University of Southern Queensland

Faculty of Engineering and Surveying

The Efficient Use of Building Mechanical Services for Saving Energy

A dissertation submitted by

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ABSTRACT

Energy consumption in buildings is responsible for 26% of Australia's greenhouse gas emissions (CSIRO, 2010). Furthermore the energy consumption associated with cooling and heating plant in buildings typically accounts for over 50% of the total building energy use (CSIRO, 2010). As a result this project assesses the greenhouse gas emissions associated with possible air conditioning upgrade alternatives for a multi-storied building 295 Ann Street, Brisbane.

295 Ann Street, Brisbane was constructed in 1973 making the mechanical services plant approximately 38 years old. Due to the age and condition of the air conditioning plant the system is due for replacement.

The aims of the project are to analyse, compare and contrast various air conditioning upgrade alternatives to determine which will provide the greatest greenhouse gas emissions savings. A BCA2010 reference building will be modeled for each alternative to determine if the existing system or proposed upgrades are compliant with the Building Code of Australia.

Using the TRACE 700 Load and Energy Analysis Software the upgrade alternatives and reference buildings were modeled. It was identified that significant greenhouse gas emissions savings can be achieved by upgrading the buildings mechanical services. A trigeneration system combined with chilled beams proved to be the most energy efficient.

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CERTIFICATION

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I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated

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24 October 2011

Date

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1. INTRODUCTION

Since the industrial revolution greenhouse gas emissions in the earth's atmosphere have risen significantly (Preston, Jones, 2006). The radiation absorbed by these gases is re-emitted in all directions resulting in a warming of the earth's surface (Australian Government, 2011).

Energy consumption in buildings is responsible for 26% of Australia's greenhouse gas emissions (CSIRO, 2010). Furthermore the energy consumption associated with a buildings cooling and heating plant typically accounts for over 50% of a buildings total energy usage (CSIRO, 2010). The aims of the project are to analyse, compare and contrast various air conditioning upgrade alternatives for the building 295 Ann Street, Brisbane, to determine which will provide the greatest greenhouse gas emissions savings.

In order to energy model the various upgrade alternatives, the TRACE 700 Load and Energy Analysis software was used. The existing building in its current form was the first system modelled to determine the current energy usage and the associated greenhouse gas emissions. The results were compared with the buildings actual energy usage data to verify the modelling software. Energy models for the seven upgrade alternatives were then modelled to determine the greenhouse gas emissions associated with each. For each alternative a Building Code of Australia reference building was modelled to determine which was compliant with the Building Code of Australia. A reference building is a hypothetical building that is used to calculate the maximum allowable energy load (Australian Building Codes Board, 2010).

The results were then analysed to compare the greenhouse gas emissions associated with each system. Each upgrade alternative was then compared with the associate Building Code of Australia reference building to determine which was compliant with the Building Code of Australia.

1.1 Project Aims

The aims of the project are to analyse, compare and contrast a number of air conditioning upgrade alternatives to determine which will provide the greatest greenhouse gas emissions savings. The study is performed to a building at 295 Ann Street, Brisbane.

The upgrade alternatives to be analysed include:

- Variable air volume system with central air handling plant.
- Variable air volume system with floor air handling plant.
- Active chilled beams system with central air handling plant.
- Active chilled beams system with floor air handling plant.
- Trigeneration energy production plant combined with zone mixing boxes and central air handling.
- Trigeneration energy production plant combined with variable air volume and floor air handling plant.
- Trigeneration energy production plant combined with active chilled beams and floor air handling plant.

1.2 Background

295 Ann Street is a 16 storey office building situated in the Brisbane CBD. The building was constructed in 1973 making the mechanical services plant approximately 38 years old. Due to the age and condition of the air conditioning plant, the system is due for replacement.

The existing air conditioning system serving the building consists of a central cooling and heating plant with an air distribution subsystem. The air distribution subsystem consists of eight central air handling units. Four air handling units are located in the level 16 plant room and are dedicated to the north-east, south-east, south-west and north-west zones on levels 8 to 15 inclusive. The remaining four air handling units are located in the lower ground plant room and serve the north-east, south-east, south-west and north-west zones on levels ground to 7 inclusive.

Each of the air handling units consists of a chilled water cooling coil and a hot water heating coil. A cold deck fan and a hot deck fan provide cold and hot supply air to the floor mixing boxes via individual ductwork reticulation systems. A return air fan draws air from the conditioned space and returns it back to the air handling unit. Here the return air mixes with outside air to repeat the process. Figure 1.1 shows a typical air handling unit configuration.

