University of Southern Queensland

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Energy Performance Analysis of a Six Green Star Building

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I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

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Abstract

There has been a trend around the world of green schemes and initiatives for construction industry. In Australia, the Green Building Council of Australia (GBCA) introduced a rating tool to incentivise the industry to improve; building design, construction materials and methods. In 2014 The University of Southern Queensland constructed a six green star building.

I have undertaken this project to ascertain if the green star rating tool has produced a more energy efficient building. Other studies have found mixed results regarding energy use with green schemes (Newsham et al., 2009). The technologies and materials used to obtain the green star ratings are sometimes initially expensive with both money and embedded energy however, the nett impact can still yield positive results if designed and implemented effectively. It is important to confirm if the green star rating tool is a good return on the money and embedded energy invested.

My research was mainly focused on the air conditioning and mechanical ventilation systems of the building.

Initially the 'as-built' building was evaluated using the following:

- A heat load was taken out using Camel software;
- An energy model using Design builder was created,

Actual electrical meter readings were obtained to calibrate the models energy use.

The energy model's dimensions were converted into a Deemed To Satisfy National Construction Code (Australian Building Codes Board) compliant building and the two buildings were compared.

It has become clear that USQ's Springfield campus' Building 2 is a quality building that has implemented technologies that lowers the energy usage. The Green star building when compared to the Deemed To Satisfy National Construction Code compliant building is more energy efficient.

As we live in a world of continuing improvement it is inevitable that the construction industry will be encouraged to improve energy efficiency and the technologies bought on by the Green rating tool will be common place in the industry.

1. Introduction

In response to climate change, a move towards greener buildings has been the trend both in Australia and around the globe. The pursuit of energy efficient buildings will significantly reduce greenhouse gasses and improve the predicted temperatures of the future climate. In part for this reason in 2002 The Green Building Council of Australia (GBCA) introduced a rating tool to incentivise the industry to improve building design, construction materials and methods.

1.1 Overview

The University of Southern Queensland (USQ) built one such building. Education Gateway (EDGY) now known as Building B at the Springfield campus is a Six Green Star accredited educational building. The Building was built by Badge Constructions (QLD) at a cost of $45 million The Architects who designed this building were Mode. This building won the Education Facilities over $20m category at the 2016 Master Builders Queensland, Brisbane Housing & Constructions Awards.

Building B is located at The University of Southern Queensland's Springfield campus, west of Brisbane. The building consists of four levels of educational space topped with one level of plant. These levels consist of multiple rooms for the purpose of tertiary education. Specialty learning spaces include general learning areas, flexible teaching spaces, multi-purpose areas, laboratories, media centres, toilets, change rooms, meeting rooms and offices.

The Edgy building at Springfield was certified with a Design Green Star Rating of 5 in August 2014. For the categories it obtained points refer page 49 Appendix 1 (Green Building Council Australia,2020b). One year later in August 2016, the certification was increased to a 6 Green-Star using the Education As-Built V1 rating.

Natural light is a focus in the design of Building B. High quality clear double glazed windows dominate the external façade. This glazing is generally sheltered from direct sunlight by an extensive array of angled aluminium louvres, ensuring 60% of the internal space has a direct line of sight to outside.

1.2 Air conditioning System

The air conditioning system at the EDGY building is a ducted chilled water system consisting of air handling units connected to a ducted delivery network complete with air diffusers and a return path. The chilled water is cycled from a central plant. To gain efficiency the whole system is suitably insulated.

The air handling units consist of a filter, fan and heat exchanger. Air from the indoor space is filtered and mixed with additional outside air. This air is forced over a coil that has chilled water flowing through it. The Chilled water is supplied by a central plant. The chilled water enters the coil at 6°C. As the chilled water leaves the coil the temperature of the water is 12°C. This chilled water returns to the chiller to have the heat removed to outside dropping the chilled water temp back down to 6°C. The cooled air is supplied to the indoor space and the cycle continues.

Building B utilises two pre-conditioner systems complete with energy recovery ventilators (ERV). These pre-conditioners are used to bring the condition of the outside air to 24°C and 50%RH before distributing to the zone air conditioning systems. The ERV heat exchanger recovers energy from exhausted air via a sensible and latent heat exchanger. The ERV are rated at being 75% efficient. This approach reduces the increased energy requirement associated with increasing ventilation of the building.

The pre-conditioner systems are modulated with carbon dioxide monitoring devices. This monitoring minimizes the amount of outside air required. The flow of outside air is decreased when the CO_2 sensors detect that the levels are below a level specified in AS1668.2-2012. (Standards Association of, 2012a). This allows the system to respond to the actual occupancy levels. This monitoring increases the energy efficiency of the system.

The system also is monitored with a volatile organic compounds (VOC) monitoring system. This is to ensure when the CO_2 sensors lower the ventilation rate due to low occupancy, the VOC pollutants are still being removed or at least diluted to limit a concentration.

To minimize unnecessary energy use, when sensors note the room is not being used the air conditioning set point is raised from 24^oC to 27^oC. This set point is re-instated at 24^oC when the room has again become populated. This attains Building B a potential energy saving considering at these times the raised temperature would not even be noticed.

Filtration is a key component of Building B’s air conditioning system. AS1668.2-2012 requires a minimum G4 Filter rating on air conditioning systems of over 1000 l/s supply air. (Standards Association of, 2012a). Before entering the building the outside air is filtered to removes some pollutants before they enter the space. To continually filter contaminants from the space the zone air conditioners have F5 filters installed in the return air path. AS1668.2 allows the minimum outside air rate to be decreased by 25% so long as F5 filters are implemented to continually filter pollutants from the space.

2. Review of Literature

A literature search established the parameters used in the Green Star Accreditation process. As well an investigation of existing literature was used to indicate how the green accreditation process affects the energy use of a building.

2.1 Green Star Accreditation

The Green star accreditation process is a rating tool set by the Green Building Council of Australia (GBCA). Green star buildings have specifications that are above the requirements of the National Construction Code of Australia (NCC), (Board, 2019). The main objective of green building is to benefit human well-being and the community, from both health and the life-cycle cost perspectives. Green buildings are those buildings that meet environmental performance criteria that are normally assessed against rating tools such as the Green Building Tool (Kua and Lee, 2002).

The Australian green star accreditation process was established in 2002. The Green Building Council of Australia is the nation's authority on sustainable buildings, communities and cities. Their vision is to create healthy, resilient and positive places for people. Their purpose is to lead the sustainable transformation of Australia's built environment (Green Building Council Australia, 2020a).

One acknowledged reason for implementing the Green star accreditation process is to minimize Australia's emissions. As a result of global emissions of greenhouse gases (GHGs) from human activities, the average air temperature of Australia has increased by 0.7°C over the past century (Preston and Jones, 2006). Australia as a signatory to the Paris Agreement is therefore required to hold the increase in global average temperature to below 2°C by 2050. (Article 2(1)a) (UNFCCC, 2015).

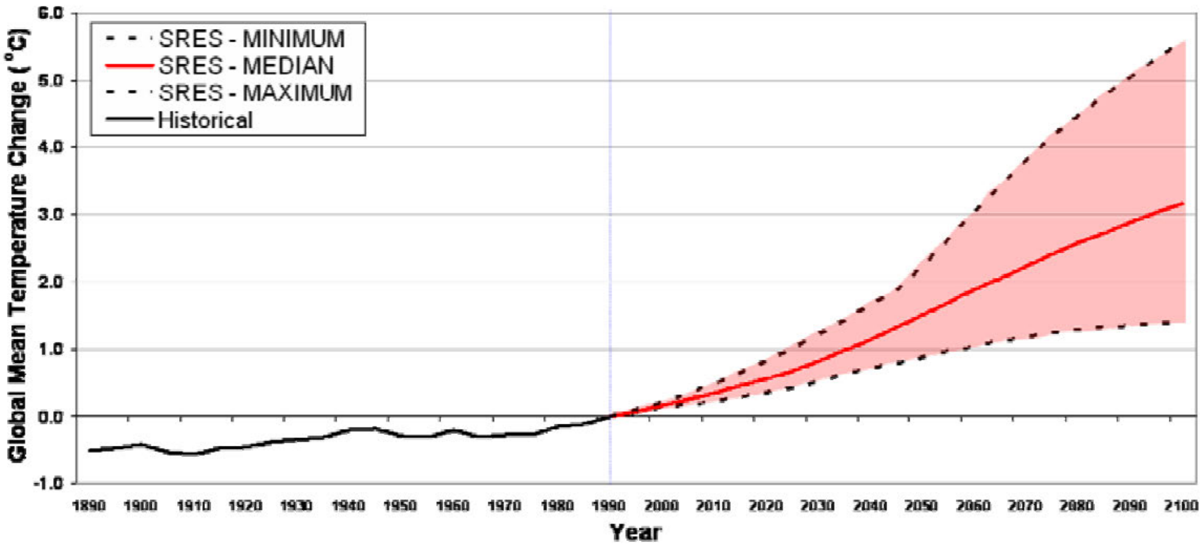


Figure 1: Predictions of 21st temperature increases (relative to 1990) MAGICC (v.4.2) (Preston and Jones, 2006)

GBCA's Green Star rating system is Australia's Green accreditation process. Around the world other systems are available, in particular:

- Building Research Establishment Environment Assessment Method (BREEAM) in the United Kingdom; and

- Leadership in Energy and Environmental Design (LEED) in North America.

GBCA's green star is comparable to these accreditation processes. A 6 star GBCA rating is equivalent to a 'Platinum' LEED or a 'Very Good' BREEAM rating (Xia et al., 2013b).

Credits are awarded on proof of implementing or improving building performance in subcategories of the above area. In the office option 142 (unweighted) points are available. 5 additional points are awarded under the innovation category. The sum of the points awarded rate the buildings into:

- **4 Star: 45-59 points, indicating "Best Practice,"**
- **5 Star: 60-74 points, indicating "Australian Excellence," and**
- **6 Star: 75-100 points, indicating "World Leader."**

2.2 Environmental Sustainability in Buildings

Environmental sustainability is fundamentally how buildings become green. GBCA have a series of rating tools to categorise buildings during the design, as built and interiors. The areas of environmental sustainability that the Green star rating tool accredits refer detail Figure 2.

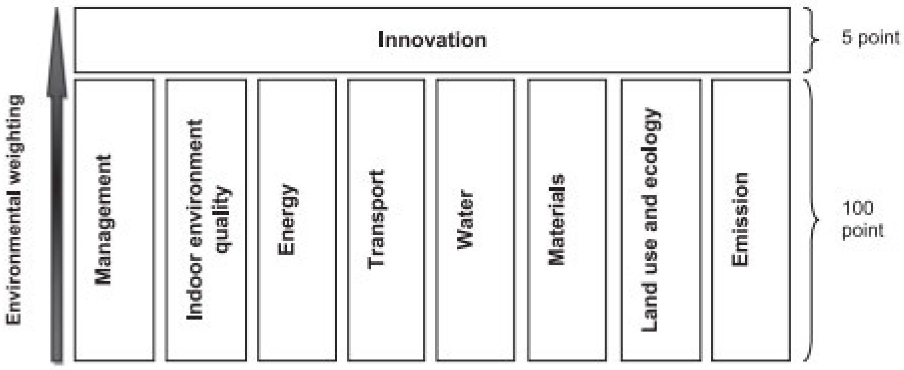


Figure 2: Green star point allocation

2.2.1 Management

The focus of this category is the adoption of processes that will bring environmental sustainability to a building. This is to set up the building for operating to its optimum potential. It is important that the building encourages the end users to utilize the design and rewards a system that uses data monitoring to continually improve the impact of the building.

If a member of the design team is Green Star Accredited that counts as a point to the design. For this accreditation the member would use their knowledge to influence the design in the direction of the required green star parameters. This aligns the design with the aim of the Green Building Council of Australia.

The commissioning or fine tuning of the building is important to optimise the design. All services require a plan for commissioning that ensures the systems are operating within the desired range as designed. This commissioning is encouraged to be retaken after the first 12 months of operation by the means of operating and maintenance manuals. Reviews of performance will determine if the actual environmental impact is aligned with the design. "Commissioning is a valid means to ensure

HVAC systems perform in building conformity with design intent hence building sustainability" (Xiao and Wang, 2009)

The green star process rewards a project if the monitoring of performance is performed by an independent commissioning agent. This removes any conflict of interest with the result and is an essential with ensuring creditability within the process. This independent commissioning agent reports directly to the project owner and is independent to any of the consultants, contractor or sub-contractors.

The incorporation and description of automated systems to control the systems of the building is necessary to confirm the systems are operating as designed. "It is noted that as the awareness for the environment increases, many companies have started to establish energy management / conservation groups. These groups undertake tasks such as energy auditing (usually with the help of energy experts), energy management and research into Building Automation Systems for energy-conservation benefits" (Kua and Lee, 2002). This includes but is not limited to, air conditioning, lighting, fire detection lifts etc. This brings a transparent approach to the operating parameters of a building.

The green process promotes resilience from natural disasters or climate change for the design of a construction. It rewards engaging a formally qualified environmental engineer to implement a climate adaption plan. This will assess the potential risks associated with the location of the proposed building. It is then necessary for the adoption of process to address at least two risks. Any risks identified as 'high' or 'extreme' must be addressed.

The implementation of meters for energy or water monitoring is a management process that will promote environmental sustainability and accredit points to the green application. The requirement for this metering is that areas that use a substantial percent of the energy or water are locally metered. Alarms may be linked to these meters and alert management of any excessive use of resources. This alert may fine tune the maintenance of the buildings system requirements.

The construction process is part of the holistic approach to building management. An environment management plan will ensure the construction processes are best practice and implemented with consideration of the sensitivities of the environment. Best practice environment management plan should manage the risk or impact of the construction process

2.2.2 Indoor Environment Quality

A focus on the quality of the indoor environment is paramount within the design of a building. The Design team obtained multiple green star credits in this area. This area has a large impact on the energy requirements of the building.

The general consensus is that improving the Indoor Environment Quality (IEQ) will have a positive impact on occupant productivity (Al Horr et al., 2016). This is not just about people being comfortable. An impact on mental health as well as minimising sickness is a flow on effect of IEQ. Mechanical services in a building are implemented to improve the IEQ.

The mechanical services credits were obtained to directly improve the Indoor Environment Quality

(1) – A carbon dioxide monitoring system is specified to track and adjust ventilation rates with low carbon dioxide levels upon occupancy. Also, a volatile organic compound (VOC) monitoring system is specified to detect and alert when pollutants are too high in the building.

(3) – Automated blinds and external shading are components of the design, reducing glare from natural lighting.
(9) - Designed ventilation systems will actively control humidity and minimise mould.
(10) - Ventilation is designed for superior air change effectiveness, according to ASHRAE 129-1997 and laminar flow patterns.
(11) - Mechanically air-conditioned work space is designed to be a comfortable temperature, within the Predicted Mean Vote levels of -0.5 to +0.5.

Refer: Appendix 2: Credit Category and achievements (Edgy Building)

The Indoor Air Quality (IAQ) is noted as a major subset of IEQ, although there is no universal definition for IAQ. The general consensus is to improve IAQ requires minimising pollutants. (Steinemann et al., 2017). In all 31 green certification systems around the world, ventilation is the procedure to minimise pollutants and improve IAQ. (Wei et al., 2015). To achieve improved IAQ the building is mechanically ventilated and air conditioned.

Limiting a build-up of VOC, excluding pesticides, in the indoor air is also addressed in the Green star design. The World Health Organisation defines VOCs as all organic compounds that are in a gaseous form between the temperatures of 50 and 260°C. VOCs are emitted from common building materials and are the major pollutant in indoor air. (Wang et al., 2007). These can be aromatics, halocarbons and aldehydes. One such VOC commonly found in building materials is formaldehyde. Formaldehyde can be released from composite woods and is hazardous to humans. (Wang et al., 2008).

This contamination of VOCs was addressed while gaining credit with the following, indirectly improving the Indoor Environment Quality:
(6) - All composite wood products being specified to have low-formaldehyde emissions.
(12) - 96% of adhesives, sealants and painted surfaces and all carpet and flooring to be specified to be low in VOCs.
This approach will minimize the release of the VOC pollutants to the air in the building.
Ventilation of an indoor space is required to flush out any pollutants and replace the air minimising any pollutants before they concentrate. The two ways to ventilate an indoor space is:

1. Natural ventilation;
2. Mechanical ventilation.

Natural ventilation requires a suitable area of openings in the façade of a building. AS1668.4 ‘The use of ventilation and air conditioning in buildings – Part 4: Natural ventilation of buildings’ (Standards Association of, 2012b) is called up in the NCC as the standard for natural ventilation of a building. This allows sufficient air flow to turn over the air to be suitable for occupation. Natural ventilation was not the ventilation used in Building B.

Mechanical ventilation is the removal of contaminants and/ or the supply of outdoor air. AS1668.2 – 2012 ‘The use of ventilation and air conditioning in buildings. Part 2: Mechanical ventilation in buildings.’(Standards Association of, 2012a). Mechanical ventilation was used to ventilate Building B.

AS1668.2-2012 uses outside air as the main strategy to improve the air quality within a building. The introduction of outside air dilutes the pollutant levels within the building. Air is introduced to the building at a predetermined amount set by the amount of people. Indoor air pollutants can be traced to many sources. Pollutants can be emitted from the building fabric, or a result of humans metabolic activity etc.(Jones, 1999)

There are up to two points on offer for increasing the outside air rates by 50 or 100% compared with AS1668.2-2012. For this to occur the air conditioning systems outside air intake and ducting needs to be increased. Even if you take on the option to used carbon dioxide sensors the system needs to be suitable sized to accommodate the increased volume of air. This option has major cost impacts and was not implemented in this project.

2.2.3 Energy

The aim of this section of the green star application is to accredit buildings that reduce the overall energy consumption in comparison to a standard-practice building. This is directly related to the following (Green Building Council of, 2015):

- Lower overall energy demand;
- Greenhouse gas emissions; and
- Reduction in operating costs.

This section offers 20 points towards green star accreditation. Energy modelling to demonstrate towards 'net zero operating emissions' will achieve the maximum 20 points. "Net emissions of CO_2 by human activities, must approach zero in order to stabilize global mean temperature."(Davis et al., 2018)

Net zero buildings are buildings that balance the emission free energy they generate with the emissions producing energy they use (Torcellini et al., 2006)."Although a net zero building is a term, subject to ambiguity (Wells et al., 2018)

To apply the prescriptive pathway the building has a requirement to exceed the section J (refer page 30) requirements by at least 5%. Additional points are available for:

- Building Envelope – 15% increase to the minimum R-Values for J1.3 Roof & ceiling construction, J1.5 Walls and J1.6 Floors ;
- Glazing – no greater than 85% vertical glazing per storey and or the SHGC of Roof lights to exceed the J1.4 requirements by 15%;
- Lighting – if the aggregate illumination power density of 30% less than maximum, 95% of the lighting to be automated and the maximum lighting zones to be less than $100m^2$;
- Ventilation and air-conditioning – fan and pump power to be 15% less than J5.2 and J5.4a requirements, thermal efficiency of heaters to be 15% higher than required by J5.4b and Packaged air conditioners to have a minimum of 15% increased efficiency as required by Minimum Energy Performance Standards (MEPS);
- Domestic hot water systems – if the hot water system is powered by either renewable energy, natural gas, electric heat pump with a COP 3.5 min or waste heat from another process, there are points awarded;
- Building sealing – points are available if a pressure test is completed in accordance with ASTM E779-10 or ATTMA TSL2; and
- Accredited green power – if 50-100% of the electricity consumption is accredited to 'GreenPower' with a commitment of a minimum 10 years points will be awarded.

Energy modelling that demonstrates a 20% reduction in energy consumption and 100% lower greenhouse emissions compared to an equivalent reference building will be awarded the maximum 20 points.

2.2.4 Transport

Minimising the amount of Greenhouse emissions used to commute to a building will be beneficial for lowering the Environmental sustainability of a building. Transportation is responsible for 15% of Greenhouse gas emissions in North America (Zahabi et al., 2012).

The Green scheme established by GBCA accredits points for reducing the impact from transport. This is from the areas of:

- Access to Public transport;
- Reducing car parking provisions;
- Low emission vehicle infrastructure;
- Active transport facilities; and
- Walkable location.

Having access to 'end of trip' facilities will encourage commuters to ride or walk to the building. This also has a flow on effect of potentially increasing the health and fitness of the commuters.

2.2.5 Water

Minimising the consumption of potable water will improve the environmental sustainability of a building. Potable water in a building can have the following uses in a building:

- Drinking;
- Sanitary;
- Appliances;
- HVAC;
- Irrigation; and
- Pools.

Minimizing potable water use minimizes the buildings energy use. The energy required to treat water to the level it can be deemed potable in Australia ranges from 36 to 720 J/l (Plappally, 2012).

Reclaimed or collected rain water can be used to replace the requirement of potable water. This collected water could be used to flush toilets or irrigate gardens. The landscaping design could utilise drought tolerant plants green schemes will accredit points for this approach.

2.2.6 Materials

Wastage of materials in construction is detrimental to the environment. "1–10% by weight of the purchased construction materials, depending on the material, leave the site as waste." (Bossink and Brouwers, 1996). The green scheme rewards documentation of process that has minimized the waste of materials during construction.

Embodied energy is the energy consumed in the extraction or manufacture of a materials for example 670kJ of energy is required to produce 1kg of concrete (Lawrence, 2015). It is also important to source materials locally. The energy required to transport material is included in the energy impact of a construction.

Concrete is seen as having a negative impact on the environments sustainability. It accounts for 7% of the global loading of CO_2 (MEHTA, 2001). Concrete is approximately 80% aggregate. This aggregate is generally composed of sand and rocks. A large amount of water is used in the production of Concrete.

There is a lean towards gaining environmental sustainability through bio-based materials. This is seen as a green alternative to concrete in particular.

