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Environmentally Sustainable Design Feature Proposal -210 Cardigan Street

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Abstract

Responding to the environmental change and the increased cost of energy, Environmentally Sustainable Design (ESD) gradually becomes a critical part in designing. Providing healthier, more comfortable and productive environments for building occupants, Sustainable design seeks to minimize waste, reduce energy costs and improve building performance. The purpose of this report is to recommend Environmentally Sustainable Design (ESD) features for our clients' building with the intention of reducing energy and water consumption, promote a more sustainable practice and improving the comfort of the building within capital cost constraints.

Keywords

Sustainable Design; Building; Energy.

1. Introduction

Our clients want to re-brand an old four-story office building which is located at 210 Cardigan Street, Carlton. This four-story office will be refurbished while maintaining the structural elements into a 5 stars Green Star building as a new marketing company headquarters. This building will strive to be a model green building within Melbourne and is aligned with the Urban Forest Strategy which is set out by Melbourne City Council.

This proposal incorporates four main criteria, which our clients prioritize are considered with their weighting as follows: Operational Cost Saving (35%), Environmental Impact (25%), Comfort (20%) and Capital Cost (20%). These criteria will determine which design system we propose within this report.

2. Building Analysis

The existing building is used as the base case. The base case allows for an identification of existing problems encountered by the building which is hindering it from performing efficiently. From the analysis, we have identified that a largest energy consumption within the building is from the existing interior fittings which is 50% of energy used, followed by building heating which makes up 32% of energy used annually. Various factors which contribute to this high energy consumption are as listed below.

The proposed project which is located at 210 Cardigan Street has unobstructed views on all four facade as it is detached and surrounded by low rise buildings. However, the insulation and air tightness of the existing building is poor, resulting a large amount of heating and cooling energy of the building to be loss to the building exterior. The building shading used in the previous building is also inefficient as it is a generic overhang that is being installed and does not compliment the openings of the building. For the building to perform optimally and provide desired comfort level, all four facade has to be considered with equal importance.

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The HVAC system of the existing building is also one of the main reasons why the building is performing poorly. The existing building uses a traditional VAV system to heat and cool the building, which is inefficient and loses a lot of energy to the surroundings and not providing heating and cooling optimally. Inefficiency within the heating and cooling of the building not only comes from the air distribution system but also the various equipment such as boiler, chiller and heat rejection.

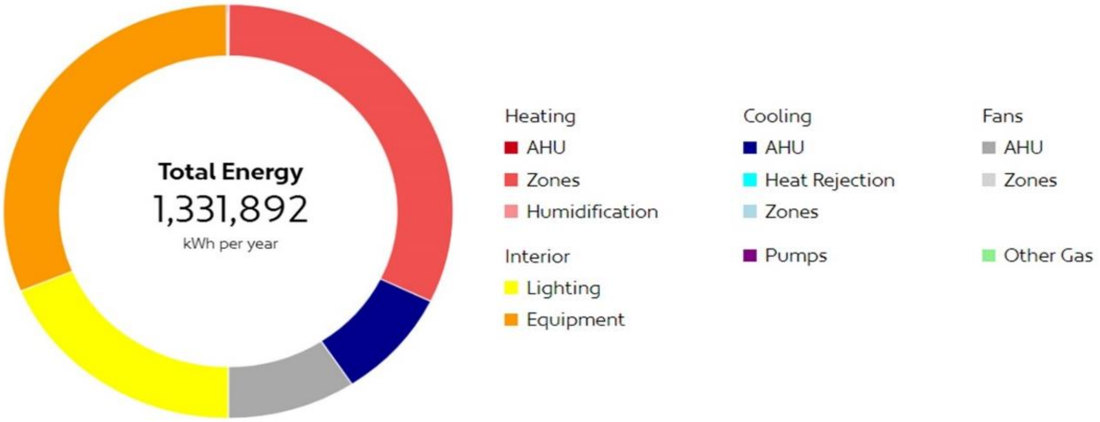

Fig. 1 Base case energy performance

Strategies	Operational cost saving	Environmental Impact	Comfort	Capital cost saving	Final score
Heat recovery + fresh air	★★★★★	★★★	★★★★	★★★★	16
Green roof	★★	★★★★★	★★★★★	★★★	15
Heating + Cooling + Heat rejection	★★★	★★★	★★★★	★★★	14
Equipment + Lighting density	★★★★	★★★	★★★	★★★	13
Photovoltaic louvers	★★★	★★★★	★★★★	★★	13
Zoning + Air distribution	★★★★	★★	★★★	★★★★	13
Insulation	★★★★	★★	★★★★	★★	12
Rain water collection	★★★★	★★★★★	★	★★	12
Glazing	★★★★	★★	★★★★	★	11
Window to wall ratio	★★★	★	★★★★	★★★	11
Underfloor air distribution	★★★	★★	★★★	★★	10
Internal venetian shading	★★★	★★	★★★	★★	10
Orientation	★★★	★	★★★	★★	9
Openable window ratio	★★★	★★	★	★★★	9
Solar hot water	★★★	★★★	★	★★	9
Sky light	★	★★	★★★★★	★	9
Night purge	★★	★★★	★★	★★	9
Wind turbine	★★	★★★★	★	★	8
Grey water storage	★★	★★★	★	★★	8
Stack Ventilation (atrium)	★★	★★	★★★	★	8
Thermal mass	★★	★	★	★★★★	8
Overhang shading	★★	★	★★★	★★	8
Infiltration	★★	★	★★	★★★	8
Black water treatment	★	★★★	★	★	6