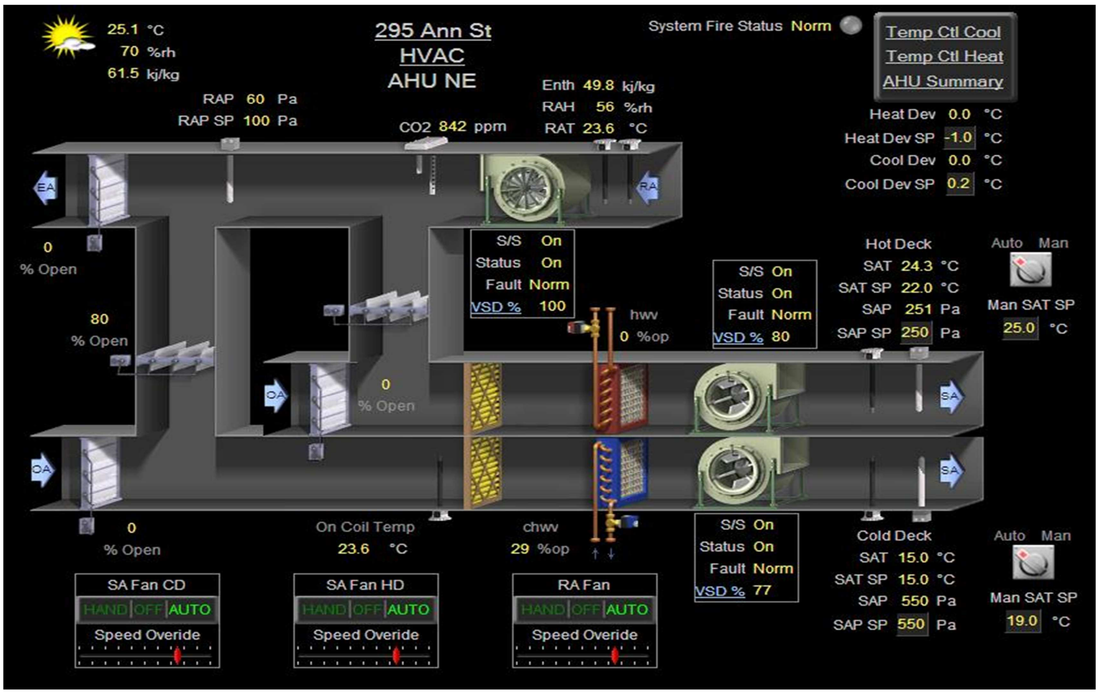

Figure 1.1: Typical Air Handling Unit Configuration at 295 Ann Street, Brisbane

There are a total of 18 mixing boxes per floor that control the air distribution to each zone. The mixing boxes contain a modulating damper that balances the proportion of hot and cold air in order to meet the required zone condition determined by a wall mounted thermostat. Figure 1.2 shows a typical mixing box configuration.