There is an option to use timber that has been responsibly sourced. If certified this can be considered sustainable. Timber sequesters carbon from the atmosphere; note this can also be deemed a property of coal or limestone. It is worth noting that the timeframe required to sequester carbon naturally into coal or limestone is very long and significantly large amounts of energy is required to achieve this if industrial processes are used. Timber also has the property that it is combustible. Timber is currently not the preferred option for larger buildings.

Cast hemp lime or hempcrete is a bio-based product produced from hemp and straw that is seen as an alternative to concrete. It sequesters carbon from the environment to give it a carbon footprint of negative 35.5 kg per $1m^2$ of brick wall compared to positive 110 kg per $1m^2$ for a traditional brick cavity wall (Lawrence, 2015). Note this comes at a cost of an additional 3970 kJ of energy per kg to produce and has no structural load bearing capability. This product is currently used as a façade on a structure.

In the Green star application there is a potential to improve the sustainability of the concrete. Using water from a reclaimed source is rewarded. Using 40% crushed slag or equivalent as the aggregate is seen as improving the sustainability of the concrete. If the Portland cement percentage is replaced with an alternative cementitious material the construction is deemed to be green. This accreditation is only suitable to a construction that concrete is at least 1% of the contract’s value.

Steel also has a high embodied energy level. The environmental impact of steel includes the release of greenhouse and acidification gas emissions to the atmosphere (Norgate et al., 2007). These have global warming and potential acidification potential ramifications. This is why the green scheme process will accredit a construction for reducing the mass of steel in the framing or concrete reinforcement compared to standard-practice.

2.2.7 Land Use & Ecology

The green star application process rewards projects that reduce the negative impacts on sites’ ecological value and minimise harm to enhances the local ecology (Green Building Council of, 2015). The assessment is in the following areas:

- Site sustainability;
- Reducing ecological impacts from occupied sites;
- Reduction in light pollution;
- Implementing best practice with stormwater treatment; and
- Demonstrating that no endangered, threatened or vulnerable species were on site at time of purchase.

It is important that at the time of purchace the site:

- Has no matter of national significance;
- No old growth forest;
- Not classified as prime agricultural land; and
- Not considered a wetland of national importance.

Construction affects the ratio of reflected radiation to incident radiation at the surface of developed areas. This occurs generally from the incorporation of hard surfaces. This is known as the urban heat island effect and green schemes encourage developers to minimise this occurrence.

The urban heat island effect is attributed to higher temperatures in city districts compared to suburban or rural areas (Razzaghmanesh et al., 2016). The phenomenon is given the “Island” designation because of the isotherm patterns that resemble the contours of an island in the sea of the surrounding rural areas (Oke, 1995).

To achieve the points for this section it is necessary to evaluate the surfaces of the land before and after completion of the proposed construction. Weighting is given to the various types of surfaces and if the relative improvement of ecological value is 20%, 40% or 60% the application is awarded 1, 2 or 3 points refer Table 1: Land types and relative weightings.

Land Type	Weighting
Hard surface (including building / concreted area and bare ground)	0.00
Exotic vegetation (including exotic garden, lawns, weed infestation, non-native plantation forest, crop-farming)	0.05
Non-improved pastures (paddocks with minimal cover of native grasses (<25% cover)	0.35
Planted native vegetation (including native garden, indigenous native garden, green roof, native plantation forest)	0.50
Artificial water-bodies (including dams, constructed wetlands, channels, bores)	0.50
Regenerating native habitat (re-growth) < 5 years old	0.50
Regenerating native habitat (re-growth) 5 – 10 years old	0.75
Regenerating native habitat (re-growth) > 10 years old	0.90
Remnant native vegetation (including indigenous native grassland and indigenous native habitat)	1.00
Natural water-bodies (including wetlands, rivers, creeks, billabongs, streams)	1.00

Table 1: Land types and relative weightings

If the site has previously been contaminated, with regards to the soil and ground water, points will be awarded if a best practice site remediation strategy is implemented. If any buildings or structures on the site contain hazardous materials such as asbestos, lead, or polychlorinated biphenyls these must be stabilised or removed from site in accordance with relevant environmental and occupational health and safety legislation to receive points.

Contaminant exposure is detrimental to humans. It is estimated that the cumulative total number of asbestos associated deaths in the United States of America will be 200 000 by the year 2030 (Kamp and Weitzman, 1999). Lead health effects range from headache, irritability, abdominal pain and various symptoms relating to the nervous system to acute psychosis, confusion and reduced consciousness (Järup, 2003). Polychlorinated biphenyls are carcinogens; alter immune system function; cause adverse alterations of the nervous system, skin, thyroid, and sex steroid hormonal systems; liver, kidney, pancreas, and the cardiovascular system. (Carpenter, 2006).

2.2.8 Emissions

This category aims to minimize the environmental impact from point source pollutions and is split into four sub categories (Green Building Council of, 2015):

- Stormwater;
- Light pollution;
- Microbial Control; and
- Refrigerant impacts.

Peak storm water outflows from a site can pollute the surrounding environment. In order to weatherproof an indoor environment it is common to concentrate the flow of storm water on the site. This concentrated flow can damage the creek systems of the area.

One way to prevent damage to the environment is to construct a bio retention system. Bio retention systems are generally soil-plant based systems complete with a filter medium (Lucke and Nichols, 2015). This slows the peak flow while filtering the stormwater before it continues into the local creek systems.

Protection for native animals from the impact light pollution may have on their migratory patterns. For example the nest selection for sea turtles can be influenced by the pollution that artificial external lighting of buildings can bring to an environment (Cabrera-Cruz et al., 2018). Migrating birds that fly at night can be affected by light pollution. The upward light output ratio (ULOR) can reduce the impact of this type light pollution. The green scheme promotes this solution.

Air conditioning systems have a notorious past of promoting the growth and distribution of microbial contaminants such as Legionnaires. It is important for the implementation of best practice applications for air conditioning systems with respect to microbial control. This would include inspection and maintenance procedures.

Some refrigerants have a large potential impact on the environmental. Even though the phase out of ozone depleting hydrofluorocarbons (HFC) has occurred there is still a potential threat for refrigerants to impact on the environment. These refrigerants are less efficient and therefore have increased greenhouse gas emissions connected with them (Calm, 2002). A global warming potential (GWP) is associated with known refrigerants.

The refrigerants that replaced the HFC's operate at high pressures. So a leak will escape a system with little time. Leak detection on large air conditioning systems (<50kWr) will minimise the impact on the environment.

2.2.9 Innovation

Innovation is a category that brings with it great risk. Implementing an innovative attribute to a design by definition suggests that the process is not tried and tested. The innovation category of the green star submission is broken into three (3) sub categories.

1. Innovative strategies and technologies, to encourage and recognize pioneering initiatives in sustainable design, process or advocacy.
2. Exceeding Green Star benchmarks, to encourage and recognize projects that achieve environmental benefits in excess of the current Green Star benchmarks.
3. Environment design initiative, to encourage and recognize sustainable building initiatives that are currently outside of the scope of this Green Star rating tool but have a substantial or significant environmental benefit.

The potential roll on effect of innovation for construction in general gives importance to this category being encouraged by green schemes.

2.3 Green Star Points

Xia et al. (2013a) investigated the parameters that points are pursued and obtained for the purpose of gaining 'Green Star' accreditation. The application and awarded points for green star projects were analysed. At the time of that study 338 projects had been certified, this figure is now over 2500. These buildings were mainly offices at 85.8% with education buildings making up 8.7%.

The research revealed management as the most awarded category: 94% of all applications were awarded point is this category. This category is comparatively easier to obtain points as it is descriptive, operable and document based. Having a Green Star-accredited as a professional principal participant in the design team will gain you 2 points.

Xia et al found that "innovation credits are the most difficult to obtain." (Xia et al., 2013a) This study illustrates the high risk for low return for using innovation to obtain points in the Green Star application process. Refer: Table 2

The credit application rate and credit points awarded for these subcategories were:

Definition	Credit application	Credit awarded
Innovative strategies and technologies, to encourage and recognize pioneering initiatives in sustainable design, process, or advocacy.	15.5%	37.3%
Exceeding Green Star benchmarks in encourage and recognize projects that achieve environmental benefits in excess of the current Green Star benchmarks.	19.6%	36.5%
Environmental design initiatives, to encourage and recognize sustainable building initiatives that are currently outside of the scope of this Green Star rating tool but that have a substantial or significant environmental benefit.	13.0%	30.2%

Table 2 : Application Rate and percentage for innovation credits

In the category of indoor environment quality 77% of applications obtained credits (Xia et al., 2013a). (Arif et al., 2016) reports that it is important for designers and engineers to take into account the indoor air quality to minimize the risk of Sick Building syndrome. The two most common approaches of eliminating the risk are to either increase ventilation rates and or reduce the source of pollution. The Green Star process gives points for both of these approaches. Indoor Environment Quality has the greatest effect on the mechanical systems. This section is where the analysis of Building B will be focused.

2.4 Energy Efficiency in Green Projects?

Green Star buildings focus on more than energy efficiency. Indoor environment quality, responsibility to the land and ecology are part of the holistic approach to a green star building. To approach this subject it was important to establish the requirements of a Green Star Building. This would be the point of difference that justified the additional time and financial investment.

For a building to be constructed in Australia it must be comply with the National Construction Code. Section J – Energy efficiency of the NCC is the section of the document that relates to the energy efficiency of the construction. Understanding the base line for construction in Australia is necessary to appreciate the different requirements of the two building types.

There are adverse results in the area of energy savings through green based schemes. On average LEED certified buildings save energy (18-39%), (Newsham et al., 2009). A Green rated building can over a 40 year life cycle save more than 250% of its up-front costs on energy savings, (Paumgartten, 2003). However Newsham also found that 28-35% of LEED buildings have an increased energy usage per area compared with non-LEED comparable projects, (Newsham et al., 2009).

Green Certified buildings are an investment that gives a good return. Research taken out in Finland by Leskinen et al found that a green rated building will have improved rental Premiums of between 0% and 23% and lower vacancies can be expected, (Leskinen et al., 2020). This may be the improved working conditions and increase in worker productivity. Companies and institutions have the ability of branding themselves as a green minded company or institution.

The indoor environment quality category can be a difficult to balance with as it can have ramifications with energy usage. One of these is that points are awarded for increased outside air quantities. This increased rate will increase the energy requirements on the Heating Ventilation and Air Conditioning (HVAC) system and the amount of materials required to manufacture the system. Another is increased glass to allow natural lighting. This also increases the energy requirements on the HVAC system. In Summary improving the indoor environment quality can increase energy demands.

2.5 Literature Review Conclusion

I found from this research that green Star Accreditation does not necessarily translate to energy reductions when compared to a Deemed To Satisfy National Construction Code compliant building. Green Star accreditation allows for opportunities for energy efficiency to be incorporated into the build. It encourages energy efficiency to be included. It does at the least require the energy efficiency of a construction project to be evaluated. However it does not guarantee the most energy efficient building is built.

Energy reduction is part of what makes a Green Build. The elements used for accreditation improve the building as a space to be occupied by people. The accreditation process does encourage this improvement to be as efficient as practical.

3. Methodology

3.1 Introduction

This dissertation is to ascertain if the Education Gateway 'EDGY' Six Green Star rated Building is more energy efficient than if it was built to the minimum requirements of the Nation Construction Code (NCC). The Green star accreditation is above and beyond the requirements of the NCC. This process potentially will increase the cost of the design and construction. I intend to investigate if there are energy reductions in running costs for this green star building. Is it probable the increased investment will be paid for by the savings in running costs.

3.2 Methodology Outline

3.2.1 Investigate Building B's Air conditioning system

It was necessary to evaluate the air conditioning system of Building B. This is the main focus of this dissertation. The Value Added Engineering (VAE) Group designed and documented Edgy building's mechanical design. Their as-built documents were used to determine the system installed.

3.2.2 Research the green star accreditation process.

The green star accreditation process was researched. This was to give an understanding of what the green schemes' intentions were. The credits gained by the Edgy building received refer: 0 Credit Category and achievements (Edgy Building).

3.2.3 Literature review on green building design

Information was gathered from previous papers on the topic of energy efficiency in green buildings refer: Review of Literature. The research covered established analysis of green construction schemes from around the globe – LEED, BREEAM. This was possible as the essence of all green construction schemes is similar and generally an implementation of the following strategies:

1. Improve the living spaces within buildings;
2. Minimize as practical the carbon footprint of the buildings;
3. Ethically work in symbiosis with the natural environment the building is located;
4. Approach all the above with a whole of life commitment.

3.2.4 Model the air conditioning requirement of the building.

The floor plans were partitioned into air conditioned zones. The air conditioning zones are linked areas with similar air conditioning requirements. For example: the eastern façade being heated by the morning sun may require cooling, meanwhile the western façade, still in darkness, may require heating. If these zones are serviced with the same air handling unit one will have the conditions moving away from the thermal comfort zone.

The air conditioning zones were drafted onto the architectural floor plans. This was used to represent each air handling unit for the heat load calculation.

Refer: Figure 3: Camel Calculation Level 1;
Figure 4: Camel Calculation Level 2;
Figure 5: Camel Calculation Level 3;
Figure 6: Camel Calculation Level 4.

A heat load was required to establish the thermal requirements of the building. This was calculated using ACAD Camel software, refer: Appendix 3: Camel Heat Load Output. The building use and construction details were inputted into the program.

a. Air conditioning system type;
b. Set indoor conditions;
c. Building location;
d. Wall, floor and roof type, orientation and dimensions;
e. Glazing type, orientation and dimensions;
f. Building shading;
g. Occupancy capacities;
h. Electrical usage.

The output from this program will give the peak load requirements. This is the required size of the HVAC equipment. These peak load requirements were converted into chilled water flow quantities. The program does not have the capability of giving annual energy consumption information.