Fig. 2 Various ESD strategies have been evaluated and compared

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The structure of the building is still in good condition and is capable of being redesigned to perform as a high performance green building. By keeping the existing structure, a large amount of capital cost can be saved due to minimal demolition work. By reducing the capital cost, new sustainable building systems that did not exist within the previous building can be introduced to achieve a 5 star Green Star Rating and still stay within the project budget. As shown in Figure 1.

3. Assessment of Strategies

Various ESD strategies have been evaluated and compared. The strategies are graded and proposed according to the following weightage: Operational Cost Saving (35%), Environmental Impact (25%), Comfort (20%) and Capital Cost (20%). As shown in Figure 2.

3.1 Zoning + Air Distribution

Choosing an efficient air distribution system and dividing them efficiently to ensure the entire indoor environmental building meets the comfort level is crucial. The old building design is using a traditional VAV-return air package system which is not efficient in keeping the indoor environment at desired levels, while experiencing a lot of energy loss during heat transmission.

Passive and active chilled beams are proposed as an alternative to replace the old VAV system. A VAV system uses air ducts to transfer heat from the chiller or boiler to the air handling unit (AHU) which then pushes hot or cold air all the way to targeted spaces. As this air travels through the air ducts, a lot of heat is loss through the air ducts and vibration of the ducts which produces noise. Chilled beams transfer heat to or away from targeted spaces through hot or cold water pipes respectively. Water pumps uses less energy compared to AHU and are used to allow a constant flow or water through this system. Water pipes are a more energy efficient way of heat transfer and can be easily insulated compared to air ducts. This makes the chilled beams loose less energy as it travels from the chiller or boiler and produces less noise. These water pipes are then channeled through the chilled beams system where a fan blows and transfer this heat to or away from the space.

This air distribution system can be divided into various zones to be controlled optimally. Zoning is divided 4m along the building perimeter, separating the perimeter zone and the core zone which have different heating requirements. Areas along the building perimeter are easily affected by external building conditions and are more difficult to control, unlike the core zone which is more stable. Passive chilled beams are used in the core zone while active chilled beams are used to regulate comfort of the perimeter zone. This allows for a more energy efficient temperature control for each floor level and reduces the energy consumption used to heat and cool spaces. As shown in Figure 3.

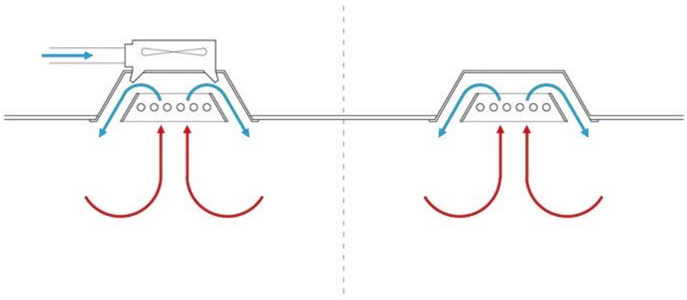

Fig. 3 Active chilled beam located in perimeter zone while passive chilled beam located in core zone

By dividing the heating and cooling into zones and distributing it through insulated water pipes and chilled beam system, the energy consumption of the building is reduced by drastically from 1,331,892 kWh to 1,035,909 kWh. This reduces the operational cost of the building by 22% while providing a more comfortable environment for the users. As shown in Figure 4.

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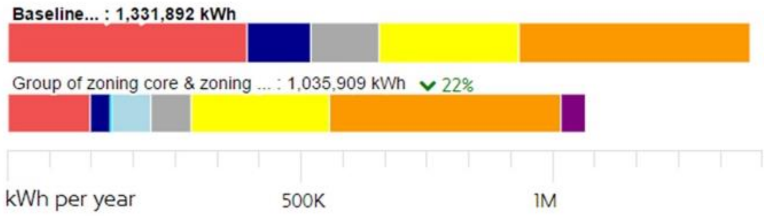

Fig. 4 Energy reduction of chilled beams compared to VAV system

3.2 Heating + Cooling + Heat Rejection

Heating and cooling is the major factor in why the old building design is performing inefficiently. This system can be broken down into multiple components to be analyzed and improved individually to form a more efficient HVAC system. As shown in Figure 5.

