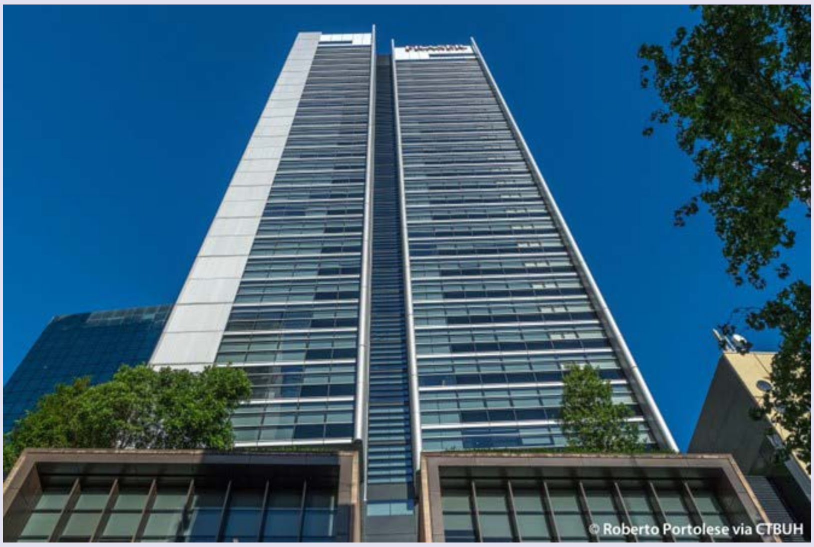

Fig. A3. Exterior view of the building.

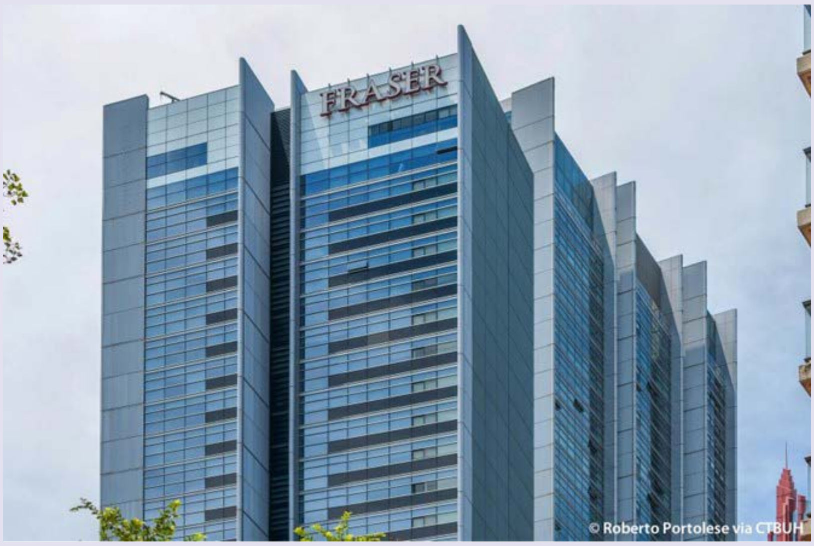

Fig. A4. Exterior view of the building.