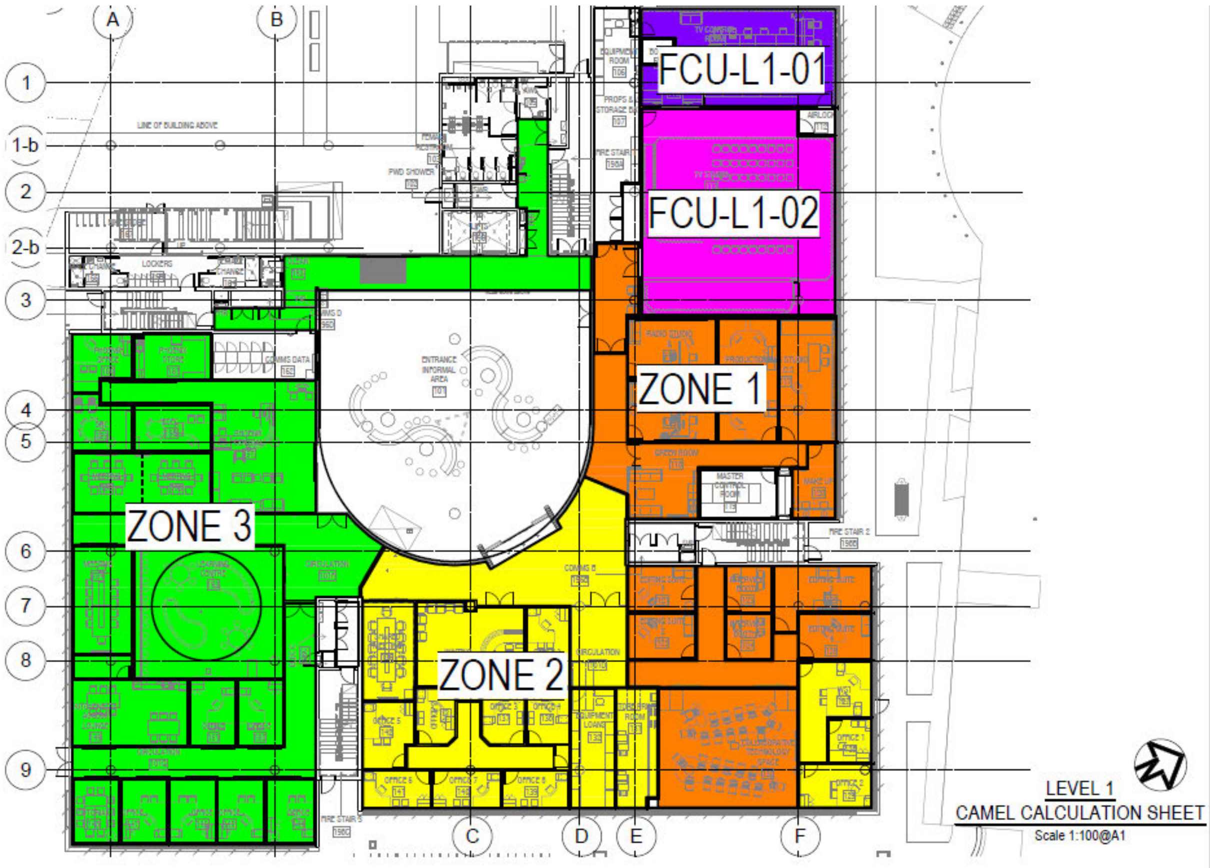


Figure 3: Camel Calculation Level 1

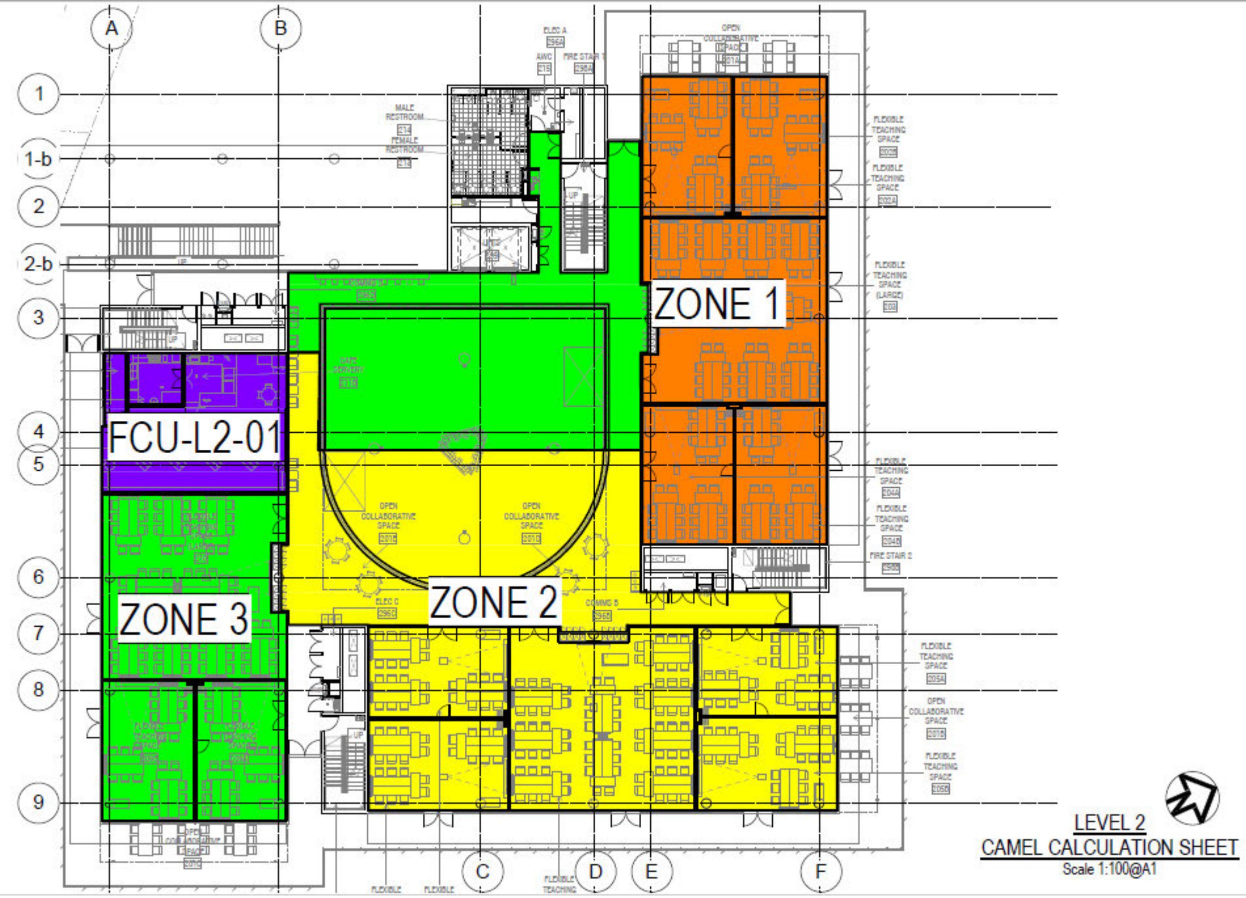


Figure 4: Camel Calculation Level 2

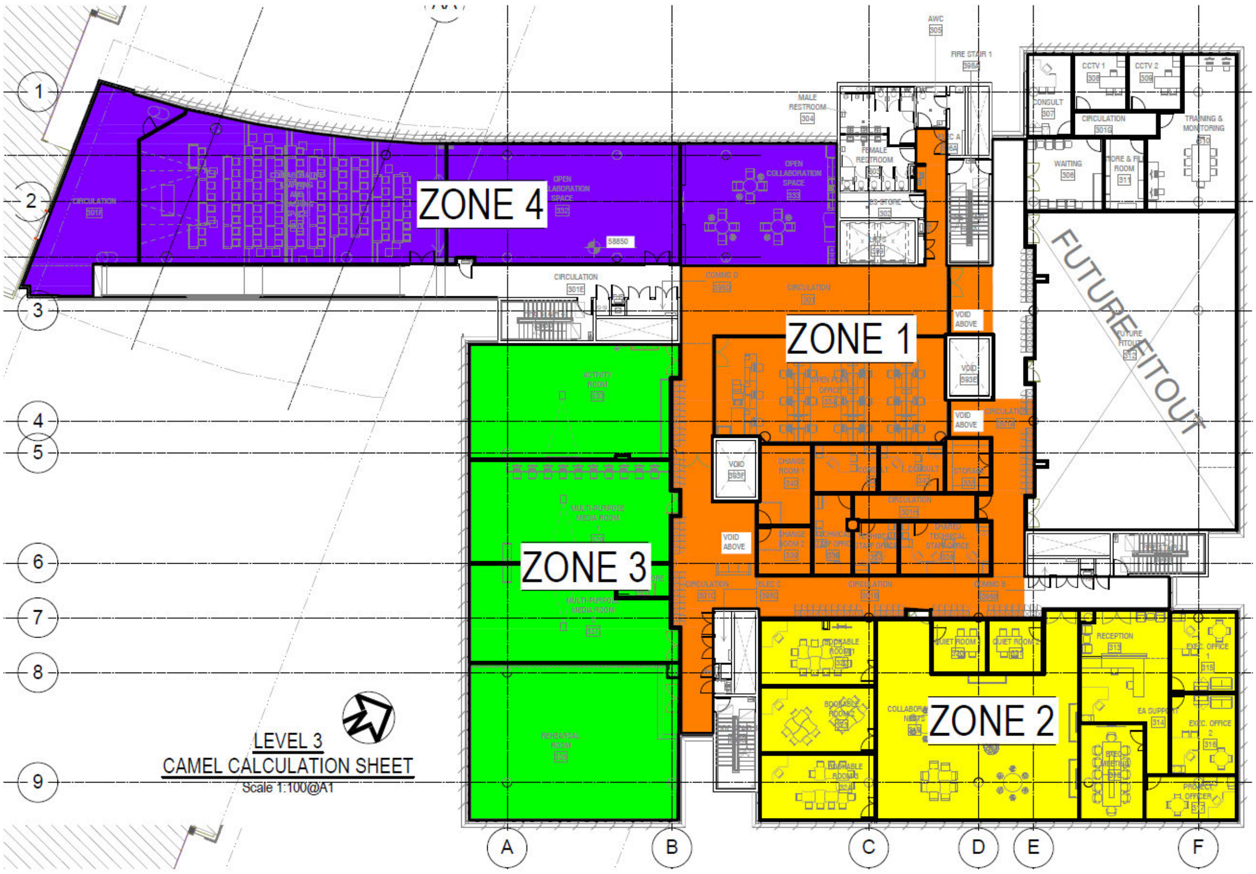


Figure 5: Camel Calculation Level 3

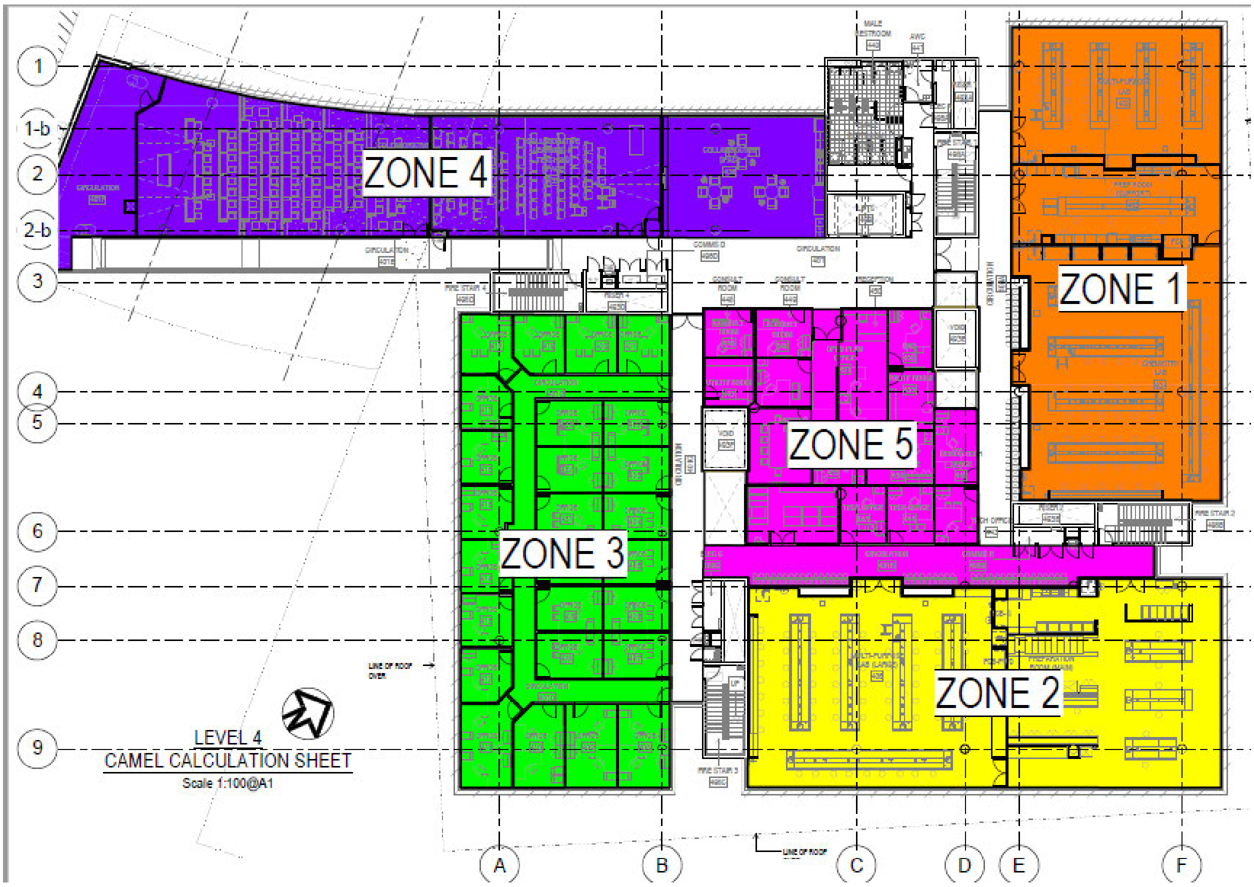


Figure 6: Camel Calculation Level 4

3.2.5 Model the energy usage.

The Building was modelled using the Design Builder software, refer: Appendix 4: Design Builder Output – As Built. Design builder is an energy simulation program that is accredited by the National Construction Code for use in Australia for compliance using a JV3 (commercial, Vol 1) assessment. This model will include:

1. Air conditioning system;
2. Set indoor conditions;
3. Building location;
4. Wall, floor and roof type, orientation and dimensions;
5. Glazing type, orientation and dimensions;
6. Building shading;
7. Occupancy capacities;
8. Electrical usage.

Although this is a repeat of the Camel Calculation it is necessary to achieve an accurate energy output for the building. The air conditioning information will be used to determine the accuracy of camel's results.

3.2.6 Undertake a Parametric Study.

It was necessary to remove the green star elements from the model. I replaced the green star elements with the DTS NCC compliant elements. To obtain the DTS NCC compliant elements a JV3 analysis was taken out on the building. Refer: **Error! Reference source not found.** Design Builder – NCC 2013 DTS. The model was rerun to calculate the energy differences of the revised building.

I have the data from the energy meter readings of the building. I have compared the modelled energy use with the actual energy use of the building. This comparison gave an opportunity to both fine-tune the model and confirm the accuracy of the model. This required varying the occupancy rates within the model until it reflects the actual data.

3.2.7 Analyse the energy differences to energy use that the green star attributes bring.

An analysis of the energy differences of the as built building and the NCC compliant building was completed. A graph was produced to document this. Conclusions were made from this information.

3.3 Resources

Modelling of the building is required to ascertain the energy requirement of the building. For this I will be using three different software applications:

1. AutoCAD (Drafting);
2. ACAD Camel (Heat Load);
3. Design Builder (Energy Modelling).

These software applications will allow me to determine the energy requirements of the building.

8.1 AutoCAD – AutoCAD is a Computer-aided design (CAD) Software application. This application will be used to measure and analyse the parameters through a model of the building. These parameters will be used as input data in the following programs;

8.2 ACAD Camel- Camel is software for calculating heat loads of buildings. The parameters from above will be inputted into the software and the peak heat loads will be outputted. These heat loads will be used as input data in the following program;

8.3 Design Builder estimates the peak and total energy consumption of a building over a given period. The above heat loads form part of the input data for the calculation of energy use of a building.

These programs have been made available for my use by my current employer Cushway Blackford Consulting Engineers.

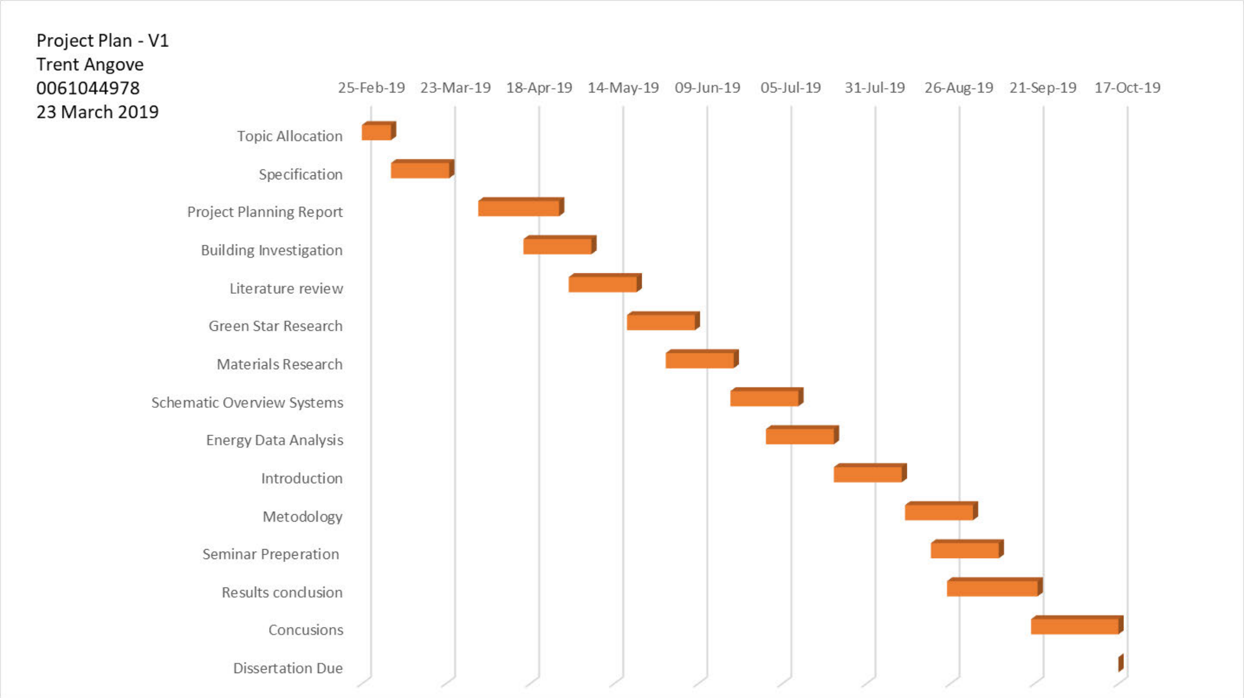


Figure 7: Timeline

4. Data Input for Modelling

4.1 Camel Input (air conditioning only) – As Built

The VAE Group Value Added Engineering designed and documented Edgy building's mechanical design. Their as-built documents were used to determine the system installed. The building parameters were inputted into camel to produce a heat load. The following parameters were used:

- **Building Location :** Archerfield Airport (Closest location in Camels Data base)
- **Design conditions :**

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
3pm °CDB	33.1	33.1	33.1	30.7	27.7	25.5	25.7	27.8	32.1	33.1	33.1	33.1
3pm °CWB	25.5	25.5	25.4	22.9	21.5	19.5	19.3	19.9	21.9	23.0	24.5	25.5

Years on which Design Conditions based 1990-2013

Table 3: Camel climate design conditions

- **Internal set points:** Summer 23°C dry bulb 50% relative humidity;
- **Bypass factor:** 0.15;
- **Return duct gains:** 2% heat, 2% leak;
- **Cooling safety factor:** 10%;
- **Storage mass:** 300kg/m^2;
- **Outside air:** Maximum of 7.5 l/s per person and 1 l/s/m^2;
- **Building fabric - U-value, surface density:** Walls - 0.556 W/m^{2}k, 490 kg/m^2;
  Roof – 0.281 W/m^{2}k, 26 kg/m^2;
  Floor – 1.56 W/m^{2}k, 240 kg/m^2;
- **Glazing U-value:** 3.2 wm^{2}k;
- **Glazing Shade factor:** 0.7;
- **Glazing Frame sash and haze correction:** 1.18;
- **Dimensions;** as per architectural drawings;
- **People:** as per architectural drawings;
- **Lighting:** 8 W/m^2;
- **Sensible:** 15 W/m^2.

4.2 Design Builder Input – As Built

As with the Camel heat load, the as built documents designed and documented by VAE were used to input the parameters into Design builder to produce a heat and energy use load. The following parameters were used:

- **Building Location :** Brisbane (Closest location in Design Builder's Data base)
- **Design conditions :**

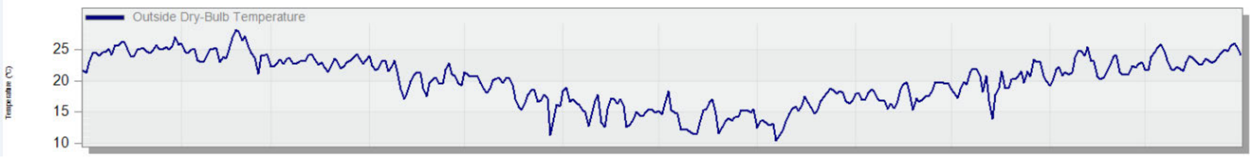


Figure 8: Design Builder climate design conditions (C)

- **Internal set points:** Summer 23°C dry bulb 50% relative humidity;
- **Bypass factor:** 0.15;
- **Cooling safety factor:** 11.5%;
- **Storage mass:** 300kg/m^2;
- **Outside air:** Maximum of 7.5 l/s per person and 1 l/s/m^2;
- **Building fabric - U-value:** Walls - 0.556 W/m^{2}k, 490 kg/m^2;
  Roof – 0.281 W/m^{2}k, 26 kg/m^2;
  Floor – 1.56 W/m^{2}k, 240 kg/m^2;
- **Glazing U-value:** 3.2 wm^{2}k;
- **Glazing Shade factor:** 0.7;
- **Glazing Frame sash and haze correction:** 1.18;
- **Dimensions;** as per architectural drawings;
- **People:** as per architectural drawings;
- **Lighting:** 5 W/m^2;
- **Sensible:** 15 W/m^2.

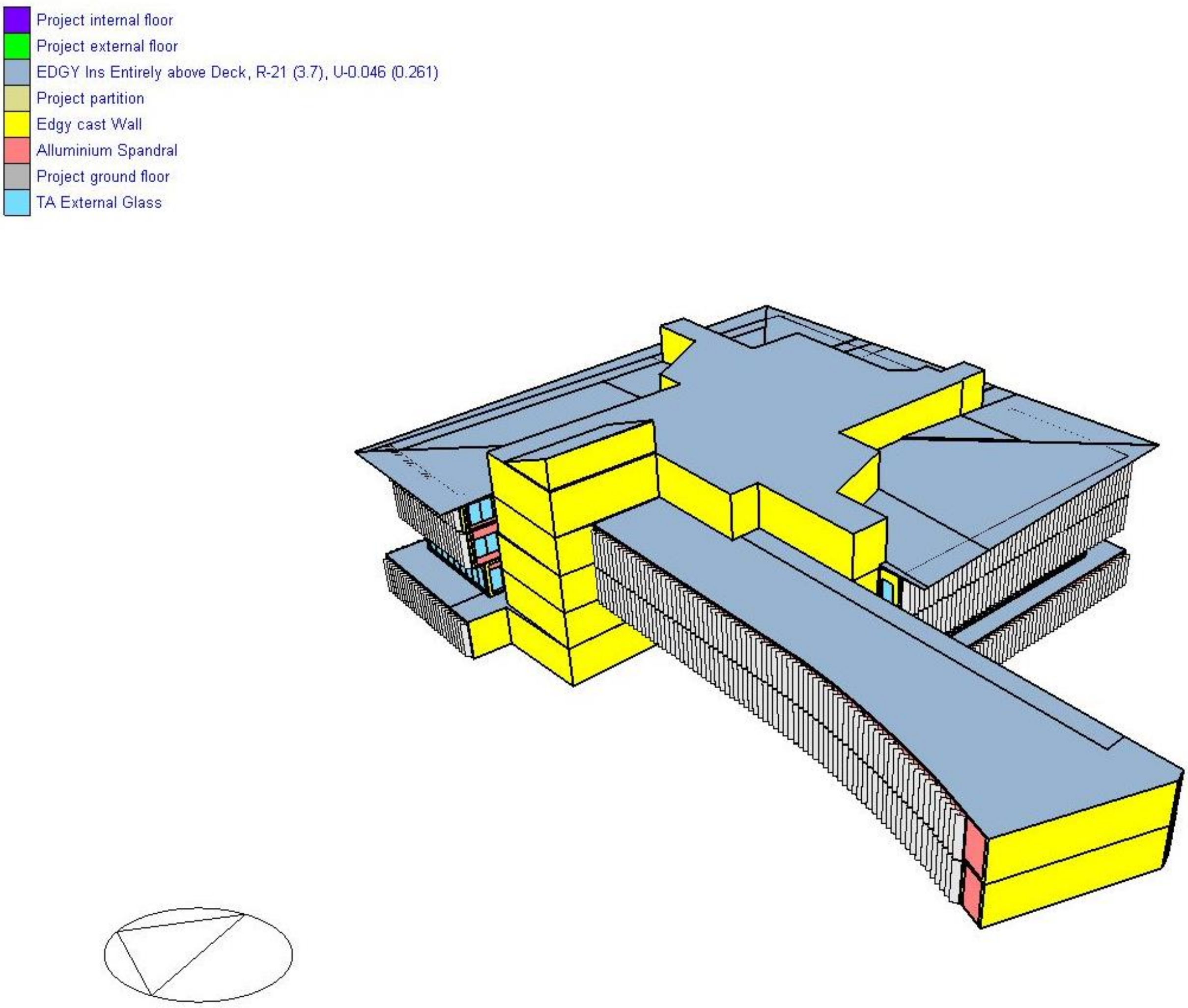


Figure 9: Design Builder As built Model

4.3 Design Builder Input – NCC 2013 DTS

In order to have an energy comparison the building model was amended to meet the deemed to satisfy outlines with respect to Section J of the National Construction Code (NCC) 2013 Building Code of Australia Volume 1.(Board, 2013) The verification method used was a JV3 Verification using a reference building. This is to verify that the building meets:

4.3.1 JP1 Performance Requirements

A building, including its services, must have, to the degree necessary, features that facilitate the efficient use of energy appropriate to-

a. the function and use of the building and services; and
b. the internal environment; and
c. the geographic location of the building; and
d. the effects of nearby permanent features such as topography, structures and buildings; and
e. solar radiation being –
    i. utilised for heating; and
    ii. controlled to minimise energy for cooling; and
f. the sealing of the building envelope against air leakage; and
g. the utilisation of air movement to assist heating and cooling; and
h. the energy source of the services.

(Board, 2013)

4.3.2 JV3 Performance Requirements

For compliance with JV3 you must show, with energy modelling, that the proposed building and its services is not more than the annual energy consumption of a reference building.

There are parameters that must be adhered to. Both models need to have the same services modelled. There is a reduction allowed if the proposed building uses a renewable on-site energy source or another process of reclaimed energy contributing to its annual energy consumption. I did not incorporate this into the model as it does not reduce the energy requirement of the building. The modelling must be calculated with software that is certified by the ABCB, Design Builder has ABCB certification.

The NCC 2013 Volume 1 sets the parameters of the reference building that can be used for **JV3** verifications. Including that it must:

i. comply with Parts **J1** to **J7** of the NCC 2013 volume 1; and
ii. use a solar absorbance of 0.6 for walls and 0.7 for roofs; and
iii. the maximum illumination power density; and
iv. air conditioning with the temperature range of 18° CDB and to 26° CDB for 98% of the operation time; and
v. occupancy profiles must comply with **JV** (a chapter in the NCC that determines the variables of a model).
vi. the infiltration amounts are if a pressurization plant is operating with the set the perimeter zone, width equal to the floor to ceiling height, at 1.0 air change per hour. If pressurization plant is not operating the whole building shall be set at 1.5 air changes per hour.
vii. all other parameters must be the same as the proposed building.

viii. the reference building must comply with **J1.2** for general thermal construction, **J1.3(c)** for compensation for a loss of ceiling insulation, **J1.6 (a)(ii), J1.6 (c) and J1.6(d)** for floor edging insulation.

(Board, 2013)

I have allocated the parameters for the reference building with respect to the NCC 2013 volume 1 requirement as detailed:

The NCC requirements for parts J1 to J7 vary depending on a building's classification and the climate zone in which the building is located.

4.3.3 Building classification

For this appraisal the building classification are expected to have sections that are:

- Class 5 – an office building used for professional or commercial purposes; and
- Class 9b – an assembly building.

4.3.4 Climate zone

The building is in Springfield, Ipswich, Queensland which falls within NCC climate zone 2.

4.3.5 J1 Building Fabric

4.3.5.1 J1.0 Deemed-to-Satisfy Provisions

This sets the provisions that are necessary for a deemed-to-satisfy building and those that are necessary for an alternate solution to the deemed-to-satisfy building. The reference model is required to be a Deemed-to-satisfy building.

4.3.5.2 J1.1 Application of part

This contains some building elements that not transferable to the reference model.

4.3.5.3 J1.2 Thermal construction

These contain some building elements and construction details referring to insulation that not transferable to the reference model.