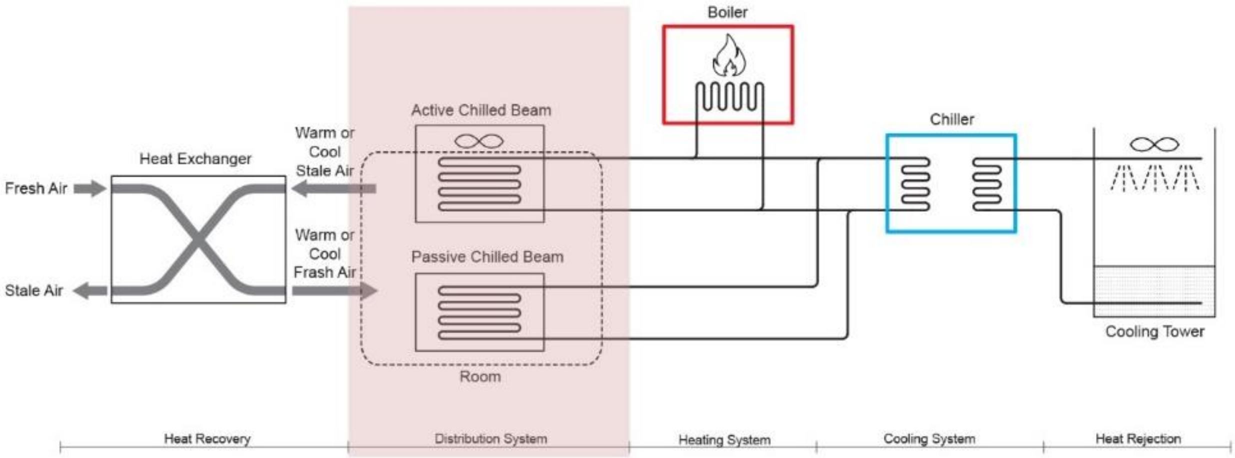

Fig. 5 Chilled beam system located within HVAC

Efficient heating of a building requires a high performance boiler. There are two main types of boilers, namely gas fired boiler and electrical boiler. We would like to propose using a gas fired boiler due to a lower operating cost. Using methane as a natural gas to fuel a boiler is cheaper compared to using electricity. Natural gases are also more environmental friendly compared to electrical energy which are generated in power plants by burning fossil fuels. The building requires a heating equipment capacity of 327.6 kW which can be supplied by 4 units of Dunkirk DKVLT series1 gas fired boilers. These gas fired boilers have a Coefficient of Performance (COP) of 95% and is rated under ENERGY STAR as most efficient boiler 2017, compared to conventional boilers which only reaches 85%. The gas fired boiler will supply hot water to targeted spaces at 80oC with a peak distribution efficiency of 0.85. As shown in Figure 6.

There are also two major types of refrigerant system that can be used to cool a building, which are vapor compression system and vapor absorption system. A vapor compression system has a higher COP compared to vapor absorption system. YK Centrifugal water chiller2 by Johnson Controls can supply up to 661 kW of cooling equipment capacity needed to cool the building. The proposed chiller is a more environmentally responsible model compared to regular chillers as it’s refrigerant has zero ozone depletion and a low impact on global-warming. YL Centrifugal chiller has a COP of 6, which is capable of reducing annual energy cost up to 30%. The chiller will supply cold water to targeted spaces at 7oC with a peak distribution efficiency of 0.9. As shown in Figure 7.

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Fig. 6 Dunkirk DKVLT series boiler

Fig. 7 YK Centrifugal water chiller

Efficient heat rejection system is also important in keeping the chiller functioning at high performance. Due to site constraints, using a cooling tower is the most viable option, as it is easy to install and maintain. Options such as underground heat rejection and split system has a COP of 6 and 3 respectively compared to a cooling tower with a COP of 10. The building requires a heat rejection capacity of 853.9 kW and can be supplied by Baltimore Air Coil Series 30003 cooling tower. This cooling tower uses axial fans to reject heat which is two times more efficient that cooling towers which uses centrifugal-forced draft. As shown in Figure 8.

Fig. 8 Baltimore Air Coil Series 3000 cooling tower

By replacing these 3 components within the HVAC system, the energy consumption used to heat the building can be reduced by 15% from 155,260 kWh to 130,745 kWh and cooling can be reduced by 32% from 126,696 kWh to 85,508 kWh. As shown in Figure 9. Using a more energy efficient HVAC system not only reduces operational cost, but also have a better environmental impact. As shown in Figure 10.

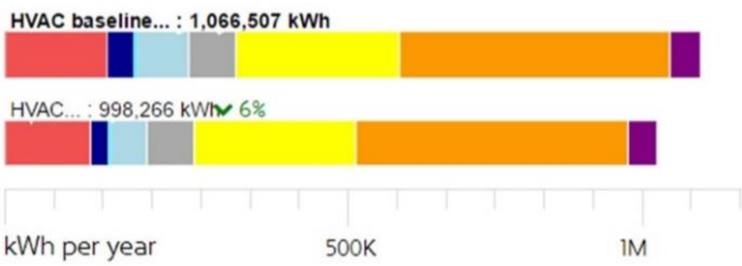

Fig. 9 Energy consumption of proposed boiler, chiller and cooling tower

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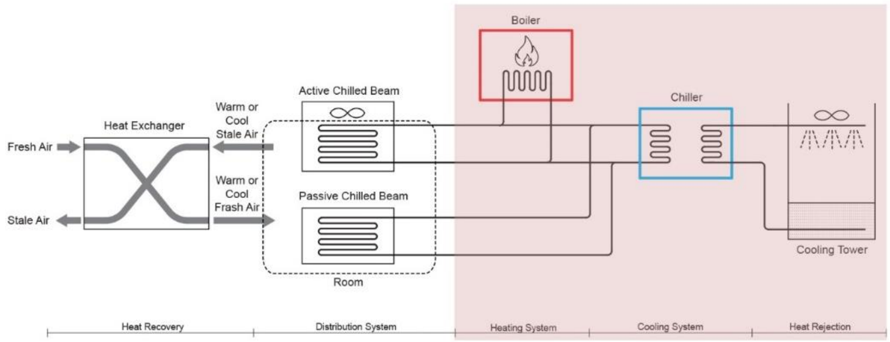

Fig. 10 Boiler, chiller and cooling tower located within HVAC system

3.3 Heat Recovery + Fresh Air

Heat recovery is a method to reduce operational cost that the previous building design did not adopt. Heat from stale air that is being released out of the building can be re-used to warm incoming fresh air without mixing during winter. During summer, the external air temperature which is much warmer than indoor temperature can be cooled by dispersing heat to cooler stale air which is leaving the space. This system of heat recovery and supplying fresh air is through a heat exchanger, which regulates the temperature of incoming fresh air. This system saved a large amount of energy as fresh air do not need to be heated or cooled with the full heating and cooling load of the building.

Fig. 11 Rocheggiani RRU FA heat wheel

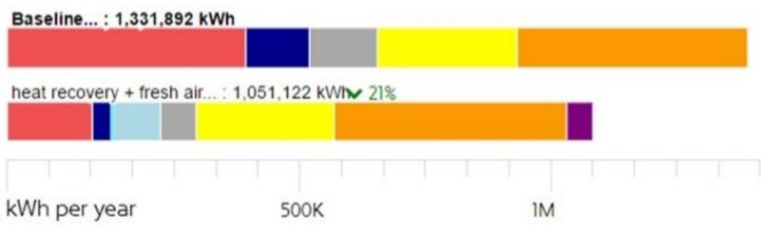

Fig. 12 Energy reduction of using heat wheel

There are various types of heat exchangers that can be used to regulate the temperature of fresh air. As shown in Figure 11. We propose using a heat wheel as it is compatible with the chilled beam system. Rocheggiani's RRU FA4 has a heat recovery sensible efficiency of 85% with a peak specific fan power of 3.00 W/Ls and ensures fresh air to be filtered before entering the space. By using a heat wheel to provide fresh air at desirable temperature, the annual operational cost and energy consumption of the building can also be reduced by 21%, from 1,331,892 kWh to 1,051,122 kWh.

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As shown in Figure 12. A constant supply of fresh air also ensures users to work healthier and maintain a sharper mind. As shown in Figure 13.

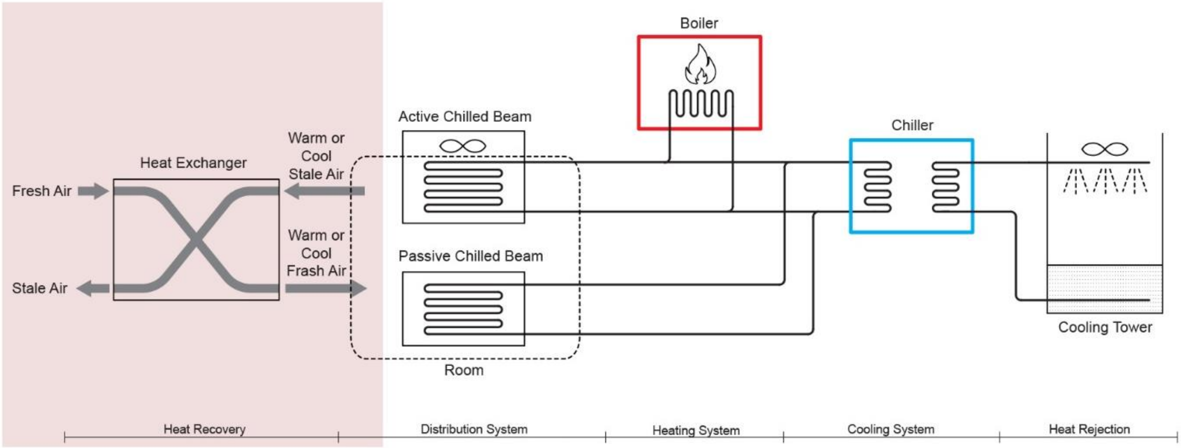

Fig. 13 Heat exchanger location within HVAC system

3.4 Equipment + lighting density

Based on the energy consumed in the original building, the predominant energy is used by lighting and equipment, making up over half of total energy. Thus, minimizing electricity of these things are important for high performance building. In addition to equipment, like HVAC systems, this part mainly involves lighting and display computer monitors.