4.3.5.4 J1.3 Roof and ceiling construction

This stipulates the minimum R-value for the roof and ceiling construction. From Table J1.3a Roofs and ceilings.

1. Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorbance value of not more than 0.4 – **R-Value 3.2 m^2k/W**;
2. Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorbance value of more than 0.4 but not more than 0.6 – **R-Value 3.7 m^2k/W**; or
3. Minimum Total R-Value for a roof or ceiling with a roof upper surface solar absorbance value of more than 0.6 – **R-Value 4.2 m^2k/W**;

Due to the parameter set (Page30) that the roof must use a solar absorbance of 0.7 the R-Value must be a minimum of **- R-Value 4.2 m^2k/W.**

Although there is a clause that if the only space for insulation is a furring channel or top hat section (as used to line tilt concrete panels with gypsum plaster) to allow **- R-Value 1.4 m^2k/W.** This requires the aggregate air conditioning energy value attributed to the glazing option B from table **J2.4a Energy index -** 0.173. Refer J2.4. The overhang or quality of glass required was deemed excessive.

4.3.5.5 J1.4 Roof lights
This section gives the maximum area percentage of floor area that roof lights can total. It also gives the thermal minimum requirements for the roof lights. As the roof lights are part of the Green Star accreditation I have excluded them from the reference model.

4.3.5.6 J1.5 Walls
This section gives the minimum R-Value for the wall construction. There are two tables to consider.
1. Table J1.5a Options for each part of an external wall that is part of an envelope, is relating to envelope walls that are external; and
2. J1.5b is for envelope walls that are internal. Note this does not include the sections of a wall that are non-glazed openings in external walls, glazing and earth retaining walls.

Therefore external walls with a wall surface density of not less than 220 kg/m^2, and a solar absorptance of not more than 0.6 as set (Page30)
- excluding south facing – **R-Value 2.3 m^2k/W;** and
- South - **R-Value 1.8 m^2k/W.**

4.3.5.7 J1.6 Floors – minimum total R-Value
This section sets the minimum R-Value for floors.
For the slab on ground with no heating or cooling system installed – Nil
A suspended floor with no heating or cooling system – 2.0 R-Value
This suspended floor located on Level Three, Zone Four, and any floor that is considered to be part of the envelope requires this R-Value of 2.0.

4.3.6 J2 Glazing

4.3.6.1 J2.0 Deemed-to-Satisfy Provisions
This sets the provisions that are necessary for a deemed-to-satisfy building and those that are necessary for an alternate solution to the deemed-to-satisfy building. The reference model is required to be a Deemed-to-satisfy building.

4.3.6.2 J2.1 Application of Part
This exempts any class 2 or 4 buildings from the Glazing requirements.

4.3.6.3 J2.2 Intentionally left blank
Therefore has no impact on this reference model.

4.3.6.4 J2.3 Intentionally left blank
Therefore has no impact on this reference model.

4.3.6.5 J2.4 Glazing,
this value is calculated in the following formula, note the average of each floor must be lower than A. The B option is only necessary if you are taking the option that the only space for insulation is a furring channel, top hat section, batten or the like for J1.5 Walls. This option B was not utilised for this project.

$$A_1[SHGC_1(C_A \text{ X } S_{H1}+C_B \text{ X } S_{C1}) + C_C \text{ X } U_1] + A_2[SHGC_2(C_A \text{ X } S_{H2}+C_B \text{ X } S_{C2}) + C_C \text{ X } U_2]\ldots$$

A_1 = the area of each glazing area; and
$C_{A,\ B\ and\ C}$ = the energy constants A, B and C from Table J2.4b; and

$SHGC_{1, 2 \text{ and } 3}$ = the total SHGC of each glazing element; and
$S_{H1, 2 \text{ and } 3}$ = the heating shading multiplier for each glazing element from Table J2.4c; and
$S_{C1, 2 \text{ and } 3}$ = the cooling shading multiplier for each glazing element from Table J2.4c; and
U_1 = the total U-Value of each glazing element.

An excel workbook was created to run this calculation. Glazing with the following properties was the minimum that would pass:

1. **SHGC** of **0.61**; and
2. Glazing **U-Value** of **5.8 W/m^{2}k**; and
3. **P/H** of **0.8**, shading overhanging the window to the depth as 80% height.

Refer Table 4: Aggregate Air Conditioning Energy Value Edgy Building DTS

J2.4 Aggregate Air Conditioning Energy Value Edgy Building DTS															
Level	Façade	C_A	C_B	C_C	Glazing area	P/H	S_C	SHGC	U	Energy index	building area	A (0.181)	Pass ?	B (0.173)	Pass ?
One	NE	0	1.4	-0.01	119.6	0.8	0.4	0.61	5.8	33.91856	143	25.883	FALSE	24.739	FALSE
	SE	0	0.84	0	119.2	0.8	0.48	0.61	5.8	29.3174784	142.9	25.8649	FALSE	24.7217	FALSE
	SW	0	0.7	0	80.9	0.8	0.54	0.61	5.8	18.653922	138.9	25.1409	TRUE	24.0297	TRUE
	NW	0	1.17	-0.01	53.7	0.8	0.43	0.61	5.8	13.3654467	134.4	24.3264	TRUE	23.2512	TRUE
Total										**95.2554071**	**559.2**	**101.215**	**TRUE**	**96.7416**	**TRUE**
Two	NE	0	1.4	-0.01	106.8	0.8	0.4	0.61	5.8	30.28848	128	23.168	FALSE	22.144	FALSE
	SE	0	0.84	0	111	0.8	0.48	0.61	5.8	27.300672	133.1	24.0911	FALSE	23.0263	FALSE
	SW	0	0.7	0	71.7	0.8	0.54	0.61	5.8	16.532586	130.3	23.5843	TRUE	22.5419	TRUE
	NW	0	1.17	-0.01	80.1	0.8	0.43	0.61	5.8	19.9361691	133.7	24.1997	TRUE	23.1301	TRUE
Total										**94.0579071**	**525.1**	**95.0431**	**TRUE**	**90.8423**	**FALSE**
Three	NE	0	0	-0.01	95	0.8	0.4	0.61	5.8	-5.51	136	24.616	TRUE	23.528	TRUE
	SE	0	0.84	0	152.2	0.8	0.48	0.61	5.8	37.4338944	214.3	38.7883	TRUE	37.0739	FALSE
	SW	0	0.7	0	75.2	0.8	0.54	0.61	5.8	17.339616	138.1	24.9961	TRUE	23.8913	TRUE
	NW	0	1.17	-0.01	75	0.8	0.43	0.61	5.8	18.666825	197.8	35.8018	TRUE	34.2194	TRUE
Total										**67.9303354**	**686.2**	**124.202**	**TRUE**	**118.7126**	**TRUE**
Four	NE	0	1.4	-0.01	114	0.8	0.4	0.61	5.8	32.3304	136	24.616	FALSE	23.528	FALSE
	SE	0	0.84	0	183	0.8	0.48	0.61	5.8	45.009216	214.1	38.7521	FALSE	37.0393	FALSE
	SW	0	0.7	0	75.2	0.8	0.54	0.61	5.8	17.339616	138.6	25.0866	TRUE	23.9778	TRUE
	NW	0	1.17	-0.01	90	0.8	0.43	0.61	5.8	22.40019	197.8	35.8018	TRUE	34.2194	TRUE
Total										**631.566721**	**4227.5**	**765.178**	TRUE	**731.3575**	TRUE

Table 4: Aggregate Air Conditioning Energy Value Edgy Building DTS

4.3.6.6 J2.5 Shading

This section sets the parameters in which the shading can be calculated. That is it is permanent and restricts at least 80% of the summer solar radiation.

4.3.7 J3 Building sealing

4.3.7.1 J3.0 Deemed-to-satisfy Provisions

Sets the provisions that are necessary for either a deemed-to-satisfy building or an alternate solution to the deemed-to-satisfy building. The reference model is required to be a Deemed-to-satisfy building.

4.3.7.2 J3.1 Application of Part
This part gives exemptions to building sealing parameters. This includes where the only cooling is from an evaporative cooler, or where it is unsafe due to gas appliances or if pressurisation is significant to prevent infiltration as determined in Part 4 of the NCC 2013 volume 1.

4.3.7.3 J3.2 Chimneys and flues
There are no chimneys or flues in this building.

4.3.7.4 J3.3 Roof Lights
Sets the parameters for roof lights to be sealed. As the roof lights are part of the Green Star accreditation I have excluded them from the reference model.

4.3.7.5 J3.4 Windows and Doors
This section outlines the requirement and description for acceptable methods for the windows and doors to be sealed.

4.3.7.6 J3.5 Exhaust fans
This denotes the need for exhaust and supply fans to have a self-closing damper.

4.3.7.7 J3.6 Construction of roofs, walls and floors
This sets construction conditions to minimize leakage, for example caulking, skirting etc.

4.3.7.8 J3.7 Evaporative coolers
Sets the requirement for evaporative coolers to have a self-closing damper.

4.3.7.9 J4 Intentionally left blank
Therefore has no impact on this reference model.

4.3.8 J5 Air-conditioning and ventilation systems

4.3.8.1 J5.0 Deemed-to-satisfy Provisions
Sets the provisions that are necessary for a deemed-to-satisfy building and those that are necessary for an alternate solution to the deemed-to-satisfy building. The reference model is required to be a Deemed-to-satisfy building.

4.3.8.2 J5.1 Intentionally left blank
Therefore has no impact on this reference model.

4.3.8.3 J5.2 Air-conditioning and ventilation systems
This section gives details to the requirements of the air conditioning systems, generally to improve efficiency. This has no impact on this reference model.

4.3.8.4 J5.3 Time switch
Time switch is requirements are stipulated in this section. This has no impact on this reference model.

4.3.8.5 J5.4 Heating and cooling systems
This section is similar to J5.2 in which it gives parameters that set the level of efficiency for these systems.

4.3.8.6 J5.5 Miscellaneous exhaust systems

Energy reducing procedures are outlined in this section.

4.3.9 J6 Artificial lighting and power

4.3.9.1 J6.0 Deemed-to-satisfy Provisions

Sets the provisions that are necessary for a deemed-to-satisfy building and those that are necessary for an alternate solution to the deemed-to-satisfy building. The reference model is required to be a Deemed-to-satisfy building.

4.3.9.2 J6.1 Application of Part

Gives exemption for class 8 electricity network substations and therefore has no impact on this reference model.

4.3.9.3 J6.2 Artificial lighting

This section give allowances to the maximum lighting levels. This information will set the lighting load in our reference building model at is **5W/m^2**.

4.3.9.4 J6.3 Interior artificial lighting and power control

This section gives details about the lighting systems control system. Therefore has no impact on this reference building model.

4.3.9.5 J6.4 Interior decorative and display lighting

This section gives details about the decorative and display lighting systems control system, Therefore has no impact on this reference building model.

4.3.9.6 J6.5 Artificial lighting around the perimeter of a building

The details here about the external lighting have no impact of the reference building model.

4.3.9.7 J6.6 Boiling water and chilled water storage units

Sets the requirements for boiling and chilled water storage units. Therefore has no impact on this reference building model.

4.3.10 J7 Hot water supply and swimming pool and spa pool plant

4.3.10.1 J7.0 Deemed-to-satisfy Provisions

Sets the provisions that are necessary for a deemed-to-satisfy building and those that are necessary for an alternate solution to the deemed-to-satisfy building. The reference model is required to be a Deemed-to-satisfy building.

4.3.10.2 J7.1 Intentionally left blank

Therefore has no impact on this reference model.

4.3.10.3 J7.2 Hot water supply

A hot water system for the purpose of food preparation or sanitary purposes must be designed and installed in accordance with Section 8 of AS/NZS 3500.4 and therefore this section has no impact on this reference model.

4.3.10.4 J7.3 Swimming pool heating and pumping

No swimming pools form part of this project and therefore this section has no impact on this reference model.

4.3.10.5 J7.4 Spa pool heating and pumping

No spa pools form part of this project and therefore this section has no impact on this reference model.

4.3.11 Input Data - Design Builder – NCC 2013 DTS

Therefore the following building parameters were inputted into Design builder to produce a Deemed to satisfy heat and energy use load. The following parameters were used:

- **Building Location :** Brisbane (Closest location in Design Builder's Data base)
- **Design conditions :**

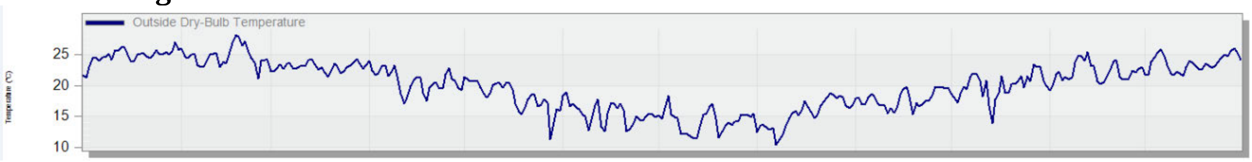


Figure 10: Design Builder climate design conditions (C)

- **Internal set points:** Summer 23°C dry bulb 50% relative humidity;
- **Bypass factor:** 0.15;
- **Cooling safety factor:** 11.5%;
- **Storage mass:** 300kg/m^2;
- **Outside air:** Maximum of 7.5 l/s per person and 1 l/s/m^2;
- **Building fabric - U-value:** Walls, not south) - 0.43 W/m^{2}k, 490 kg/m^2;
  Walls, south - 0.56 W/m^{2}k, 490 kg/m^2;
  Roof – 0.24 W/m^{2}k;
  Floor – 1.56 W/m^{2}k;
- **Glazing U-value:** 5.8 Wm^{2}k;
- **Glazing Shade factor:** 0.52;
- **Glazing Frame sash and haze correction:** 1.18;
- **SHGC** – 0.61
- **Dimensions;** as per architectural drawings;
- **People:** as per architectural drawings;
- **Lighting:** 5 W/m^2;
- **Sensible:** 15 W/m^2.

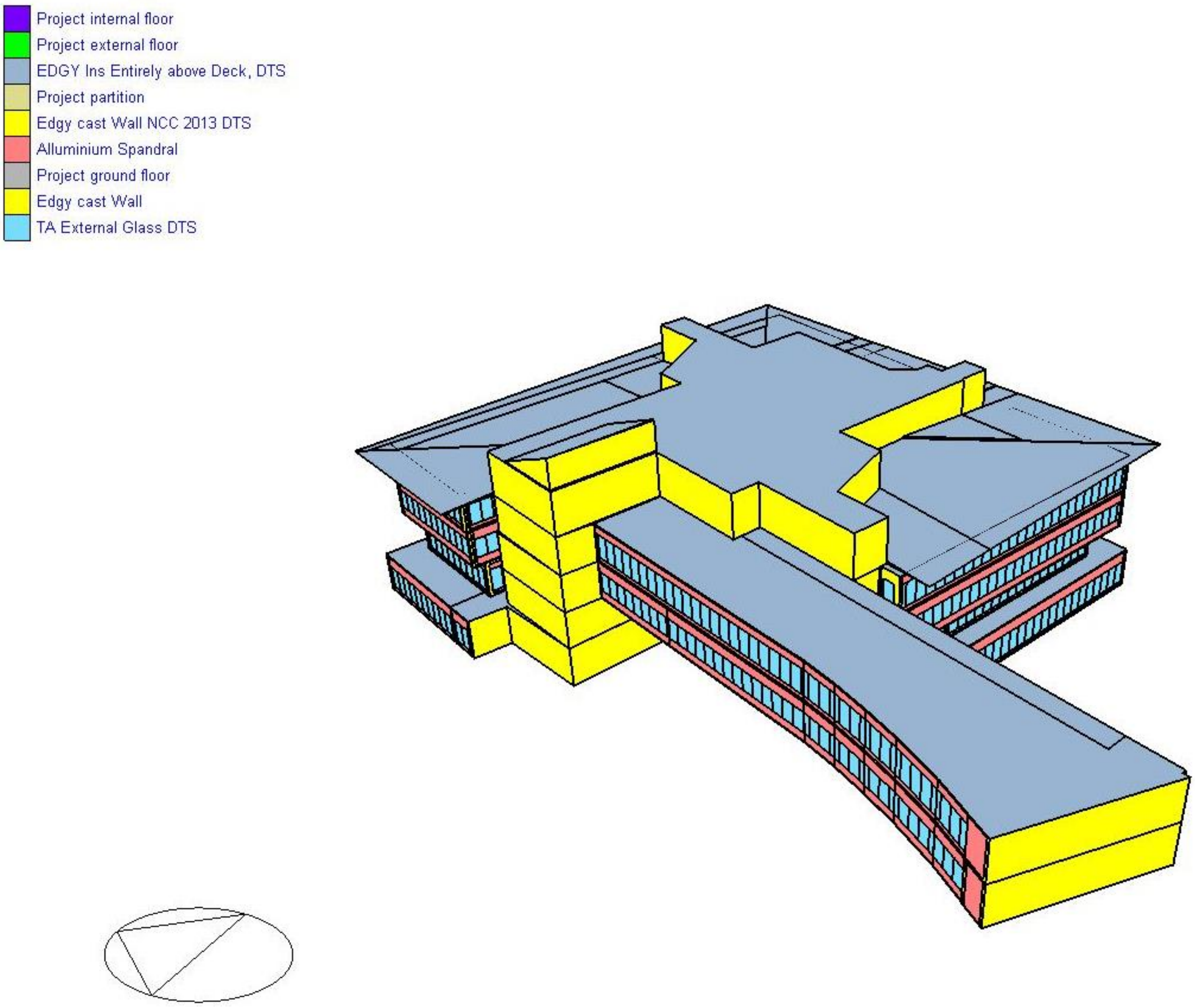


Figure 11: Design Builder NCC 2013 DTS Model

5. Results

5.1 Modelling

5.1.1 Heat Load

Refer: Page 54 Appendix 2: Camel Heat Load Output,
Page 54 Appendix 3: Design Builder Output – As Built,
Page 54 Appendix 3: Design Builder Output – As Built.

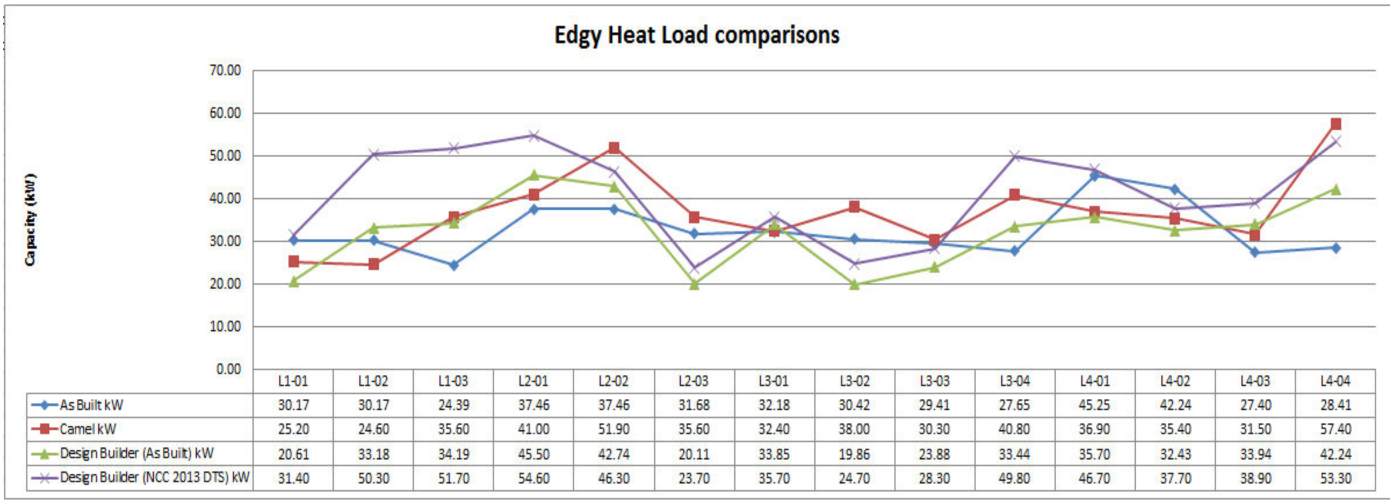
The building's heat load was calculated to determine the peak heat demand and compared with the installed system. Refer Table 5.

Model	Peak Heat Load	Percentage of Installed
Installed	454.3 kW	100.00%
Design Builder As built	451.7 kW	96.48%
Camel As built	516.6 kW	116.00%
Design Builder 2013 DTS	573.1 kW	127.60%

Table 5: Building Heat Load Results

Camel appears to be on the conservative side when compared with what was installed, while design builder appears to be a little light. The 2013 DTS building was expected to be different as it is not the same building. All of these systems would be suitably sized for the building on most days.

The individual air handling units gave some interesting results. Camel's output for units L2-02, L2-03, L3-02, L3-03 and L4-04 suggested higher loads than the less efficient design builder DTS model. However the results were generally as to be expected. Refer Figure 12



	L1-01	L1-02	L1-03	L2-01	L2-02	L2-03	L3-01	L3-02	L3-03	L3-04	L4-01	L4-02	L4-03	L4-04
As Built kW	30.17	30.17	24.39	37.46	37.46	31.68	32.18	30.42	29.41	27.65	45.25	42.24	27.40	28.41
Camel kW	25.20	24.60	35.60	41.00	51.90	35.60	32.40	38.00	30.30	40.80	36.90	35.40	31.50	57.40
Design Builder (As Built) kW	20.61	33.18	34.19	45.50	42.74	20.11	33.85	19.86	23.88	33.44	35.70	32.43	33.94	42.24
Design Builder (NCC 2013 DTS) kW	31.40	50.30	51.70	54.60	46.30	23.70	35.70	24.70	28.30	49.80	46.70	37.70	38.90	53.30

Figure 12: Edgy Heat Load Comparisons

On analyses of the Design builder model's heat load totals, the NCC 2013 DTS model is 26.9% higher than the Green star rated model. The result is influenced by the differing data input of the two models:

1. Building fabric wall u-value;
2. Glazing u-value;
3. Glazing shade factor; and
4. Glazing shades.

For Shading differences on models refer Figure 9 & Figure 11 as the shading was dramatically minimized in the DTS model. There was still a requirement to shade the glass to be able to use standard glass. For the point of difference between the two design builder models input data (As Built / 2013 DTS) refer Table 6.