In terms of lighting, a more energy-efficient and sustainable product, LED lighting, is highly proposed. As shown in Figure 14. LED lighting contributes to energy savings by effectively fulfilling lighting needs and improving working conditions. Additionally, the operational costs can be dramatically lowered because far less changing LED fixtures happens compared to usual traditional lighting, which is an important asset in public building management. While its initial cost is relative higher than traditional ones, the benefits of energy savings and the maintenance saving make it worth the effort.

Fig. 14 ENERGY STAR rated LED

Display computer monitors are another main equipment in office building that we focus on. Referring to the Council House 25 project, the LCD monitors reduce 77% energy consumption in contrast with conventional CRT monitors. Meanwhile, LCDs generates much lesser heat and therefore lower cooling needs to be provided. LCD monitors are also beneficial to health because of reduced radiation and flat screen save more table space. Thus, using LCD monitors is a good choice for occupants in this building.

Both of them, we recommend to use ENERGY STAR's most energy saving products. It is beneficial to decrease lighting and equipment power density respectively from 15 W/m2 and 25 W/m2 to 6 W/m2 and 11 W/m2. Responding to that, there are dramatic drops (35%) in both two parts energy consumption. As shown in Figure 15.

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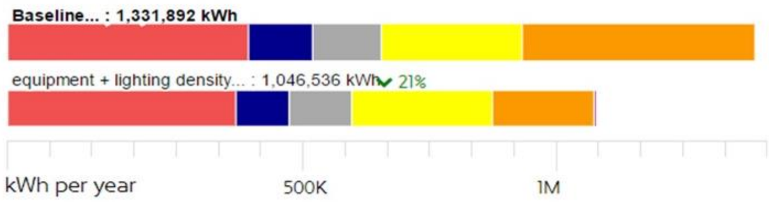

Fig. 15 Energy reduction by reducing equipment and lighting density

3.5 Window to wall ratio

A good window to wall ratio (WWR) is required to maintain a good indoor environmental quality within the building. This allows for appropriate amount of daylighting entering the workspace to increase productivity and visual comfort. The window to wall ratio also controls the amount of direct sunlight that enters the building during the summer and winter that heats up the building. The north façade has an increase in WWR from 0.31 to 0.5 to allow sunlight to penetrate the space during winter and shelter the high angle summer sunlight. The east and west façade of the building which experiences the most solar heat gain is being adjusted to a WWR of 0.4 from 0.34 and 0.68 respectively. A WWR of 0.4 allows for sufficient daylighting into the spaces while experiencing minimal solar heat gain and loss. The south façade does not experience any direct sunlight has an increase in WWR from 0.34 to 0.6 to allow diffuse light to enter the space.

The ratio of these windows are adjusted in consideration of various factors such as a large amount of heat gain during summer, large amount of heat loss during winter and sufficient daylighting to enter the space for a biophilic response. These factors are balanced and considered hand in hand with the type of glazing and shading that is going to be installed.

Utilizing natural light can lead to substantial energy saving in the heating and lighting of the building. The reconfiguration of the window to wall ratio of the building can lead up to an annual energy consumption reduction of 3%, while providing a mental and visual stimulation to regulate the human circadian rhythm. As shown in Figure 16.

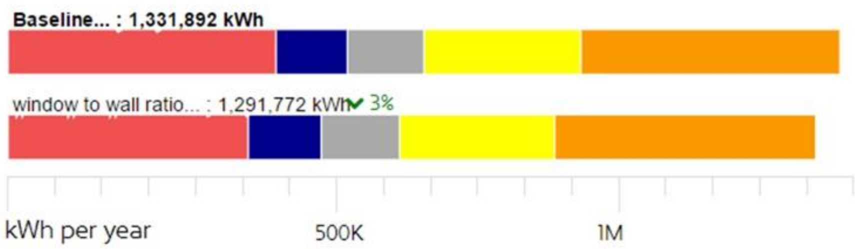

Fig. 16 Energy reduction of adjusting window to wall ratio

3.6 Glazing

A large issue, which resulted in the initial building to consume a large energy for heating and cooling, was due to the type of glazing it was using. Single glazing may have the lowest capital cost; however, it increases the operational cost of the building due to heat loss through the building façade. We propose using double-glazing as it has a better insulation quality as a reasonable cost. Double-glazing will significantly reduce the cost of heating and cooling and contribute to a reduction in greenhouse gases. Using Low E coated glass further reflects solar radiation and filters light waves to allow desired natural lighting into spaces.

We propose using Dowell ThermaLine double glazed low E window, which have a decreased U-value of 1.9 W/m2K from the original 6W/m2K. It also has a lower solar heat gain coefficient (SHGC)

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of 0.45 which is preferred for Melbourne climate with higher cooling load, compared to the original building with SHGC of 0.6. Dowell ThermaLine also has thermal break properties that allows the façade of the building to be well insulated and have minimum thermal leakage. As shown in Figure 17.

Fig. 17 ThermaLine Double Glazed Specification

By changing to double glazed low E windows, the heating load of the building can reduce up to 44% from 428,378 kWh to 238,600 kWh and cooling load of the building by 12% from 114,175 kWh to 99,768 kWh. This ensures minimal heat transmission through glass while maintaining the desired amount of daylighting from entering the space. Having a better glazing also, helps reduce transmission of UV radiation and transmission of noise. As shown in Figure 18.

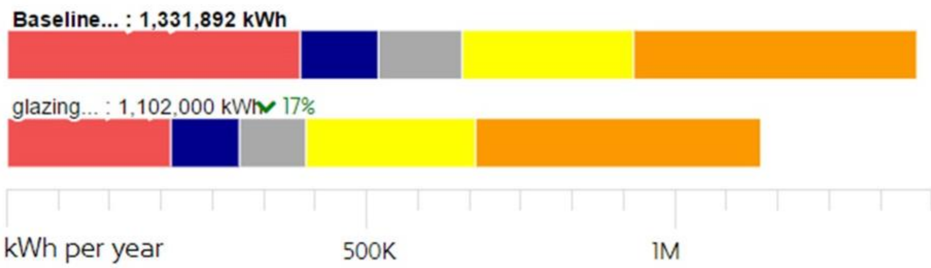

Fig. 18 Energy reduction by replacing single glazed window with double glazed window

3.7 Shading + Photovoltaic

The initial building design used generic horizontal shading which was not specific to the site and orientation. This resulted in inefficient shading and overshadow in undesired areas. The shading system we propose are a series of louvers that acts as a secondary skin of the building. Horizontal louvers installed on the north façade, while vertical façade installed at the east and west façade. This allows direct sunlight during the summer which occurs at a high angle to be blocked out while sunlight during the winter which occurs at a low angle to penetrate through the louvers. The louvers designed to be 800mm each with a 1.3m spacing to allow sufficient diffuse light and exterior views into the building. By redesigning the shading of the building, energy consumption of the building used for heating reduced by 18% from 428,378 kWh to 349,917 kWh while the energy used for cooling reduced by 15% from 114,175 kWh to 96,903 kWh. This also reduces glare experienced within the building and enhances the indoor comfort of the users.

In addition to using louvers as shading, polycrystalline photovoltaic panels are installed on the horizontal panels of the north façade to generate green energy. As shown in Figure 19. The PV panels are installed at a 30o angle to maximize energy efficiency gain and uses micro-inverter instead of a direct inverter to convert direct current from the PV to alternating current. Micro-inverter is not compatible with battery to store energy, however is ensures the PV panel to perform optimally. By

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generating green energy, the building consumes less energy while promoting a more sustainable practice. A case study to evaluate the benefits of having photovoltaic within a close premise is the Alan Gilbert Building on the Parkville Campus of The University of Melbourne. As shown in Figure 20. The Alan Gilbert Building has a similar PV system where it is use as a shading device and is facing north. The panels generate up to 40,000 kWh of green energy and save up to $755,000 per year. As shown in Figure 21.

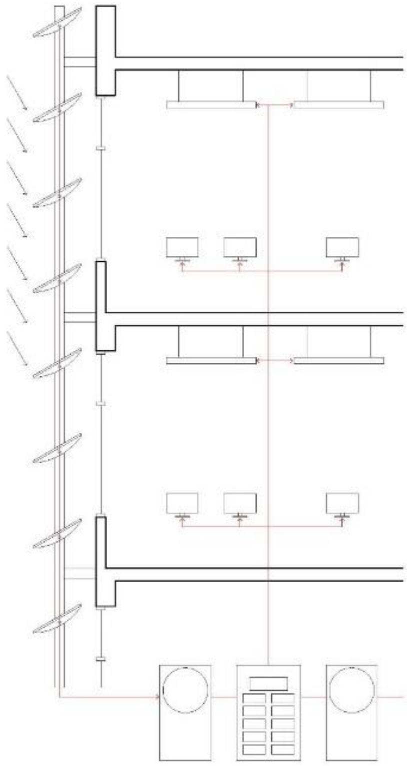

Fig. 19 Photovoltaic panels on horizontal louvers system

Fig. 20 Alan Gilbert Building PV study

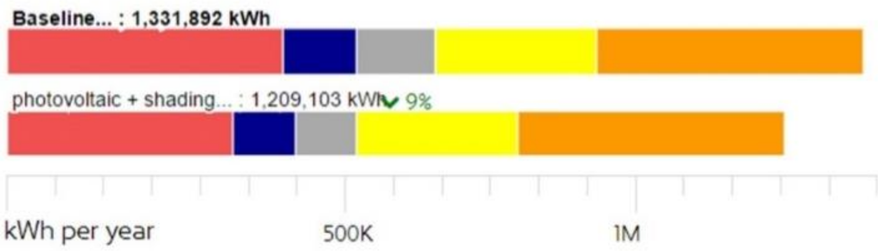

Fig. 21 Energy reduction by redesigning shading system

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3.8 Insulation

The strategy of insulation is most cost-effective way to improve energy efficiency and comfort. It's about optimization of ability to keep heat out or in, and therefore save money on energy bills. The adoption of insulation also helpful reduce condensation, damp and mould in the building to provide health benefits.