The change in heat load appears linear across the year but not for the individual fan coil units. Refer Figure 13 and Figure 14: Design Builder as Built and NCC 2013 DTS Comparisons (air conditioning). This appears to be due to the large amounts of aluminium shading contained in these air conditioning zones. Refer Figure 3 and Figure 5

Input Category	As Built	2013 DTS
Wall U-Value	0.35 W/m^2k	0.46 W/m^2k (0.43 W/m^2k & 0.56 W/m^2k -South)
Glazing U-Value	3.2 W/m^2k	5.8 W/m^2k
Glazing Shade Factor	0.7	0.52
Glazing shades	Refer Figure 9	Refer Figure 11

Table 6 : Design Builder Differing Input Data

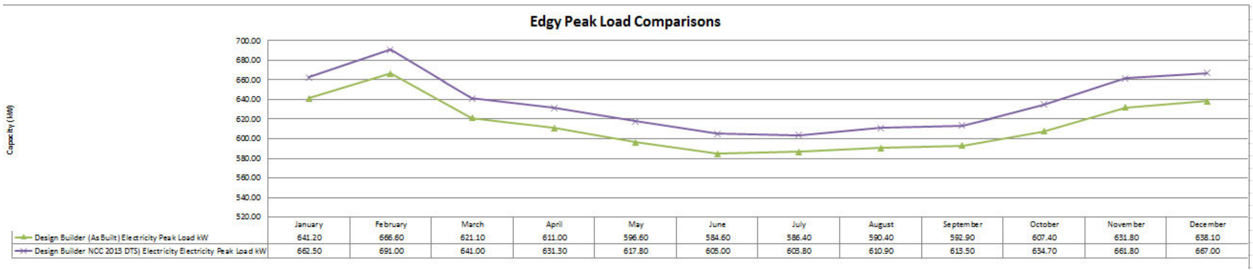


Figure 13: Edgy Peak Heat Load

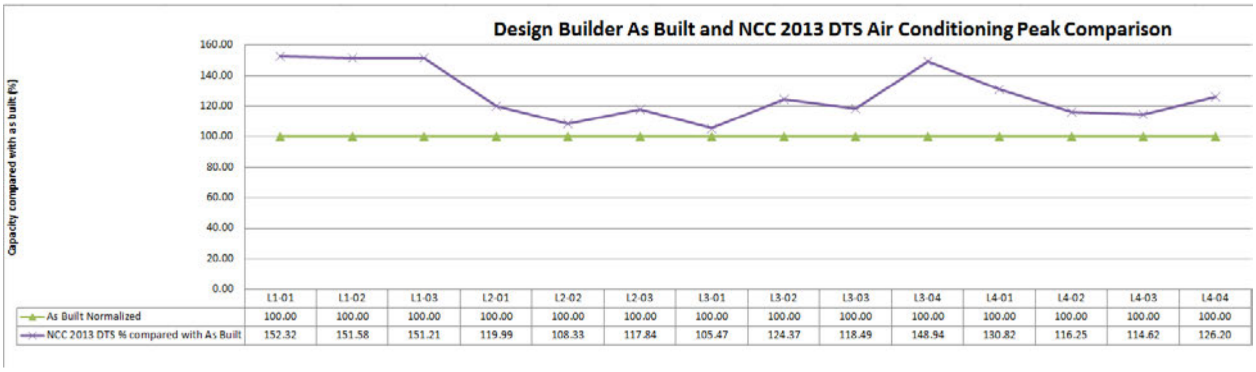


Figure 14: Design Builder as Built and NCC 2013 DTS Comparisons (air conditioning)

5.1.2 Energy Model

Refer: Page 54 Appendix 3: Design Builder Output – As Built
Page 54 Appendix 4: Design Builder Output – NCC 2013 DTS

The energy use of the two models was calculated using design builder. This determined the peak electrical use and monthly energy usage. The results are outlined in Appendix 4: Design Builder Output – As Built and Appendix 5: Design Builder Output – NCC 2013 DTS

The annual energy meter totals for the models were:

Design Builder Output – As Built 2704 MWh
Design Builder Output – NCC 2013 DTS 2905 MWh

The electrical peaks load for the models were:

Design Builder Output – As Built	666.6 kW
Design Builder Output – NCC 2013 DTS	691.0 kW

When compared with the green star model, the design builder output shows the NCC 2013 DTS model's annual energy use increases by 7.4% while the peak electrical load increases by 3.7%. This increase appears to be uniform across the year. This is expected as the total heat load that is the point of difference between the two models is uniform also.

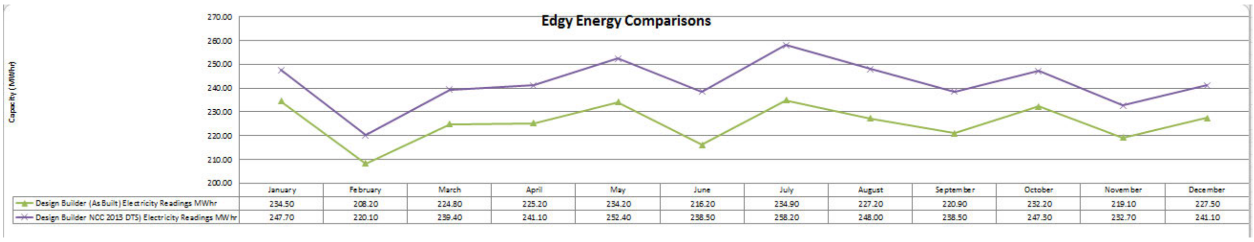


Figure 15: Edgy Electrical Use

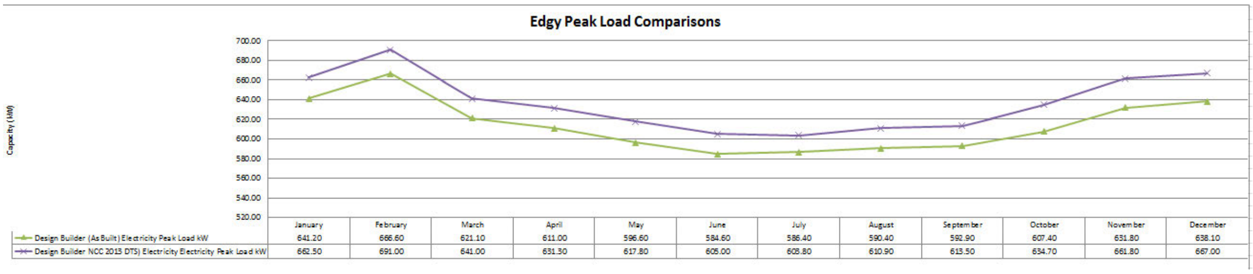


Figure 16: Edgy Peak Electrical Load

5.2 Elements of the green design that reduce electrical use

Of the categories that the edgy building 2 achieved green points for, the following would have a reducing effect on the energy use. However due to the reactive nature of these elements it was difficult to model in the any actual advantages. For this reason these elements were not included in the modelling:

1. HVAC in each separate enclosed space within 90% the nominated area is designed to allow a wider temperature control band (an additional 2 degrees in each direction) when not in use.
2. A carbon dioxide monitoring system is specified to track and adjust ventilation rates with low carbon dioxide levels upon occupancy. Also, a VOC monitoring system is specified to detect and alert when pollutants are too high in the building.
3. Automated blinds and external shading are components of the design, reducing glare from natural lighting.
4. Lighting levels are designed to be maintained at no more than 25% above the minimum maintained illuminance levels recommended in AS1680.2.3 Table E1.

5.3 Parametric study

A parametric study was taken out on the two design builder models (As Built and 2013 DTS). The parameters for evaluation were the points of difference in the models as stated in chapter 5.1.1. The resulted effect on the energy consumption of the building was recorded. Refer Table 7 and Figure 17

Input Category	As Built	2013 DTS	Increased Energy (%)
Wall U-Value	0.35 W/m^{2}k	0.46 W/m^{2}k	0.47
Glazing U-Value	3.2 W/m^{2}k	5.8 W/m^{2}k	1.05
Glazing Shade Factor	0.7	0.52	
Glazing shades	Refer Figure 9	Refer Figure 11	5.92

Table 7: Model input outcomes variance

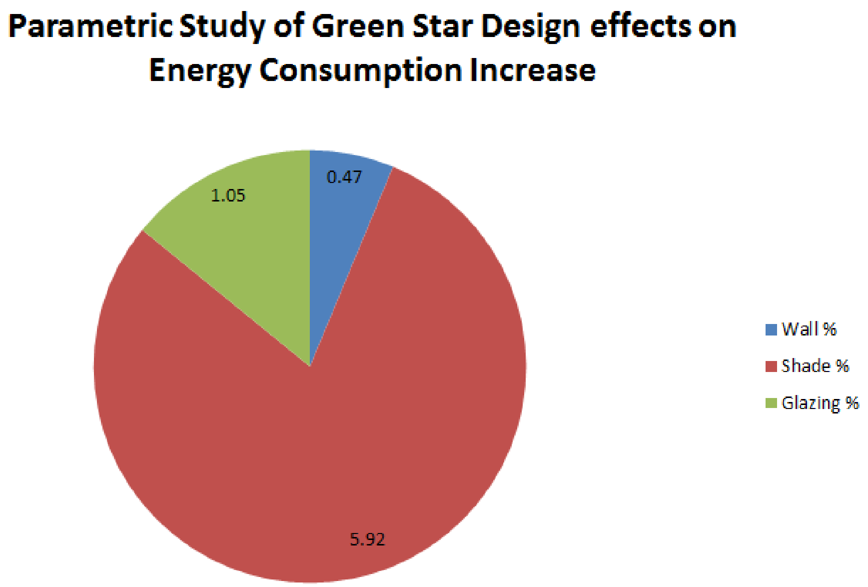


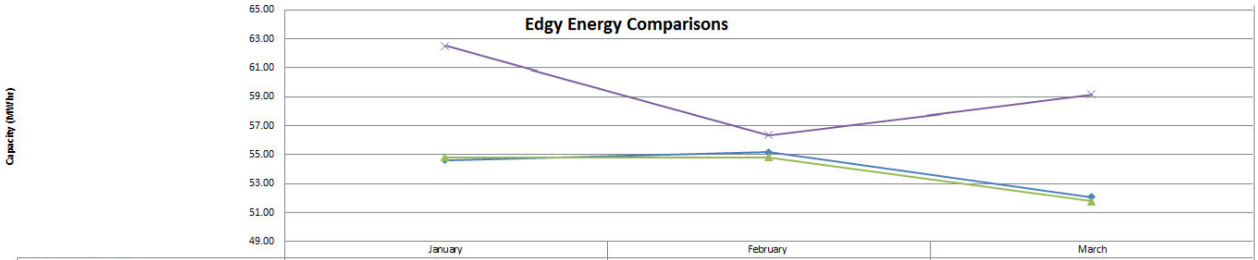
Figure 17: Parametric study pie-chart

It is clear that the aluminium louvres that shade the glazing are the main parameter to bring a decrease in electrical consumption.

5.4 Energy meter readings

The meter readings from Edgy building were used to document the monthly energy use. The original data gives readings every half hour for electricity use that is sent to the Building Management System (BMS). I totalled each month. To calibrate the model I minimized the people schedule to 20% occupancy. This aligned the model with the actual energy data.

The data suggested the building is being underutilized. I received the meter reading data of the first three months of 2019. A fair proportion of this time was between traditional semester timeframes. Due to COVID-19 lockdowns, data from 2020 would have been less representative of general use. The concern from the low people loads is the portion of energy used to air condition the building. The load from the building fabric is constant in both situations. It would be productive to take a sample from when things get back to normal and compare the results.



	January	February	March
Energy Meters MWhr	54.62	55.15	52.06
Design Builder (As Built) kWhr - 20% Occupancy	54.82	54.82	51.79
Design Builder (NCC 2013 DTS) kWhr - 20% Occupancy	62.49	56.35	59.14

Figure 18 : Energy comparison to actual meter readings

6. Conclusion

This report demonstrates the Green star process did reduce the energy consumption of USQ’s Springfield campus Building B. Modelling exhibited a 7.5% reduction to annual energy use in the green star model. The main parameter of the green design to improve the efficiency of the building was the aluminium louvres that shaded the glazing. A reduction to air conditioning plant and electrical infrastructure were also achieved from the green star process.

The positive impact the green star process had on building B was more than a reduction to ongoing electrical use. The green star process set in motion the matrix to construct a world leading building. Benefits to the impact on the environment from this construction were greatly lowered. Improvements to the indoor environment can be attributed to the green star process. In at least this case, the green star process can be attributed to reducing the energy use of a building.

7. Further Work

Further investigation into the financial effect the green star process brings to the design and construction of a building is required. The increased demands on the design team are substantial. There must be an increase to modelling to predict the parameters of the proposed building. The design team requires additional time to coordinate the design. Analyses of the payback time for the design, in particular the aluminium louvres that shade the glazing, would be helpful to sell the green process.

There is an indication of an increase to the energy the green star process requires. This is through an increase of materials or new technologies used in the design. It would be beneficial to know how long the building will operate before the energy use is in balance through the green star process.

Finally, investigation into the actual energy use of the building during full occupancy would be necessary to fully investigate the building.

8. Risk Assessment

The Work Health and Safety Act (2011) require a risk assessment be undertaken on this engineering activity. The duty of care falls on the responsibility of all and all reasonable precautions must be taken to minimise the risk to both myself and others.

A risk assessment was taken out on this project. All risk was evaluated in the following parameters:
1. Impacting;
2. Initial likelihood;
3. Consequence;
4. Initial risk ranking;
5. Primary risk Treatment and
6. Treatment plan.

This project was conducted during the COVID 19 pandemic. This bought on additional risks that were assessed.

Most of the Project will be conducted on a laptop or personal computer with access to the internet. With the following assessment results:

Risk	Impacting	Initial Likelihood	Consequence	Initial risk ranking	Primary risk Treatment	Treatment plan
Electric shock	Self	Low	Major	High	Eliminate/and Avoid	Remain clear of water.
Slips, trips and falls	Self	Low	Medium	High	Eliminate/and Avoid	Ensure area is clear of trip hazards.
Fire	Self	Rare	Major	High	Eliminate and avoid	Be aware of fire egress.
COVID 19	Self/others	Low	Major	High	Eliminate/ and Avoid	Follow Government procedures including at a minimum ‘social distancing’.

Table 8: Home Risk Analysis

As a site visit is required the following risks have been noted

Risk	Impacting	Initial Likelihood	Consequence	Initial risk ranking	Primary risk Treatment	Treatment plan
Electric shock	Self	Low	Major	High	Eliminate/and Avoid	Remain clear of water. Student will be escorted by a member of staff.
Slips, trips and falls	Self	Low	Medium	High	Eliminate/and Avoid	Ensure area is clear of trip hazards. Student will be escorted by a member of staff.

Fire	Self	Rare	Major	High	Eliminate and avoid	Be aware of fire egress. Student will be escorted by a member of staff.
Noise	Self	Possible	Major	High	PPE	Use appropriate PPE when in Mechanical Plant areas. Student will be escorted by a member of staff.
Being struck by vehicles	Self	Possible	Major	Medium	Eliminate and avoid	Remain in a pedestrian area unless unavoidable. Student will be escorted by a member of staff.
COVID 19	Self	Low	Major	High	Eliminate/ and Avoid	Follow Government procedures, social distancing etc. Avoid site visit until deemed allowed.

Table 9: Site Visit Risk Analysis

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10. Appendix

Appendix 1: Specification

ENG4111/4112 Research Project
Project Specification

For: Trent Angove
Title: Energy Performance Analysis of a Six Green Star Building
Major: Mechanical Engineering
Supervisor: Dr Andrew Wandel
Enrolment: ENG4111 – EXT S1, 2020
ENG4112 – EXT S2, 2020

Project aim: To analyse the energy use of a six green star building in order to determine the green star attributes that affect the energy efficiency of the building.

Programme: Version 2, 4 April 2020

1. Research the Green Star Accreditation process.
2. Literature review on green building design.
3. Model the energy use of the building. (refer resource Plan-1 & 2)
4. Validate the model on actual energy data.
5. Undertake a parametric study of removing the Green star inclusions of the building. (refer resource Plan-1, 2 & 3)
6. Analyse the differences to energy use that the green star attributes bring.
7. Evaluate the life cycle energy use of the building. (refer resource Plan)
8. Report on which elements of the green star process are beneficial to reducing the energy use of a building.

Resource Plan

Resources

1. AutoCAD – AutoCAD is a Computer-aided design (CAD) Software application. This application will be used to measure and analyse the parameters through a model of the building. These parameters will be used as input data in the following programs;

2. ACAD Camel- Camel is software for calculating heat loads of buildings. The parameters from above will be inputted into the software and the peak heat loads will be outputted. These heat loads will be used as input data in the following program;

3. ACAD Beaver- Beaver estimates the hourly energy consumption of a building over a given period. The above heat loads form part of the input data for the calculation of energy use of a building.

These programs have been made available for my use by my current employer Cushway Blackford & Associates.

Appendix 2: Credit Category and achievements (Edgy Building)

The Edgy building at Springfield was certified with a Design Green Star Rating of 5 on the August 2014. It obtained credit from the following categories: (Green Building Council Australia,2020b).

Emissions:

1. All specified thermal insulation avoids the use of ozone-depleting substances in both manufacture and composition.
2. No water-based heat rejection systems to be included in the project.
3. Exterior lighting designs comply with AS4282 and do not direct any light beams into the night sky or beyond site boundaries. At least 95% of outdoor spaces are not to exceed the minimum requirements of AS1158 for illuminance levels.
4. All specified HVAC refrigerants have an ozone Depleting Potential (ODP) of zero.

Energy:

5. External lighting will be connected to daylight sensors and have a light source efficacy of more than 65 lumens/watt. Outdoor spaces exceed the minimum requirements of AS1158 for illuminance levels.
6. Sub-metering is to be installed to monitor lighting and general power consumption for primary functional areas, such as class and lecture areas, office and administration spaces and laboratories.
7. Lighting is designed to automated zones of not more than 100m2 with occupant detection and daylight adjustment.
8. On-site energy systems are shared by at least two (2) buildings.
9. HVAC in each separate enclosed space within 90% the nominated area is designed to allow a wider temperature control band (an additional 2 degrees in each direction) when not in use.
10. The building's predicted greenhouse gas emissions are reduced 40% compared to a standard benchmark building.

Indoor Environment Quality:

1. A carbon dioxide monitoring system is specified to track and adjust ventilation rates with low carbon dioxide levels upon occupancy. Also, a VOC monitoring system is specified to detect and alert when pollutants are too high in the building.
2. Daylight modelling shows that 30% of the project's nominated area provides a Daylight Factor (DF) of 2% for building users.
3. Automated blinds and external shading are components of the design, reducing glare from natural lighting.
4. Lighting levels are designed to be maintained at no more than 25% above the minimum maintained illuminance levels recommended in AS1680.2.3 Table E1.
5. 60% of the nominated area is designed for direct line of site to the outdoors or a day-lit internal atrium.
6. All composite wood products specified have low-formaldehyde emissions.
7. Following a survey, all hazardous materials (asbestos, lead or polychlorinated biphenyls) found and removed.
8. High frequency ballasts are to be included to reduce occupants' eye strain from low frequency flicker.
9. Designed ventilation systems will actively control humidity and minimise mould.
10. Ventilation is designed for superior air change effectiveness, according to ASHRAE 129-1997 and laminar flow patterns.

11. Mechanically air-conditioned work space is designed to be a comfortable temperature, within the Predicted Mean Vote levels of -0.5 to +0.5.
12. 96% of adhesives, sealants and painted surfaces and all carpets and flooring are specified to be low in volatile organic compounds.

Land Use & Ecology:

1. Development will reduce environmental impact upon the site.
2. 75% (or greater) of the site was previously developed.
3. Site was contaminated before the project works and will be fully remediated prior to construction.

Management:

1. A Building User's Guide is developed.
2. A Building Maintenance Guide is developed.
3. Contracted for a minimum 12 month building tuning period after handover, including quarterly reviews, monthly monitoring and final re-commissioning.
4. Appointed a commissioning agent independent of the design team and contractors.
5. Three (3) of the building's environmental attributes will be displayed for easy understanding with the measurable environmental and economic benefit to the building users.
6. A design review will occur at both preliminary and final design stages by the person responsible for building maintenance concerning the access, ongoing maintenance and ongoing cleaning of the building services and external building features.
7. Contracted to provide comprehensive pre-commissioning, commissioning and quality monitoring for all building services. The design team and contractor are to transfer the information and documentation to the building owner upon completion.
8. The contractor is to implement a project-specific Environmental Management Plan (EMP) in accordance with section 4 of the NSW Environmental Management System Guidelines during construction. The contractor must also hold ISO14001 accreditation.
9. A Green Star Accredited Professional; is a principle participant in the project team to provide advice on the Green Star aims and processes from design through to delivery.
10. Committed to re-using or recycling 80% of construction waste (by weight).

Materials:

1. The design of flooring throughout the project has a reduced environmental impact.
2. The design of joinery throughout the project has a reduced environmental impact.
3. 95% of specified timber and composite timber products (by cost) to be used in the building and construction works was sourced from more sustainable means or are reused/recycled.
4. Alternative materials are specified to replace 60% (by cost) of total PVC costs.
5. 90% of all steel (by mass) specified is reused or contains a post-consumer recycled content greater than 50%.
6. Specified higher than 30% reduction in absolute quality of Portland cement across all concrete mixes. 20% of all structural mixes is recycled and no natural aggregates are used in non-structural uses.

Transport:

1. More than 10% of the total parking spaces are for small cars, motorbikes and mopeds. 80% of those spaces are preferred spaces near the entrance.
2. Car parking provisions are within 10% of the minimum local planning allowance.
3. One dedicated pedestrian route will be provided on and off the site alongside a Travel Plan with a site-specific transport assessment and a report on sustainable transport initiatives.

4. Cyclist facilities are to be provided for 10% of the building staff. Public transport networks operate in close proximity with peak hour services.

Water:

1. Metering is specified for all major water uses, with an effective mechanism for monitoring consumption.
2. No labs require once-through cooling for equipment.
3. A xeriscape garden is to be installed.
4. Potable water consumption of water-based heat rejection systems is designed to be reduced by 90%.
5. The projected use of potable water for sanitary use has been significantly reduced from best practice benchmark.

Appendix 3: Camel Heat Load Output

ACADS BSG Program
CAMEL
Version Number 5.11.1

Springfield Building 2
Edgy Green Project 2020

```
INPUT FILE NAME ~C:/USERS/TRENTA/DESKTOP/UNI/PROJECT/CAMEL/EDGY.DAT
OUTPUT FILE NAME ~C:/USERS/TRENTA/DESKTOP/UNI/PROJECT/CAMEL/EDGY.OUT

CALCULATION BUILD NUMBER 5.11.1A

OUTDOOR DESIGN CONDITIONS ~ with ACADS WEATHER DATA FILE (May 2015) for
Location 40211   ARCHERFIELD AERO                    QLD
Latitude -27.6 DEG(SOUTH)  Daily Range 10.0  Building Rotation 24.0
Elevation    13.0 m (from file)

WINTER OUTDOOR DESIGN   7.3 CDB  80.0 RH

TOTAL FLOOR AREA IS   7447.4 m2
FLOOR AREA SERVED BY CHILLER IS      0.0 m2
FLOOR AREA SERVED BY PRE-CONDITIONER UNITS
  1                     5170.3 m2
  2                     1929.1 m2
```

AHU SUMMARY - COOLING
At Time of Peak Grand Total Heat (GTH)

TITLE	NO. OFF	S/A l/s	OUT/AIR l/s	%	GTH kW	GTSH kW	COIL ENT CDB	CWB	COIL LVG CDB	CWB	PRECON NO.
L1-01	1	1878	556	30	25.2	25.2	23.7	15.8	12.6	11.5	1
L1-02	1	1841	648	35	24.6	24.6	22.9	15.2	11.8	10.7	1
L1-03	1	2617	1013	39	35.6	35.6	23.2	15.3	11.9	10.8	2
FCU-L1-01	1	1011	495	49	38.0	21.3	28.0	21.1	10.5	10.0	
FCU-L1-02	1	855	105	12	14.1	11.5	24.2	17.2	13.1	12.1	
L2-01	1	2730	1223	45	41.0	39.5	23.8	15.6	11.8	10.7	1
L2-02	1	3550	1478	42	51.9	50.3	23.7	15.6	12.0	10.8	1
L2-03	1	2552	1067	42	35.6	35.4	23.4	15.4	11.9	10.8	2
FCU-L2-01	1	452	158	35	14.3	8.49	26.3	19.8	10.8	10.1	
L3-01	1	2189	1165	53	32.4	32.4	23.8	15.3	11.5	10.3	1
L3-02	1	2887	870	30	38.0	37.0	23.0	15.6	12.4	11.3	1
L3-03	1	2513	304	12	30.3	30.2	23.1	16.0	13.2	12.2	2
L3-04	1	3141	921	29	40.8	40.6	23.2	15.6	12.5	11.4	2
L4-01	1	2819	780	28	36.9	35.9	23.0	15.7	12.5	11.4	1
L4-02	1	2798	540	19	35.4	34.7	23.1	15.9	12.9	11.8	1
L4-03	1	2544	524	21	31.5	31.3	23.1	15.9	12.9	11.9	1
L4-04	1	4001	1448	36	57.4	57.4	23.5	15.2	11.6	10.5	1
L4-05	1	1563	450	29	21.1	21.1	23.5	15.6	12.3	11.2	1
L3-01b	1	2951	405	14	37.0	36.6	23.4	16.1	13.2	12.1	1
PRE-CONDITIONERS WITH DESICCANT HCU											
1			10086	100	403	(Precool plus DX, 3pm Jan)					1
2			3304	100	138	(Precool plus DX, 3pm Jan)					2

FOR DETAILS REFER DESICCANT HUMIDITY CONTROL UNITS SUMMARY

AHU SUMMARY - COOLING CHECK FIGURES and HEATING

TITLE	% O/A	FLOOR AREA	W/ m2	CH/ Hr	l/s/ m2	SHF	HEATING S/A	O/A	kW	FAN kW SUP	RET

L1-01	30	376.0	67	6.7	5.0	1.0	1878	556	7.71
L1-02	35	383.0	64	6.4	4.8	1.0	1841	648	8.41
L1-03	39	575.0	62	6.1	4.6	1.0	2617	1013	12.6
FCU-L1-01	49	168.0	226	8.0	6.0	.56	1011	495	10.1
FCU-L1-02	12	77.0	183	14.8	11.1	.82	855	105	4.11
L2-01	45	341.0	120	10.7	8.0	.96	2730	1223	12.8
L2-02	42	730.0	71	6.5	4.9	.97	3550	1478	18.0
L2-03	42	503.0	71	6.8	5.1	.99	2552	1067	13.4
FCU-L2-01	35	103.0	139	5.9	4.4	.59	452	158	4.02
L3-01	53	561.4	58	5.2	3.9	1.0	2189	1165	11.4
L3-02	30	406.9	93	9.5	7.1	.97	2887	870	12.1
L3-03	12	405.9	75	8.3	6.2	1.0	2513	304	11.8
L3-04	29	445.2	92	9.4	7.1	1.0	3141	921	17.0
L4-01	28	409.0	90	9.2	6.9	.97	2819	780	11.8
L4-02	19	406.8	87	9.2	6.9	.98	2798	540	11.0
L4-03	21	412.1	76	8.2	6.2	1.0	2544	524	10.3
L4-04	36	441.0	130	12.1	9.1	1.0	4001	1448	14.7
L4-05	29	340.4	62	6.1	4.6	1.0	1563	450	12.5
L3-01b	14	362.7	102	10.8	8.1	.99	2951	405	10.7
Whole Building	**32**	**7447.4**	**152**	**8.7**	**6.0**	**(at building peak time: 3pm Dec)**			

PRIMARY PLANT RESULTS (Excludes unitary plant)

CHILLER PLANT

```
Operating hours midn to  1am
   AIR HANDLING LOAD                     3pm Jan=     424
    (including Desiccant HCU pre-cooling)
   PROVISION FOR CHILLER PUMP(S)               =     0.00
   PROVISION FOR CHILLER PIPE GAINS            =     0.00
                                                   ______
             CHILLER GRAND TOTAL HEAT (kW)     =      424
```

AHU 1 L1-01

```
  Type ~ Single Zone H & C                                  No. Off ~  1
  Temperature Control ~ Return Air

  Connected to ~ Chiller No   Boiler  No
  Connected to pre conditioner unit number  1 ~ 1
  Floor Area ~   376 m2   Volume ~ 1015.2 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 25.2 kW AT 1PM AUG

```
 DESIGN COOLING LOAD IS AT PEAK AHU GTH
 OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
 NOTE: The room average outdoor air is used. Some rooms will be under supplied
 AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
```

			CDB	CWB	g/kg	%RH
GTSH	25.2 kW	AVERAGE ROOM AIR	23.0	16.1	8.64	49.3
GTLH	0.00 kW	AHU O/A	25.8	19.3	11.32	
AHU SH FACT	1.00	O/AIR(PRE EXCH)	23.7	18.6	11.32	
		O/AIR(PRE HCU)	24.3	14.6	6.39	
SUPPLY AIR	1878 l/s	COIL DEW POINT	10.6		7.97	
AHU O/A	556 l/s	COIL LEAVING AIR	12.6	11.5	7.97	
DEHUMID AIR	1878 l/s	COIL ENTERING AIR	23.7	15.8	7.97	
AIR ch/hr	6.7	RETURN AIR	23.4	16.3	8.64	
l/s/m2	5.0	AVERAGE ROOM ENT.	12.6	11.5	7.97	
l/s/kW	74.5	BYPASS FACTOR	0.15 (N)			
W/m2	67	MIX R/A AND O/A	23.7	15.8	7.97	

NOTE : (N) MEANS NOMINATED VALUE USED

AHU COOLING LOAD CHART AT MAXIMUM LOAD 1PM AUG

AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

```
    ADJUSTED ROOM SENSIBLE                                  =  23648
    ADJUSTED ROOM LATENT                                    =   3696
                                                             ________________
                                      ADJUSTED TOTAL HEAT =          27344
```

OTHER GAINS

```
    O/A SENSIBLE (from PRECON)      556 l/s    1.3 CDB  1.21 =    901
    O/A LATENT   (from PRECON)      556 l/s  -2.2 g/kg  2.97 =  -3696
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =    946
    EXHAUSTED RETURN DUCT GAINS CORRECTION                   =   -280
                                                             ________________
                                        TOTAL OTHER GAINS =          -2129
                                                                    _________
                                 COOLING GRAND TOTAL HEAT =          25214
```

```
                    COOLING GRAND TOTAL SENSIBLE HEAT =         25214
                      COOLING GRAND TOTAL LATENT HEAT =             0
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                      =   5.57 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)        =   0.00 kW

OUTDOOR AIR     556 l/s x  3.18 CDB x 1.21       =   2.13 kW
WARM UP (  0.0% = 10.40% x  0.00)                =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)        =   7.71 kW

LATENT

AHU O/A         556. l/s x 2.20 g/kg x 2.97 =   3.62 KW
                                              _______
                         HUMIDIFIER LOAD =   3.62 KW (73 g/min water)

SUPPLY AIR     1878 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         556 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             20            RETURN AIR         20.0 CDB
W/m3            7.6            COIL LEAVING AIR   22.5 CDB
                               COIL ENTERING AIR  19.1 CDB
```

AHU 2 L1-02

```
 Type ~ Single Zone H & C                               No. Off ~  1
 Temperature Control ~ Return Air

 Connected to ~ Chiller No   Boiler  No
 Connected to pre conditioner unit number  1 ~ 1
 Floor Area ~   383 m2   Volume ~ 1034.1 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 24.6 kW AT 10AM DEC

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                   CDB       CWB      g/kg  %RH
GTSH           24.6 kW         AVERAGE ROOM AIR   23.0      15.8      8.22 47.0
GTLH           0.00 kW         AHU O/A            28.1      24.2     17.50
AHU SH FACT    1.00            O/AIR(PRE EXCH)    24.3      23.2     17.50
                               O/AIR(PRE HCU)     21.9      13.7      6.39
SUPPLY AIR     1841 l/s        COIL DEW POINT      9.9                7.58
AHU O/A         648 l/s        COIL LEAVING AIR   11.8      10.7      7.58
DEHUMID AIR    1841 l/s        COIL ENTERING AIR  22.9      15.2      7.58
AIR ch/hr       6.4            RETURN AIR         23.4      15.9      8.22
l/s/m2          4.8            AVERAGE ROOM ENT.  11.8      10.7      7.58
l/s/kW         74.8            BYPASS FACTOR      0.15 (N)
W/m2             64            MIX R/A AND O/A    22.9      15.2      7.58

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 10AM DEC

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                               =  24845
    ADJUSTED ROOM LATENT                                 =   3511
                                                          ________________
                                    ADJUSTED TOTAL HEAT =         28356
OTHER GAINS

    O/A SENSIBLE (from PRECON)      648 l/s   -1.1 CDB  1.21 =   -873
    O/A LATENT   (from PRECON)      648 l/s  -1.8 g/kg  2.97 =  -3511
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =    994
    EXHAUSTED RETURN DUCT GAINS CORRECTION                   =   -350
                                                          ________________
                                      TOTAL OTHER GAINS =         -3740
                                                                _________
                              COOLING GRAND TOTAL HEAT =         24616
                      COOLING GRAND TOTAL SENSIBLE HEAT =         24616
                        COOLING GRAND TOTAL LATENT HEAT =             0
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                      =   5.92 kW
```

```
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)    =   0.00 kW

OUTDOOR AIR     648 l/s x  3.18 CDB x 1.21  =   2.49 kW
WARM UP (  0.0% = 10.40% x  0.00)           =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)   =   8.41 kW
```

LATENT

```
AHU O/A         648. l/s x 2.20 g/kg x 2.97 =   4.22 KW
                                             _______
                          HUMIDIFIER LOAD =   4.22 KW (85 g/min water)

SUPPLY AIR     1841 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         648 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             22            RETURN AIR         20.0 CDB
W/m3            8.1            COIL LEAVING AIR   22.7 CDB
                               COIL ENTERING AIR  18.9 CDB
```

AHU 3 L1-03

```
Type ~ Single Zone H & C                              No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  2 ~ 2
Floor Area ~   575 m2   Volume ~ 1552.5 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 35.6 kW AT 10AM OCT

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                 CDB      CWB      g/kg  %RH
GTSH           35.6 kW         AVERAGE ROOM AIR   23.0     16.1      8.61 49.2
GTLH           0.00 kW         AHU O/A            28.1     21.6     13.51
AHU SH FACT    1.00            O/AIR(PRE EXCH)    24.3     20.4     13.51
                               O/AIR(PRE HCU)     22.8     13.7      6.05
SUPPLY AIR     2617 l/s        COIL DEW POINT     10.0               7.62
AHU O/A        1013 l/s        COIL LEAVING AIR   11.9     10.8      7.62
DEHUMID AIR    2617 l/s        COIL ENTERING AIR  23.2     15.3      7.62
AIR ch/hr       6.1            RETURN AIR         23.4     16.3      8.61
l/s/m2          4.6            AVERAGE ROOM ENT.  11.9     10.8      7.62
l/s/kW         73.4            BYPASS FACTOR      0.15 (N)
W/m2             62            MIX R/A AND O/A    23.2     15.3      7.62

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 10AM OCT

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                =  34971
    ADJUSTED ROOM LATENT                                  =   7700
                                                           ________________
                                     ADJUSTED TOTAL HEAT =          42671
OTHER GAINS

    O/A SENSIBLE (from PRECON)    1013 l/s   -0.2 CDB  1.21 =   -200
    O/A LATENT   (from PRECON)    1013 l/s  -2.6 g/kg  2.97 =  -7700
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =   1399
    EXHAUSTED RETURN DUCT GAINS CORRECTION                  =   -541
                                                           ________________
                                       TOTAL OTHER GAINS =          -7043
                                                                  _________
                                COOLING GRAND TOTAL HEAT =          35629
                       COOLING GRAND TOTAL SENSIBLE HEAT =          35629
                         COOLING GRAND TOTAL LATENT HEAT =              0
```

AHU HEATING LOAD CHART & SUMMARY

SENSIBLE

```
FABRIC LOAD                                 =   8.76 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)   =   0.00 kW

OUTDOOR AIR    1013 l/s x  3.17 CDB x 1.21  =   3.88 kW
WARM UP (  0.0% = 10.40% x  0.00)           =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)   =   12.6 kW
```

LATENT

```
AHU O/A        1012. l/s x 2.20 g/kg x 2.97 =   6.60 KW
```

```
                   HUMIDIFIER LOAD =    6.60 KW (133 g/min water)

SUPPLY AIR     2617 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A        1013 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             22            RETURN AIR         20.0 CDB
W/m3             8.1           COIL LEAVING AIR   22.8 CDB
                               COIL ENTERING AIR  18.8 CDB
```

AHU 4 FCU-L1-01

```
Type ~ Single Zone H & C                              No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Floor Area ~   168 m2   Volume ~  453.6 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 38.0 kW AT 2PM MAR

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                   CDB       CWB      g/kg  %RH
GTSH           21.3 kW         AVERAGE ROOM AIR   23.0      16.2      8.76 50.0
GTLH           16.7 kW         AHU O/A            32.1      25.1     17.33
AHU SH FACT    0.56
SUPPLY AIR     1011 l/s        COIL DEW POINT      7.4                6.40
AHU O/A         495 l/s        COIL LEAVING AIR   10.5      10.0      7.40
DEHUMID AIR    1011 l/s        COIL ENTERING AIR  28.0      21.1     12.96
AIR ch/hr       8.0            RETURN AIR         24.0      16.6      8.76
l/s/m2          6.0            AVERAGE ROOM ENT.  10.5       9.9      7.40
l/s/kW         26.6            BYPASS FACTOR      0.15 (N)
W/m2            226            MIX R/A AND O/A    28.0      21.1     12.96

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 2PM MAR

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                 =  15277
    ADJUSTED ROOM LATENT                                   =   4066

                                     ADJUSTED TOTAL HEAT =          19343
OTHER GAINS

    O/A SENSIBLE                  495 l/s    9.1 CDB  1.21 =   5442
    O/A LATENT                    495 l/s   8.6 g/kg  2.97 =  12586
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS            4.0% =    611

                                       TOTAL OTHER GAINS =          18639

                               COOLING GRAND TOTAL HEAT =           37982
                       COOLING GRAND TOTAL SENSIBLE HEAT =          21330
                         COOLING GRAND TOTAL LATENT HEAT =          16651
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                  =   2.50 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)    =   0.00 kW

OUTDOOR AIR     495 l/s x 12.70 CDB x 1.21   =   7.60 kW
WARM UP (  0.0% = 10.40% x  0.00)            =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)    =   10.1 kW

LATENT

AHU O/A         495. l/s x 2.20 g/kg x 2.97 =   3.22 KW

                   HUMIDIFIER LOAD =    3.22 KW (65 g/min water)

SUPPLY AIR     1011 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         495 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             60            RETURN AIR         20.0 CDB
W/m3           22.3            COIL LEAVING AIR   22.0 CDB
                               COIL ENTERING AIR  13.8 CDB
```

AHU 5 FCU-L1-02

```
Type ~ Single Zone H & C                                 No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Floor Area ~    77 m2   Volume ~  207.9 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 14.1 kW AT 2PM APR

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                         CDB      CWB     g/kg  %RH
GTSH           11.5 kW         AVERAGE ROOM AIR   23.0     16.2     8.76 50.0
GTLH           2.61 kW         AHU O/A            29.7     22.6    14.36
AHU SH FACT    0.82
SUPPLY AIR      855 l/s        COIL DEW POINT     11.1              8.24
AHU O/A         105 l/s        COIL LEAVING AIR   13.1     12.1     8.42
DEHUMID AIR     855 l/s        COIL ENTERING AIR  24.2     17.2     9.44
AIR ch/hr      14.8            RETURN AIR         23.5     16.4     8.76
l/s/m2         11.1            AVERAGE ROOM ENT.  13.1     12.1     8.42
l/s/kW         60.5            BYPASS FACTOR      0.15 (N)
W/m2            183            MIX R/A AND O/A    24.2     17.2     9.44

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 2PM APR

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                     =  10257
    ADJUSTED ROOM LATENT                                       =    862
                                                                ________________
                                          ADJUSTED TOTAL HEAT =          11119
OTHER GAINS

    O/A SENSIBLE                  105 l/s    6.7 CDB  1.21 =    850
    O/A LATENT                    105 l/s   5.6 g/kg  2.97 =   1746
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS             4.0% =    410
                                                                ________________
                                            TOTAL OTHER GAINS =           3006
                                                                       _________
                                       COOLING GRAND TOTAL HEAT =         14125
                          COOLING GRAND TOTAL SENSIBLE HEAT =         11517
                            COOLING GRAND TOTAL LATENT HEAT =          2609
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                   =   2.50 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)    =   0.00 kW

OUTDOOR AIR     105 l/s x 12.70 CDB x 1.21  =   1.61 kW
WARM UP (  0.0% = 10.40% x  0.00)            =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)    =   4.11 kW

LATENT

AHU O/A         105. l/s x 2.20 g/kg x 2.97 =   0.68 KW
                                               ________
                          HUMIDIFIER LOAD =    0.68 KW (14 g/min water)

SUPPLY AIR      855 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         105 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             53            RETURN AIR         20.0 CDB
W/m3           19.8            COIL LEAVING AIR   22.4 CDB
                               COIL ENTERING AIR  18.4 CDB
```

AHU 6 L2-01

```
Type ~ Single Zone H & C                                 No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  1 ~ 1
Floor Area ~   341 m2   Volume ~  920.7 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 41.0 kW AT 5PM JUN