A large issue with the design of the baseline is lack of insulation in the roof and wall. Green roof is used instead of metal desk roof to reduce the thermal transmittance. Meanwhile, by using Bradford gold R1.8 roof insulation8, the R-value of the roof is enhanced from 3 to 6.25. As shown in Figure 22. To improve thermal resistance of walls, a same brand product, Bradford gold R2.5 wall insulation9, is also adopted to this building and the R-value of the wall is increased from 2 to 2.6. Insulation is not used for the floor, because the ground temperature of Melbourne is average of 18 degrees and helps in cooling the building. With proposed insulation strategy, the total energy can be reduced by 8%. As shown in Figure 23.

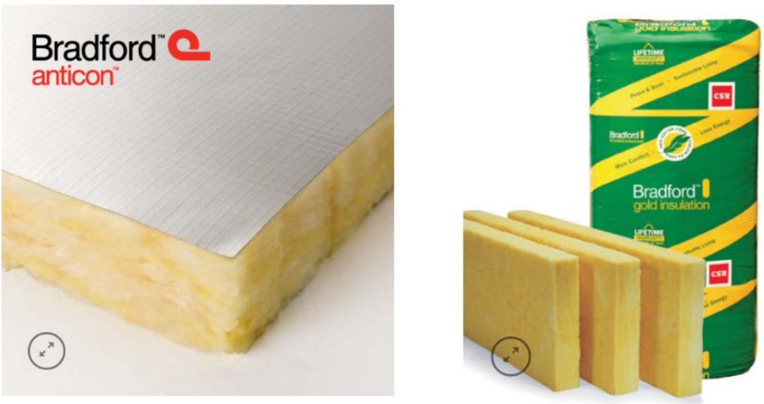

Fig. 22 Bradford Gold wall and roof insulation

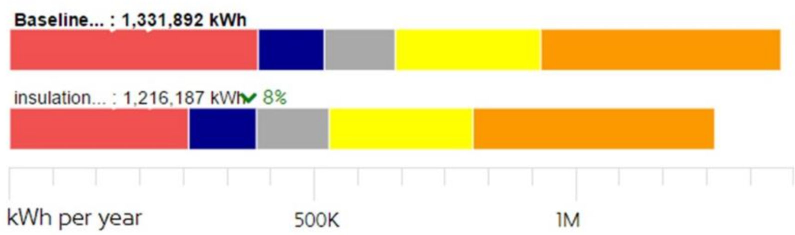

Fig. 23 Energy reduction by adding insulation

4. Green Roof

Another new feature proposed is to add a semi-extensive green roof above the office. A semi-extensive green roof is easy to maintain and does not require a large amount of capital cost to be installed. The benefit of having a green roof is that it is able to act as a roof insulation for the building. Unlike concrete or metal roofs, a green roof has a much lower surface temperature and constantly keeps the building cool. This in return reduces the heating and cooling load of the building that results in a lower energy consumption. The green roof is also able to help environmentally in various aspects, such as reducing heat island effect and carbon emission. Green roof is also able to reducing surface runoff by retaining 70% to 90% of precipitation, and reducing stress on the sewer system at peak flow periods. As shown in Figure 24.

The main benefit of a green roof however is an improved office lifestyle and healthier working environment. Having a private green space provides opportunity for various activity to be held on the

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roof in which was previously not possible. This new environment can be used as a meeting space, event space or relaxation space in which the productivity of users can be boosted. CH2 is a model sustainable building within Melbourne and case study that is well known as a sustainable office where users benefit from green spaces. As shown in Figure 25.