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
```

NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

			CDB	CWB	g/kg	%RH
GTSH	39.5 kW	AVERAGE ROOM AIR	23.0	16.2	8.76	50.0
GTLH	1.48 kW	AHU O/A	23.5	18.9	11.74	
AHU SH FACT	0.96	O/AIR(PRE EXCH)	23.1	18.7	11.74	
		O/AIR(PRE HCU)	24.2	14.6	6.39	
SUPPLY AIR	2730 l/s	COIL DEW POINT	9.7		7.48	
AHU O/A	1223 l/s	COIL LEAVING AIR	11.8	10.7	7.52	
DEHUMID AIR	2730 l/s	COIL ENTERING AIR	23.8	15.6	7.70	
AIR ch/hr	10.7	RETURN AIR	23.4	16.4	8.76	
l/s/m2	8.0	AVERAGE ROOM ENT.	11.8	10.7	7.52	
l/s/kW	66.6	BYPASS FACTOR	0.15 (N)			
W/m2	120	MIX R/A AND O/A	23.8	15.6	7.70	

NOTE : (N) MEANS NOMINATED VALUE USED

AHU COOLING LOAD CHART AT MAXIMUM LOAD 5PM JUN

AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

ADJUSTED ROOM SENSIBLE = 36960
ADJUSTED ROOM LATENT = 10041

ADJUSTED TOTAL HEAT = 47001

OTHER GAINS

O/A SENSIBLE (from PRECON)	1223 l/s	1.2 CDB	1.21 =	1712
O/A LATENT (from PRECON)	1223 l/s	-2.4 g/kg	2.97 =	-8563
RETURN DUCT HEAT GAIN AND LEAKAGE LOSS			4.0% =	1478
EXHAUSTED RETURN DUCT GAINS CORRECTION			=	-662

TOTAL OTHER GAINS = -6035

COOLING GRAND TOTAL HEAT = 40967
COOLING GRAND TOTAL SENSIBLE HEAT = 39489
COOLING GRAND TOTAL LATENT HEAT = 1478

AHU HEATING LOAD CHART & SUMMARY

SENSIBLE

FABRIC LOAD = 8.09 kW
WARM UP (0.0% = 10.40% x 0.93 x 0.00) = 0.00 kW

OUTDOOR AIR 1223 l/s x 3.18 CDB x 1.21 = 4.69 kW
WARM UP (0.0% = 10.40% x 0.00) = 0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER) = 12.8 kW

LATENT

AHU O/A 1222. l/s x 2.20 g/kg x 2.97 = 7.96 KW

HUMIDIFIER LOAD = 7.96 KW (161 g/min water)

SUPPLY AIR	2730 l/s	ROOM AIR	20.0 CDB 50.0%RH 13.8 CWB
AHU O/A	1223 l/s	OUTDOOR AIR	7.3 CDB 80.0%RH
W/m2	37	RETURN AIR	20.0 CDB
W/m3	13.9	COIL LEAVING AIR	22.5 CDB
		COIL ENTERING AIR	18.6 CDB

AHU 7 L2-02

Type ~ Single Zone H & C No. Off ~ 1
Temperature Control ~ Return Air

Connected to ~ Chiller No Boiler No
Connected to pre conditioner unit number 1 ~ 1
Floor Area ~ 730 m2 Volume ~ 1971.0 m3 Average Ceiling Height ~ 2700. mm

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 51.9 kW AT 3PM SEP

DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

			CDB	CWB	g/kg	%RH
GTSH	50.3 kW	AVERAGE ROOM AIR	23.0	16.2	8.76	50.0
GTLH	1.61 kW	AHU O/A	32.1	21.9	12.30	
AHU SH FACT	0.97	O/AIR(PRE EXCH)	25.3	19.8	12.30	
		O/AIR(PRE HCU)	24.0	14.5	6.39	
SUPPLY AIR	3550 l/s	COIL DEW POINT	9.9		7.59	
AHU O/A	1478 l/s	COIL LEAVING AIR	12.0	10.8	7.62	

```
DEHUMID AIR    3550 l/s        COIL ENTERING AIR  23.7      15.6      7.77
AIR ch/hr       6.5            RETURN AIR         23.4      16.4      8.76
l/s/m2          4.9            AVERAGE ROOM ENT.  12.0      10.8      7.62
l/s/kW         68.4            BYPASS FACTOR      0.15 (N)
W/m2             71            MIX R/A AND O/A    23.7      15.6      7.77

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM SEP

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                = 47362
    ADJUSTED ROOM LATENT                                  = 11969
                                                           ________________
                                   ADJUSTED TOTAL HEAT =          59331
OTHER GAINS

    O/A SENSIBLE (from PRECON)    1478 l/s    1.0 CDB  1.21 =   1834
    O/A LATENT   (from PRECON)    1478 l/s  -2.4 g/kg  2.97 = -10354
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =   1894
    EXHAUSTED RETURN DUCT GAINS CORRECTION                  =   -789
                                                           ________________
                                     TOTAL OTHER GAINS =          -7415
                                                                 _________
                             COOLING GRAND TOTAL HEAT =           51916
                    COOLING GRAND TOTAL SENSIBLE HEAT =           50301
                      COOLING GRAND TOTAL LATENT HEAT =            1615
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                =   12.3 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)  =   0.00 kW

OUTDOOR AIR    1478 l/s x  3.18 CDB x 1.21 =   5.67 kW
WARM UP (  0.0% = 10.40% x  0.00)          =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)  =   18.0 kW

LATENT

AHU O/A        1478. l/s x 2.20 g/kg x 2.97 =   9.63 KW
                                              _______
                          HUMIDIFIER LOAD =   9.63 KW (195 g/min water)

SUPPLY AIR     3550 l/s        ROOM AIR          20.0 CDB 50.0%RH  13.8 CWB
AHU O/A        1478 l/s        OUTDOOR AIR        7.3 CDB 80.0%RH
W/m2             25            RETURN AIR        20.0 CDB
W/m3            9.1            COIL LEAVING AIR  22.9 CDB
                               COIL ENTERING AIR 18.7 CDB
```

AHU 8 L2-03

```
 Type ~ Single Zone H & C                                 No. Off ~  1
 Temperature Control ~ Return Air

 Connected to ~ Chiller No   Boiler  No
 Connected to pre conditioner unit number  2 ~ 2
 Floor Area ~   503 m2   Volume ~ 1358.1 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 35.6 kW AT 3PM SEP

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                  CDB       CWB      g/kg  %RH
GTSH           35.4 kW         AVERAGE ROOM AIR   23.0      16.2      8.76 50.0
GTLH           0.20 kW         AHU O/A            32.1      21.9     12.30
AHU SH FACT    0.99            O/AIR(PRE EXCH)    25.3      19.8     12.30
                               O/AIR(PRE HCU)     23.4      13.9      6.05
SUPPLY AIR     2552 l/s        COIL DEW POINT      9.9                7.59
AHU O/A        1067 l/s        COIL LEAVING AIR   11.9      10.8      7.60
DEHUMID AIR    2552 l/s        COIL ENTERING AIR  23.4      15.4      7.62
AIR ch/hr       6.8            RETURN AIR         23.4      16.4      8.76
l/s/m2          5.1            AVERAGE ROOM ENT.  11.9      10.8      7.60
l/s/kW         71.6            BYPASS FACTOR      0.15 (N)
W/m2             71            MIX R/A AND O/A    23.4      15.4      7.62

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM SEP

AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

```
    ADJUSTED ROOM SENSIBLE                                   =  34154
    ADJUSTED ROOM LATENT                                     =   8760
                                                              ________________
                                      ADJUSTED TOTAL HEAT =           42913
```

OTHER GAINS

```
    O/A SENSIBLE (from PRECON)     1067 l/s    0.4 CDB  1.21 =    488
    O/A LATENT   (from PRECON)     1067 l/s  -2.7 g/kg  2.97 =  -8561
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =   1366
    EXHAUSTED RETURN DUCT GAINS CORRECTION                   =   -571
                                                              ________________
                                        TOTAL OTHER GAINS =           -7278

                                                                     _________
                                  COOLING GRAND TOTAL HEAT =          35636
                          COOLING GRAND TOTAL SENSIBLE HEAT =          35437
                            COOLING GRAND TOTAL LATENT HEAT =            199
```

AHU HEATING LOAD CHART & SUMMARY

SENSIBLE

```
FABRIC LOAD                                  =   9.28 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)    =   0.00 kW

OUTDOOR AIR    1067 l/s x  3.17 CDB x 1.21   =   4.09 kW
WARM UP (  0.0% = 10.40% x  0.00)            =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)    =   13.4 kW
```

LATENT

```
AHU O/A        1066. l/s x 2.20 g/kg x 2.97 =   6.95 KW
                                                _______
                          HUMIDIFIER LOAD =   6.95 KW (141 g/min water)

SUPPLY AIR     2552 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A        1067 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             27            RETURN AIR         20.0 CDB
W/m3             9.8           COIL LEAVING AIR   23.0 CDB
                               COIL ENTERING AIR  18.7 CDB
```

AHU 9 FCU-L2-01

```
 Type ~ Single Zone H & C                                 No. Off ~  1
 Temperature Control ~ Return Air

 Connected to ~ Chiller No   Boiler  No
 Floor Area ~   103 m2   Volume ~  278.1 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 14.3 kW AT 6PM DEC

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                 CDB      CWB      g/kg  %RH
GTSH           8.49 kW         AVERAGE ROOM AIR  23.0     16.2      8.76 50.0
GTLH           5.82 kW         AHU O/A           31.1     25.0     17.50
AHU SH FACT    0.59
SUPPLY AIR      452 l/s        COIL DEW POINT     8.0               6.68
AHU O/A         158 l/s        COIL LEAVING AIR  10.8     10.1      7.46
DEHUMID AIR     452 l/s        COIL ENTERING AIR 26.3     19.8     11.80
AIR ch/hr       5.9            RETURN AIR        23.8     16.5      8.76
l/s/m2          4.4            AVERAGE ROOM ENT. 10.8     10.1      7.46
l/s/kW         31.6            BYPASS FACTOR     0.15 (N)
W/m2            139            MIX R/A AND O/A   26.3     19.8     11.80
```

NOTE : (N) MEANS NOMINATED VALUE USED

AHU COOLING LOAD CHART AT MAXIMUM LOAD 6PM DEC

AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

```
    ADJUSTED ROOM SENSIBLE                                   =   6678
    ADJUSTED ROOM LATENT                                     =   1733
                                                              ________________
                                      ADJUSTED TOTAL HEAT =            8410
```

OTHER GAINS

```
    O/A SENSIBLE                      158 l/s    8.1 CDB  1.21 =   1541
    O/A LATENT                        158 l/s    8.7 g/kg  2.97 =   4083
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS                4.0% =    267
                                                              _______________
                                           TOTAL OTHER GAINS =            5891
                                                                     _________
                                    COOLING GRAND TOTAL HEAT =           14302
                            COOLING GRAND TOTAL SENSIBLE HEAT =            8486
                              COOLING GRAND TOTAL LATENT HEAT =            5816
```

AHU HEATING LOAD CHART & SUMMARY

```
 SENSIBLE

 FABRIC LOAD                                     =   1.60 kW
 WARM UP (  0.0% = 10.40% x  0.93 x  0.00)       =   0.00 kW

 OUTDOOR AIR     158 l/s x 12.70 CDB x 1.21     =   2.42 kW
 WARM UP (  0.0% = 10.40% x  0.00)               =   0.00 kW
 TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)       =   4.02 kW

 LATENT

 AHU O/A         158. l/s x 2.20 g/kg x 2.97 =   1.03 KW
                                              _______
                           HUMIDIFIER LOAD =   1.03 KW (21 g/min water)

 SUPPLY AIR      452 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
 AHU O/A         158 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
 W/m2             39            RETURN AIR         20.0 CDB
 W/m3           14.4            COIL LEAVING AIR   22.9 CDB
                                COIL ENTERING AIR  15.6 CDB
```

AHU 10   L3-01

```
  Type ~ Single Zone H & C                                 No. Off ~  1
  Temperature Control ~ Return Air

  Connected to ~ Chiller No   Boiler  No
  Connected to pre conditioner unit number  1 ~ 1
  Floor Area ~   561 m2   Volume ~ 1515.9 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS   32.4 kW AT 3PM SEP

```
 DESIGN COOLING LOAD IS AT PEAK AHU GTH
 OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
 NOTE: The room average outdoor air is used. Some rooms will be under supplied
 AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                  CDB       CWB      g/kg  %RH
 GTSH           32.4 kW         AVERAGE ROOM AIR   23.0      15.9      8.37 47.8
 GTLH           0.00 kW         AHU O/A            32.1      21.9     12.30
 AHU SH FACT    1.00            O/AIR(PRE EXCH)    25.3      19.8     12.30
                                O/AIR(PRE HCU)     24.0      14.5      6.39
 SUPPLY AIR     2189 l/s        COIL DEW POINT      9.4                7.32
 AHU O/A        1165 l/s        COIL LEAVING AIR   11.5      10.3      7.32
 DEHUMID AIR    2189 l/s        COIL ENTERING AIR  23.8      15.3      7.32
 AIR ch/hr       5.2            RETURN AIR         23.5      16.1      8.37
 l/s/m2          3.9            AVERAGE ROOM ENT.  11.5      10.3      7.32
 l/s/kW         67.6            BYPASS FACTOR      0.15 (N)
 W/m2             58            MIX R/A AND O/A    23.8      15.3      7.32

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM SEP

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                   =  30376
    ADJUSTED ROOM LATENT                                     =   6838
                                                              _______________
                                         ADJUSTED TOTAL HEAT =           37214
OTHER GAINS

    O/A SENSIBLE (from PRECON)     1165 l/s    1.0 CDB  1.21 =   1445
    O/A LATENT   (from PRECON)     1165 l/s   -2.0 g/kg  2.97 =  -6838
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS                4.0% =   1215
    EXHAUSTED RETURN DUCT GAINS CORRECTION                    =   -647
                                                              _______________
                                           TOTAL OTHER GAINS =           -4824
                                                                     _________
                                    COOLING GRAND TOTAL HEAT =           32390
                            COOLING GRAND TOTAL SENSIBLE HEAT =           32390
                              COOLING GRAND TOTAL LATENT HEAT =               0
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                  =   6.95 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)   =   0.00 kW

OUTDOOR AIR    1165 l/s x  3.18 CDB x 1.21  =   4.47 kW
WARM UP (  0.0% = 10.40% x  0.00)           =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)   =   11.4 kW

LATENT

AHU O/A        1165. l/s x 2.20 g/kg x 2.97 =   7.59 KW
                                               _______
                          HUMIDIFIER LOAD =   7.59 KW (154 g/min water)

SUPPLY AIR     2189 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A        1165 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             20            RETURN AIR         20.0 CDB
W/m3             7.5           COIL LEAVING AIR   22.6 CDB
                               COIL ENTERING AIR  18.3 CDB
```

AHU 11 L3-02

```
 Type ~ Single Zone H & C                                 No. Off ~  1
 Temperature Control ~ Return Air

 Connected to ~ Chiller No   Boiler  No
 Connected to pre conditioner unit number  1 ~ 1
 Floor Area ~   407 m2   Volume ~ 1098.6 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 38.0 kW AT 10AM DEC

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                  CDB       CWB       g/kg  %RH
GTSH           37.0 kW         AVERAGE ROOM AIR   23.0      16.2      8.76 50.0
GTLH           1.05 kW         AHU O/A            28.1      24.2     17.50
AHU SH FACT    0.97            O/AIR(PRE EXCH)    24.3      23.2     17.50
                               O/AIR(PRE HCU)     21.9      13.7      6.39
SUPPLY AIR     2887 l/s        COIL DEW POINT     10.5                7.90
AHU O/A         870 l/s        COIL LEAVING AIR   12.4      11.3      7.92
DEHUMID AIR    2887 l/s        COIL ENTERING AIR  23.0      15.6      8.04
AIR ch/hr       9.5            RETURN AIR         23.4      16.4      8.76
l/s/m2          7.1            AVERAGE ROOM ENT.  12.4      11.3      7.92
l/s/kW         75.9            BYPASS FACTOR      0.15 (N)
W/m2             93            MIX R/A AND O/A    23.0      15.6      8.04

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 10AM DEC

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                = 37121
    ADJUSTED ROOM LATENT                                  =   7146
                                                           ________________
                                     ADJUSTED TOTAL HEAT =         44266
OTHER GAINS

    O/A SENSIBLE (from PRECON)     870 l/s   -1.1 CDB  1.21 = -1172
    O/A LATENT   (from PRECON)     870 l/s  -2.4 g/kg  2.97 = -6094
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =  1485
    EXHAUSTED RETURN DUCT GAINS CORRECTION                   =  -447
                                                           ________________
                                       TOTAL OTHER GAINS =         -6228
                                                                  ________
                                COOLING GRAND TOTAL HEAT =         38038
                       COOLING GRAND TOTAL SENSIBLE HEAT =         36986
                         COOLING GRAND TOTAL LATENT HEAT =          1052
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                  =   8.75 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)   =   0.00 kW
```

```
OUTDOOR AIR     870 l/s x  3.18 CDB x 1.21  =   3.34 kW
WARM UP (  0.0% = 10.40% x  0.00)           =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)   =   12.1 kW

LATENT

AHU O/A         870. l/s x 2.20 g/kg x 2.97 =   5.67 KW
                                              _______
                        HUMIDIFIER LOAD =   5.67 KW (115 g/min water)

SUPPLY AIR     2887 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         870 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             30            RETURN AIR         20.0 CDB
W/m3           11.0            COIL LEAVING AIR   22.5 CDB
                               COIL ENTERING AIR  19.0 CDB
```

AHU 12 L3-03

```
Type ~ Single Zone H & C                                 No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  2 ~ 2
Floor Area ~   406 m2   Volume ~ 1095.9 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 30.3 kW AT 3PM DEC

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                  CDB       CWB      g/kg  %RH
GTSH           30.2 kW         AVERAGE ROOM AIR   23.0      16.2      8.76 50.0
GTLH           0.06 kW         AHU O/A            33.1      25.5     17.50
AHU SH FACT    1.00            O/AIR(PRE EXCH)    25.5      23.5     17.50
                               O/AIR(PRE HCU)     21.3      13.1      6.05
SUPPLY AIR     2513 l/s        COIL DEW POINT     11.4                8.42
AHU O/A         304 l/s        COIL LEAVING AIR   13.2      12.2      8.42
DEHUMID AIR    2513 l/s        COIL ENTERING AIR  23.1      16.0      8.43
AIR ch/hr       8.3            RETURN AIR         23.4      16.4      8.76
l/s/m2          6.2            AVERAGE ROOM ENT.  13.2      12.2      8.42
l/s/kW         83.0            BYPASS FACTOR      0.15 (N)
W/m2             75            MIX R/A AND O/A    23.1      16.0      8.43

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM DEC

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                               =  29786
    ADJUSTED ROOM LATENT                                 =   2500
                                                          ________________
                                     ADJUSTED TOTAL HEAT =         32286
OTHER GAINS

    O/A SENSIBLE (from PRECON)     304 l/s   -1.7 CDB  1.21 =   -612
    O/A LATENT   (from PRECON)     304 l/s  -2.7 g/kg  2.97 =  -2444
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS             4.0% =   1191
    EXHAUSTED RETURN DUCT GAINS CORRECTION                  =   -144
                                                          ________________
                                       TOTAL OTHER GAINS =         -2009
                                                                 _________
                                COOLING GRAND TOTAL HEAT =         30278
                       COOLING GRAND TOTAL SENSIBLE HEAT =         30221
                         COOLING GRAND TOTAL LATENT HEAT =            57
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                 =   10.6 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)   =   0.00 kW

OUTDOOR AIR     304 l/s x  3.17 CDB x 1.21  =   1.17 kW
WARM UP (  0.0% = 10.40% x  0.00)           =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)   =   11.8 kW

LATENT

AHU O/A         304. l/s x 2.20 g/kg x 2.97 =   1.98 KW
                                              _______
                        HUMIDIFIER LOAD =   1.98 KW (40 g/min water)
```

```
SUPPLY AIR     2513 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         304 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             29            RETURN AIR         20.0 CDB
W/m3           10.7            COIL LEAVING AIR   23.5 CDB
                               COIL ENTERING AIR  19.6 CDB
```

AHU 13 L3-04

```
Type ~ Single Zone H & C                                  No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  2 ~ 2
Floor Area ~   445 m2   Volume ~ 1202.0 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 40.8 kW AT 3PM APR

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                  CDB       CWB       g/kg  %RH
GTSH           40.6 kW         AVERAGE ROOM AIR   23.0      16.2      8.76 50.0
GTLH           0.17 kW         AHU O/A            30.7      22.9     14.36
AHU SH FACT    1.00            O/AIR(PRE EXCH)    24.9      21.2     14.36
                               O/AIR(PRE HCU)     22.5      13.6      6.05
SUPPLY AIR     3141 l/s        COIL DEW POINT     10.6                7.94
AHU O/A         921 l/s        COIL LEAVING AIR   12.5      11.4      7.94
DEHUMID AIR    3141 l/s        COIL ENTERING AIR  23.2      15.6      7.96
AIR ch/hr       9.4            RETURN AIR         23.4      16.4      8.76
l/s/m2          7.1            AVERAGE ROOM ENT.  12.4      11.4      7.94
l/s/kW         76.9            BYPASS FACTOR      0.15 (N)
W/m2             92            MIX R/A AND O/A    23.2      15.6      7.96

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM APR

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                  =  40039
    ADJUSTED ROOM LATENT                                    =   7564
                                                             ________________
                                        ADJUSTED TOTAL HEAT =          47603
OTHER GAINS

    O/A SENSIBLE (from PRECON)      921 l/s   -0.5 CDB  1.21 =   -525
    O/A LATENT   (from PRECON)      921 l/s  -2.7 g/kg  2.97 =  -7393
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =   1602
    EXHAUSTED RETURN DUCT GAINS CORRECTION                   =   -470
                                                             ________________
                                          TOTAL OTHER GAINS =          -6786
                                                                    _________
                                 COOLING GRAND TOTAL HEAT =            40818
                        COOLING GRAND TOTAL SENSIBLE HEAT =            40646
                          COOLING GRAND TOTAL LATENT HEAT =              172
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                    =   13.5 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)      =   0.00 kW

OUTDOOR AIR     921 l/s x  3.17 CDB x 1.21     =   3.53 kW
WARM UP (  0.0% = 10.40% x  0.00)              =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)      =   17.0 kW

LATENT

AHU O/A         921. l/s x 2.20 g/kg x 2.97 =    6.00 KW
                                               ________
                           HUMIDIFIER LOAD =     6.00 KW (121 g/min water)

SUPPLY AIR     3141 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         921 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             38            RETURN AIR         20.0 CDB
W/m3           14.1            COIL LEAVING AIR   23.5 CDB
                               COIL ENTERING AIR  19.1 CDB
```

AHU 14 L4-01

```
Type ~ Single Zone H & C                                 No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  1 ~ 1
Floor Area ~   409 m2   Volume ~ 1104.3 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS   36.9 kW AT 3PM DEC

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                 CDB      CWB      g/kg  %RH
GTSH           35.9 kW        AVERAGE ROOM AIR   23.0     16.2      8.76 50.0
GTLH           0.94 kW        AHU O/A            33.1     25.5     17.50
AHU SH FACT    0.97           O/AIR(PRE EXCH)    25.5     23.5     17.50
                              O/AIR(PRE HCU)     22.0     13.7      6.39
SUPPLY AIR     2819 l/s       COIL DEW POINT     10.6               7.97
AHU O/A         780 l/s       COIL LEAVING AIR   12.5     11.4      7.99
DEHUMID AIR    2819 l/s       COIL ENTERING AIR  23.0     15.7      8.10
AIR ch/hr       9.2           RETURN AIR         23.4     16.4      8.76
l/s/m2          6.9           AVERAGE ROOM ENT.  12.5     11.4      7.99
l/s/kW         76.4           BYPASS FACTOR      0.15 (N)
W/m2             90           MIX R/A AND O/A    23.0     15.7      8.10

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM DEC

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                               =  35830
    ADJUSTED ROOM LATENT                                 =   6406
                                                         ________________
                                     ADJUSTED TOTAL HEAT =          42236
OTHER GAINS

    O/A SENSIBLE (from PRECON)      780 l/s   -1.0 CDB  1.21 =   -939
    O/A LATENT   (from PRECON)      780 l/s  -2.4 g/kg  2.97 =  -5463
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =   1433
    EXHAUSTED RETURN DUCT GAINS CORRECTION                   =   -397
                                                         ________________
                                       TOTAL OTHER GAINS =          -5366
                                                                _________
                                COOLING GRAND TOTAL HEAT =          36870
                       COOLING GRAND TOTAL SENSIBLE HEAT =          35927
                         COOLING GRAND TOTAL LATENT HEAT =            943
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                   =   8.78 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)    =   0.00 kW

OUTDOOR AIR     780 l/s x  3.18 CDB x 1.21   =   2.99 kW
WARM UP (  0.0% = 10.40% x  0.00)            =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)    =   11.8 kW

LATENT

AHU O/A         780. l/s x 2.20 g/kg x 2.97 =   5.08 KW
                                               _______
                           HUMIDIFIER LOAD =   5.08 KW (103 g/min water)

SUPPLY AIR     2819 l/s       ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         780 l/s       OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             29           RETURN AIR         20.0 CDB
W/m3           10.7           COIL LEAVING AIR   22.6 CDB
                              COIL ENTERING AIR  19.1 CDB
```

AHU 15   L4-02

```
Type ~ Single Zone H & C                                 No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  1 ~ 1
Floor Area ~   407 m2   Volume ~ 1098.4 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 35.4 kW AT 3PM DEC

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                        CDB      CWB      g/kg  %RH
GTSH           34.7 kW         AVERAGE ROOM AIR   23.0     16.2      8.76 50.0
GTLH           0.65 kW         AHU O/A            33.1     25.5     17.50
AHU SH FACT    0.98            O/AIR(PRE EXCH)    25.5     23.5     17.50
                               O/AIR(PRE HCU)     22.0     13.7      6.39
SUPPLY AIR     2798 l/s        COIL DEW POINT     11.1               8.21
AHU O/A         540 l/s        COIL LEAVING AIR   12.9     11.8      8.22
DEHUMID AIR    2798 l/s        COIL ENTERING AIR  23.1     15.9      8.30
AIR ch/hr       9.2            RETURN AIR         23.4     16.4      8.76
l/s/m2          6.9            AVERAGE ROOM ENT.  12.9     11.8      8.22
l/s/kW         79.1            BYPASS FACTOR      0.15 (N)
W/m2             87            MIX R/A AND O/A    23.1     15.9      8.30

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM DEC

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT
    ADJUSTED ROOM SENSIBLE                                 =  34265
    ADJUSTED ROOM LATENT                                   =   4435
                                                            ________________
                                        ADJUSTED TOTAL HEAT =         38700
OTHER GAINS

    O/A SENSIBLE (from PRECON)     540 l/s   -1.0 CDB  1.21 =   -650
    O/A LATENT   (from PRECON)     540 l/s  -2.4 g/kg  2.97 =  -3782
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS             4.0% =   1371
    EXHAUSTED RETURN DUCT GAINS CORRECTION                  =   -264
                                                            ________________
                                          TOTAL OTHER GAINS =         -3326
                                                                   _________
                                   COOLING GRAND TOTAL HEAT =         35374
                           COOLING GRAND TOTAL SENSIBLE HEAT =        34721
                             COOLING GRAND TOTAL LATENT HEAT =          653
```

AHU HEATING LOAD CHART & SUMMARY

```
SENSIBLE

FABRIC LOAD                                      =   8.91 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)        =   0.00 kW

OUTDOOR AIR     540 l/s x  3.18 CDB x 1.21       =   2.07 kW
WARM UP (  0.0% = 10.40% x  0.00)                =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)        =   11.0 kW

LATENT

AHU O/A         540. l/s x 2.20 g/kg x 2.97 =   3.52 KW
                                                _______
                          HUMIDIFIER LOAD =   3.52 KW (71 g/min water)

SUPPLY AIR     2798 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         540 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             27            RETURN AIR         20.0 CDB
W/m3           10.0            COIL LEAVING AIR   22.6 CDB
                               COIL ENTERING AIR  19.4 CDB
```

AHU 16 L4-03

```
Type ~ Single Zone H & C                                   No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  1 ~ 1
Floor Area ~    412 m2   Volume ~ 1112.7 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 31.5 kW AT 3PM DEC

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                        CDB      CWB      g/kg  %RH
GTSH           31.3 kW         AVERAGE ROOM AIR   23.0     16.2      8.76 50.0
```

GTLH	0.15 kW	AHU O/A	33.1	25.5	17.50
AHU SH FACT	1.00	O/AIR(PRE EXCH)	25.5	23.5	17.50
		O/AIR(PRE HCU)	22.0	13.7	6.39
SUPPLY AIR	2544 l/s	COIL DEW POINT	11.1		8.25
AHU O/A	524 l/s	COIL LEAVING AIR	12.9	11.9	8.25
DEHUMID AIR	2544 l/s	COIL ENTERING AIR	23.1	15.9	8.27
AIR ch/hr	8.2	RETURN AIR	23.4	16.4	8.76
l/s/m2	6.2	AVERAGE ROOM ENT.	12.9	11.9	8.25
l/s/kW	80.8	BYPASS FACTOR	0.15 (N)		
W/m2	76	MIX R/A AND O/A	23.1	15.9	8.27

NOTE : (N) MEANS NOMINATED VALUE USED

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM DEC

AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

ADJUSTED ROOM SENSIBLE	= 30986	
ADJUSTED ROOM LATENT	= 3819	
ADJUSTED TOTAL HEAT =		34806

OTHER GAINS

O/A SENSIBLE (from PRECON)	524 l/s	-1.0 CDB	1.21 =	-631	
O/A LATENT (from PRECON)	524 l/s	-2.4 g/kg	2.97 =	-3670	
RETURN DUCT HEAT GAIN AND LEAKAGE LOSS			4.0% =	1239	
EXHAUSTED RETURN DUCT GAINS CORRECTION			=	-255	
TOTAL OTHER GAINS =					-3316
COOLING GRAND TOTAL HEAT =					**31490**
COOLING GRAND TOTAL SENSIBLE HEAT =					31340
COOLING GRAND TOTAL LATENT HEAT =					150

AHU HEATING LOAD CHART & SUMMARY

SENSIBLE

FABRIC LOAD	=	8.26 kW
WARM UP (0.0% = 10.40% x 0.93 x 0.00)	=	0.00 kW
OUTDOOR AIR 524 l/s x 3.18 CDB x 1.21	=	2.01 kW
WARM UP (0.0% = 10.40% x 0.00)	=	0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)	**=**	**10.3 kW**

LATENT

AHU O/A 524. l/s x 2.20 g/kg x 2.97 = 3.41 KW

HUMIDIFIER LOAD = 3.41 KW (69 g/min water)

SUPPLY AIR	2544 l/s	ROOM AIR	20.0 CDB 50.0%RH 13.8 CWB
AHU O/A	524 l/s	OUTDOOR AIR	7.3 CDB 80.0%RH
W/m2	25	RETURN AIR	
W/m3	9.2	COIL LEAVING AIR	22.7 CDB
		COIL ENTERING AIR	19.3 CDB

AHU 17 L4-04

Type ~ Single Zone H & C   No. Off ~ 1
Temperature Control ~ Return Air

Connected to ~ Chiller No Boiler No
Connected to pre conditioner unit number 1 ~ 1
Floor Area ~ 441 m2 Volume ~ 1190.7 m3 Average Ceiling Height ~ 2700. mm

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 57.4 kW AT 4PM SEP

DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS 1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM

			CDB	**CWB**	**g/kg**	**%RH**
GTSH	57.4 kW	AVERAGE ROOM AIR	23.0	15.6	7.98	45.6
GTLH	0.00 kW	AHU O/A	31.1	21.6	12.30	
AHU SH FACT	1.00	O/AIR(PRE EXCH)	25.0	19.8	12.30	
		O/AIR(PRE HCU)	24.0	14.5	6.39	
SUPPLY AIR	4001 l/s	COIL DEW POINT	9.5		7.41	
AHU O/A	1448 l/s	COIL LEAVING AIR	11.6	10.5	7.41	
DEHUMID AIR	4001 l/s	COIL ENTERING AIR	23.5	15.2	7.41	
AIR ch/hr	12.1	RETURN AIR	23.2	15.6	7.98	
l/s/m2	9.1	AVERAGE ROOM ENT.	11.6	10.5	7.41	
l/s/kW	69.6	BYPASS FACTOR	0.15 (N)			

```
 W/m2            130             MIX R/A AND O/A    23.5     15.2     7.41

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 4PM SEP

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
```

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

```
    ADJUSTED ROOM SENSIBLE                                  =  54964
    ADJUSTED ROOM LATENT                                    =   6812
                                                              ________________
                                         ADJUSTED TOTAL HEAT =         61776
OTHER GAINS

    O/A SENSIBLE (from PRECON)    1448 l/s    1.0 CDB  1.21 =   1774
    O/A LATENT   (from PRECON)    1448 l/s  -1.6 g/kg  2.97 =  -6812
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS             2.0% =   1099
    EXHAUSTED RETURN DUCT GAINS CORRECTION                  =   -398
                                                              ________________
                                           TOTAL OTHER GAINS =         -4336
                                                                      _________
                                   COOLING GRAND TOTAL HEAT =          57439
                          COOLING GRAND TOTAL SENSIBLE HEAT =          57439
                            COOLING GRAND TOTAL LATENT HEAT =              0
```

AHU HEATING LOAD CHART & SUMMARY

SENSIBLE

```
 FABRIC LOAD                                   =   9.10 kW
 WARM UP (  0.0% = 10.40% x  0.63 x  0.00)     =   0.00 kW

 OUTDOOR AIR    1448 l/s x  3.18 CDB x 1.21    =   5.55 kW
 WARM UP (  0.0% = 10.40% x  0.00)             =   0.00 kW
 TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)     =   14.7 kW
```

LATENT

```
 AHU O/A        1448. l/s x 2.20 g/kg x 2.97 =   9.43 KW
                                              _______
                           HUMIDIFIER LOAD =   9.43 KW (191 g/min water)

 SUPPLY AIR     4001 l/s         ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
 AHU O/A        1448 l/s         OUTDOOR AIR         7.3 CDB 80.0%RH
 W/m2             33             RETURN AIR         20.0 CDB
 W/m3           12.3             COIL LEAVING AIR   21.9 CDB
                                 COIL ENTERING AIR  18.9 CDB
```

AHU 18 L4-05

```
  Type ~ Single Zone H & C                                   No. Off ~  1
  Temperature Control ~ Return Air

  Connected to ~ Chiller No   Boiler  No
  Connected to pre conditioner unit number  1 ~ 1
  Floor Area ~   340 m2   Volume ~  919.1 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS 21.1 kW AT 3PM OCT

```
 DESIGN COOLING LOAD IS AT PEAK AHU GTH
 OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
 NOTE: The room average outdoor air is used. Some rooms will be under supplied
 AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                     CDB      CWB      g/kg  %RH
 GTSH           21.1 kW          AVERAGE ROOM AIR   23.0     15.9      8.38 47.9
 GTLH           0.00 kW          AHU O/A            33.1     23.0     13.51
 AHU SH FACT    1.00             O/AIR(PRE EXCH)    25.5     20.8     13.51
                                 O/AIR(PRE HCU)     23.6     14.3      6.39
 SUPPLY AIR     1563 l/s         COIL DEW POINT     10.3               7.81
 AHU O/A         450 l/s         COIL LEAVING AIR   12.3     11.2      7.81
 DEHUMID AIR    1563 l/s         COIL ENTERING AIR  23.5     15.6      7.81
 AIR ch/hr       6.1             RETURN AIR         23.4     16.1      8.38
 l/s/m2          4.6             AVERAGE ROOM ENT.  12.3     11.2      7.81
 l/s/kW         74.0             BYPASS FACTOR      0.15 (N)
 W/m2             62             MIX R/A AND O/A    23.5     15.6      7.81

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 3PM OCT

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
```

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

```
    ADJUSTED ROOM SENSIBLE                                  =  20248
    ADJUSTED ROOM LATENT                                    =   2649
                                                             ________________
                                       ADJUSTED TOTAL HEAT =         22897
```

OTHER GAINS

```
    O/A SENSIBLE (from PRECON)      450 l/s    0.6 CDB  1.21 =    313
    O/A LATENT   (from PRECON)      450 l/s  -2.0 g/kg  2.97 =  -2649
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =    810
    EXHAUSTED RETURN DUCT GAINS CORRECTION                   =   -233
                                                             ________________
                                         TOTAL OTHER GAINS =         -1759
                                                                    _________
                                  COOLING GRAND TOTAL HEAT =         21138
                          COOLING GRAND TOTAL SENSIBLE HEAT =         21138
                            COOLING GRAND TOTAL LATENT HEAT =             0
```

AHU HEATING LOAD CHART & SUMMARY

SENSIBLE

```
FABRIC LOAD                                  =   10.8 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)    =   0.00 kW

OUTDOOR AIR     450 l/s x  3.18 CDB x 1.21   =   1.73 kW
WARM UP (  0.0% = 10.40% x  0.00)            =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)    =   12.5 kW
```

LATENT

```
AHU O/A         450. l/s x 2.20 g/kg x 2.97 =   2.93 KW
                                               _______
                          HUMIDIFIER LOAD =   2.93 KW (59 g/min water)

SUPPLY AIR     1563 l/s        ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         450 l/s        OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             37            RETURN AIR         20.0 CDB
W/m3           13.6            COIL LEAVING AIR   25.7 CDB
                               COIL ENTERING AIR  19.1 CDB
```

AHU 19   L3-01b

```
Type ~ Single Zone H & C                                 No. Off ~  1
Temperature Control ~ Return Air

Connected to ~ Chiller No   Boiler  No
Connected to pre conditioner unit number  1 ~ 1
Floor Area ~   363 m2   Volume ~  979.3 m3   Average Ceiling Height ~ 2700. mm
```

AHU COOLING LOAD SUMMARY

DESIGN COOLING LOAD IS   37.0 kW AT 2PM MAY

```
DESIGN COOLING LOAD IS AT PEAK AHU GTH
OUTDOOR AIR IS ENTERED IN ROOMS WITHOUT AS1668 CALCULATION
NOTE: The room average outdoor air is used. Some rooms will be under supplied
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
                                                  CDB       CWB       g/kg  %RH
GTSH           36.6 kW         AVERAGE ROOM AIR   23.0      16.2      8.76 50.0
GTLH           0.49 kW         AHU O/A            26.7      21.2     13.57
AHU SH FACT    0.99            O/AIR(PRE EXCH)    23.9      20.4     13.57
                               O/AIR(PRE HCU)     23.5      14.3      6.39
SUPPLY AIR     2951 l/s        COIL DEW POINT     11.3                8.37
AHU O/A         405 l/s        COIL LEAVING AIR   13.2      12.1      8.38
DEHUMID AIR    2951 l/s        COIL ENTERING AIR  23.4      16.1      8.43
AIR ch/hr      10.8            RETURN AIR         23.4      16.4      8.76
l/s/m2          8.1            AVERAGE ROOM ENT.  13.1      12.1      8.38
l/s/kW         79.6            BYPASS FACTOR      0.15 (N)
W/m2            102            MIX R/A AND O/A    23.4      16.1      8.43

NOTE : (N) MEANS NOMINATED VALUE USED
```

AHU COOLING LOAD CHART AT MAXIMUM LOAD 2PM MAY

```
AHU OPERATING HOURS  1AM TO MIDN. CALCS BASED ON 24 HOURS OPERATION FROM 6AM
```

ACCUMULATED ZONE/ROOM ADJUSTED HEAT

```
    ADJUSTED ROOM SENSIBLE                                  =  35123
    ADJUSTED ROOM LATENT                                    =   3326
                                                             ________________
                                       ADJUSTED TOTAL HEAT =         38449
```

OTHER GAINS

```
    O/A SENSIBLE (from PRECON)      405 l/s    0.5 CDB  1.21 =    222
    O/A LATENT   (from PRECON)      405 l/s  -2.4 g/kg  2.97 =  -2837
    RETURN DUCT HEAT GAIN AND LEAKAGE LOSS              4.0% =   1405
```

```
   EXHAUSTED RETURN DUCT GAINS CORRECTION                 =   -193
                                                         ________________
                                     TOTAL OTHER GAINS =          -1403
                                                                _________
                              COOLING GRAND TOTAL HEAT =          37046
                       COOLING GRAND TOTAL SENSIBLE HEAT =        36557
                         COOLING GRAND TOTAL LATENT HEAT =          490
```

AHU HEATING LOAD CHART & SUMMARY

SENSIBLE

```
FABRIC LOAD                                  =   9.13 kW
WARM UP (  0.0% = 10.40% x  0.93 x  0.00)    =   0.00 kW

OUTDOOR AIR     405 l/s x  3.18 CDB x 1.21   =   1.55 kW
WARM UP (  0.0% = 10.40% x  0.00)            =   0.00 kW
TOTAL AHU HEATING LOAD (EXCL. HUMIDIFIER)    =   10.7 kW
```

LATENT

```
AHU O/A         405. l/s x 2.20 g/kg x 2.97 =   2.64 KW
                                             _______
                          HUMIDIFIER LOAD =   2.64 KW (53 g/min water)

SUPPLY AIR     2951 l/s         ROOM AIR           20.0 CDB 50.0%RH  13.8 CWB
AHU O/A         405 l/s         OUTDOOR AIR         7.3 CDB 80.0%RH
W/m2             29             RETURN AIR         20.0 CDB
W/m3           10.9             COIL LEAVING AIR   22.6 CDB
                                COIL ENTERING AIR  19.6 CDB
```

Appendix 4: Design Builder Output – As Built

Edgy As Built Energy Report.htm

	ELECTRICITY:FACILITY [kWh]	ELECTRICITY:FACILITY {Maximum}[W]	ELECTRICITY:FACILITY {TIMESTAMP}	GAS:FACILITY []	GAS:FACILITY []
January	219288.36	608892.39	30-JAN-14:00	0.00	0.00
February	194223.94	633753.83	19-FEB-14:00	0.00	0.00
March	207855.65	591564.30	22-MAR-14:20	0.00	0.00
April	209183.31	581115.33	05-APR-16:00	0.00	0.00
May	217519.76	568580.56	02-MAY-14:00	0.00	0.00
June	199111.44	557617.45	19-JUN-14:00	0.00	0.00
July	217474.00	559402.20	04-JUL-14:00	0.00	0.00
August	209834.76	562737.66	23-AUG-15:39	0.00	0.00
September	203317.56	564516.03	26-SEP-16:30	0.00	0.00
October	216111.60	581871.69	29-OCT-12:00	0.00	0.00
November	203723.47	599656.92	13-NOV-15:00	0.00	0.00
December	211510.05	606651.75	06-DEC-15:00	0.00	0.00
Annual Sum or Average	2509153.90				
Minimum of Months	194223.94	557617.45		0.00	0.00
Maximum of Months	219288.36	633753.83		0.00	0.00

Table 10: Design builder as built custom monthly energy report

Appendix 5: Design Builder Output – NCC 2013 DTS

Edgy DTS Energy Report.htm

	ELECTRICITY:FACILITY [kWh]	ELECTRICITY:FACILITY {Maximum}[W]	ELECTRICITY:FACILITY {TIMESTAMP}	GAS:FACILITY []	GAS:FACILITY []
January	247762.28	662922.66	30-JAN-14:00	0.00	0.00
February	220271.97	691460.50	19-FEB-14:00	0.00	0.00
March	238405.45	640422.69	22-MAR-14:50	0.00	0.00
April	241022.85	631645.42	05-APR-16:30	0.00	0.00
May	252608.11	618150.67	02-MAY-15:20	0.00	0.00
June	235955.24	604795.98	19-JUN-14:00	0.00	0.00
July	254798.39	603483.93	04-JUL-14:00	0.00	0.00
August	244755.20	609705.42	23-AUG-14:00	0.00	0.00
September	235457.86	613671.71	26-SEP-16:30	0.00	0.00
October	247524.55	635131.29	29-OCT-14:09	0.00	0.00
November	232891.74	662156.39	13-NOV-15:00	0.00	0.00
December	240234.61	667385.21	06-DEC-15:00	0.00	0.00
Annual Sum or Average	2891688.25				
Minimum of Months	220271.97	603483.93		0.00	0.00
Maximum of Months	254798.39	691460.50		0.00	0.00

Table 11: Design builder NCC 2013 DTS custom monthly energy report