Fig. 24 Case study green roof of CH2

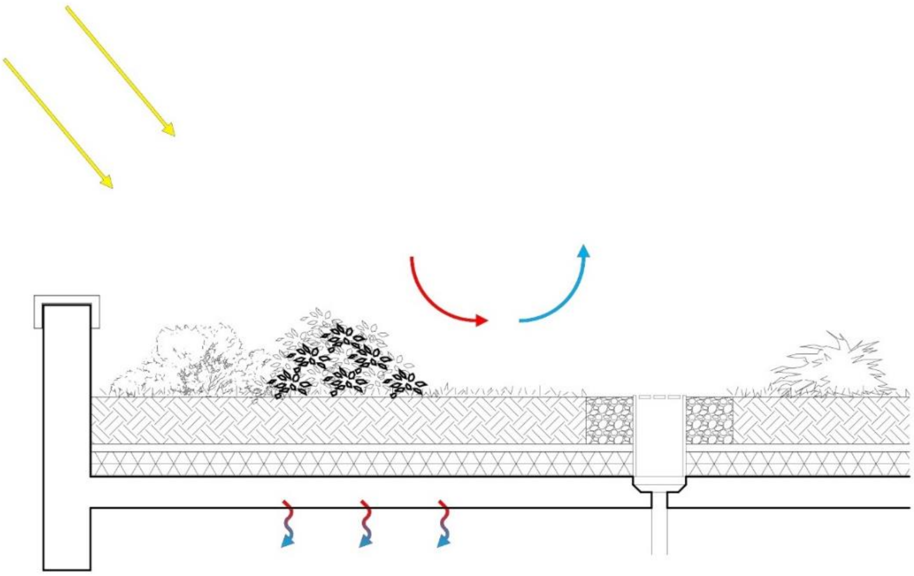

Fig. 25 Proposed green roof system

5. Rainwater Collection

We also propose for an installation of a rainwater collection system to reduce the water consumption of the building. This can help reduce the operational cost while promoting a more sustainable practice. Rainwater collection is suitable for irrigation during summer months and reduces flood and soil erosion during rainy seasons. The rainwater collected can be used for flushing toilets and showers; however, it needs to be treated before it can be used. By using a green roof as catchment area, the green roof acts as a filtration layer, but it also adds organic compounds into the collected rainwater. The collected rainwater has to go through a small filtration and osmosis treatment plant that is installed next to the rainwater tank before it is used.

A similar case study that proves great success with a green roof and rainwater collection system is the Pixel Building11, Carlton. The Pixel Building has the highest Green Star Office Design, LEED and BREEAM rating and has been a promotion model for green technologies within office buildings. By adopting rainwater collection as a sustainable practice such as the Pixel Building; your building will be able to achieve a high sustainable rating from various rating tools. As shown in Figure 26.

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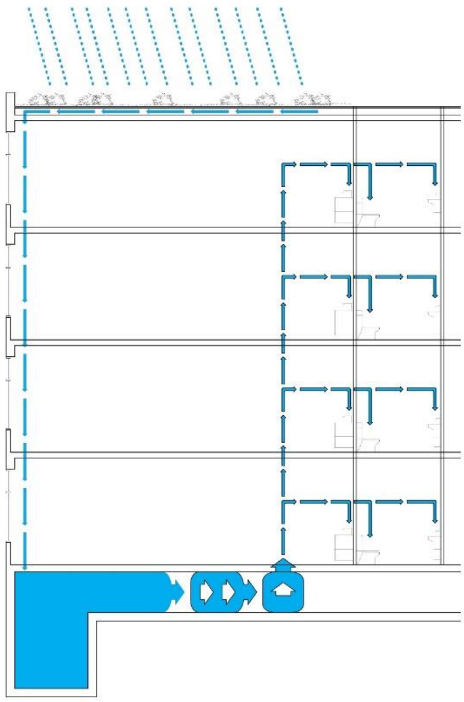

Fig. 26 Proposed rainwater collection system

6. Conclusion

With proposed strategies combined, the total annual energy consumption of the building can be reduced by 61%, from 1,331,892 kWh per year to 507,401 kWh per year. By replacing the existing equipment and services to fit the passive design strategies being introduced, the cooling of the building has been reduced by 62%, heating by 77%, fans by 49% and interior lighting and equipment by 57%. On top of that, green energy and building resources used can be reduced even further by harvesting what the site has to offer, such as solar energy and rain.

This building not only benefits from a low operational cost, but also a from high user productivity. The spaces within the building are designed with occupant comfort and environment quality in mind. By having more daylighting, more green space, optimal temperature and fresh air with less glare, less heat and noise from surrounding equipment, the building users will be able to experience good indoor environmental quality. This encourages employees to stay within the building for a longer period of time.

This project also aims to re-brand the building as a 5 Star Green Star building. This creates the opportunity for the building to be a model green building and be recognized globally. This increases the asset value of the building and attracts more attention from the public.

References

[1] Energystar.gov: ENERGY STAR Most Efficient 2017 — Boilers. 2017.5

[2] Johnson Controls:YEWS WATER-COOLED SCREW CHILLER (High Efficiency). 2017.

[3] Baltimore Air Coil: BAC Series 3000 Cooling Tower. 2017.5.13.

[4] Rocheggiani: Rocheggiani’s RRU FA. 2017.3.

[5] Dowell: Dowell awning window energy performance data comparison chart. 2017. 4.

[6] Miss V: THE IMPORTANCE OF THE BUILDING ENVELOPE. May 9, 2017.

[7] Pricewiseinsulation.com.au: Light Duty Bradford Anticon™ Roofing Insulation Blanket. 2017.4.

[8] Pricewiseinsulation.com.au: R2.5 | 580mm Gold Wall Insulation Batts. 2017.5.

[9] Sustainability.vic.gov.au: The Pixel Building Case Study – Sustainability Victoria. 2017.