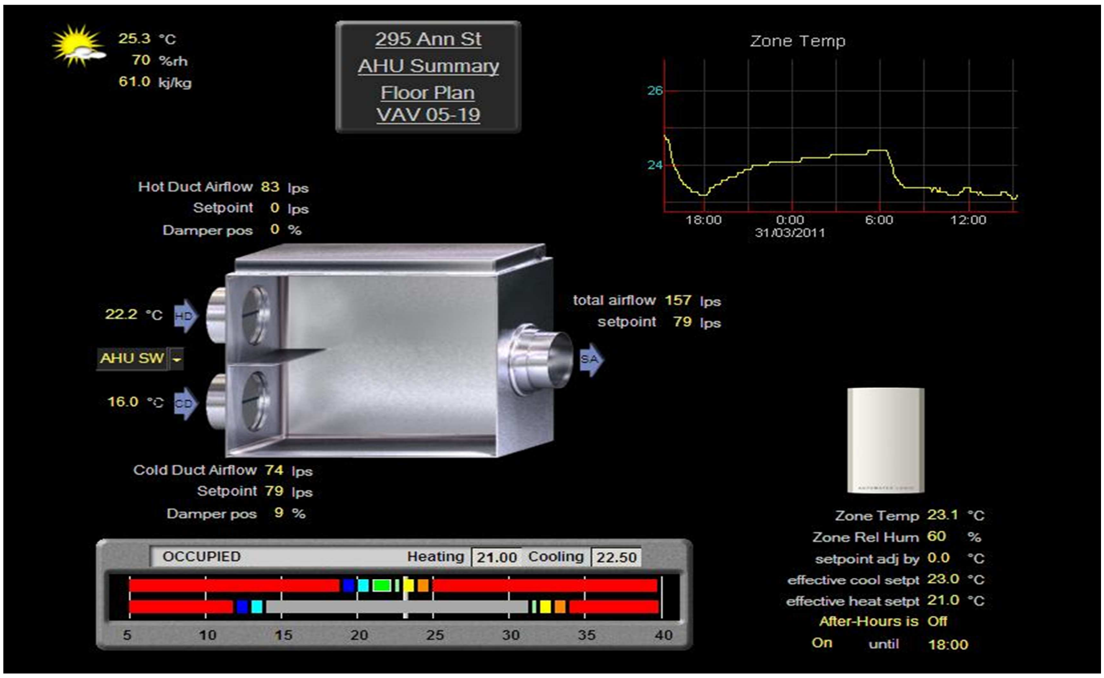

Figure 1.2: Typical Mixing Box Configuration at 295 Ann Street, Brisbane

2. LITERATURE REVIEW

2.1 Global Warming

Global warming is the gradual increase of the Earth's average surface temperature as a result of greenhouse gases in the atmosphere (Australian Government, 2010). The earth's atmosphere contains a natural level of greenhouse gases (Australian Government, 2010). The main constituents include water vapour, carbon dioxide and other important trace gases such as methane, nitrous oxide, ozone and anthropogenic halocarbon compounds (Australian Government, 2011). The radiation absorbed by these gases is re-emitted in all directions resulting in a warming of the earth's surface (Australian Government, 2011).

Since the industrial revolution, greenhouse gas emissions have risen significantly (Preston, Jones, 2006). Carbon dioxide levels have increased by over 30%, from 280 to 380 parts per million, nitrous oxide has increased by 17% and methane has increased by 151% (Preston, Jones, 2006). The increase of greenhouse gases into the atmosphere is a result of human activities, including:

- Burning fossil fuels including coal, oil and gas (Australian Government, 2010).
- Using energy generated by burning fossil fuels (Australian Government, 2010).
- Various aspects of farming such as raising livestock, using fertilisers and growing crops (Australian Government, 2010).
- Clearing land (Australian Government, 2010).
- Various industrial processes (Australian Government, 2010).

2.2 Energy Production

In Australia, the principal greenhouse gas generated by energy production is carbon dioxide (CO_2), (Australian Government, July 2010). Methane, nitrous oxide and synthetic gases are also generated in smaller amounts depending on the fuel used and the combustion conditions (Australian Government, July 2010).

2.2.1 Electricity Consumed from the Power Grid

Emission factors are used for calculating the total emissions generated as a result of energy production. Emission factors are expressed in the form of a quantity of emitted greenhouse gas per unit of energy (kg CO_2-e/kW). All emitted greenhouse gases are expressed as a carbon dioxide equivalent (kg CO_2-e/kW), (Australian Government, July 2010).

There are three categories used to report the types of emissions generated being Scope 1, Scope 2 and Scope 3.

- Scope 1 emissions are direct or point source, for example emissions from a manufacturing process, mining activity or onsite waste disposal (Australian Government, July 2010).
- Scope 2 emissions are indirect and are used to describe the emissions from the generation of purchased and consumed electricity by an organisation (Australian Government, July 2010).
- Scope 3 emissions are those attributed to the losses within the electricity distribution network (Australian Government, July 2010).

Due to the varying fuels used for the production of energy within Australia, emissions factors vary from state to state. Table 2.1 details the latest estimated Scope 2 & 3 emissions factors for each state of Australia.

Table 2.1: 2010 Emissions Factors for States of Australia (Australian Government, July 2010)

Location	EF for Scope 2 (kg CO_2-e/kWh)	EF for Scope 3 (kg CO_2-e/kWh)	EF for Scope 2 + EF for Scope 3 (kg CO_2-e/kWh)
Victoria	1.23	0.14	1.37
Queensland	0.89	0.13	1.02
South Australia	0.72	0.13	0.85
Western Australia	0.82	0.10	0.93
Northern Territory	0.68	0.09	0.77
New South Wales	0.9	0.17	1.07

From Table 2.1, it can be concluded that Queensland's emissions factors are poor in comparison with other states of Australia and needs to be improved. This can be done by investigating more efficient means for producing and distributing energy throughout the state.

2.2.2 Natural Gas Consumption

The combustion of natural gas is an option for energy consumption within buildings. The emissions factors for the consumption of natural gas distributed in a pipeline are detailed in Table 2.2.

Table 2.2: Emissions Factors for the Consumption of Natural Gas (Australian Government, July 2010)

Fuel Combusted	Emission Factor (kg CO_2-e/GJ)		
	CO_2	CH_4	N_2O
Natural Gas Distributed in a Pipeline	51.2	0.1	0.03

The following formula is used to estimate the greenhouse gas emissions from the combustion of gaseous fuels:

$$E = Q \times EF$$ ...... (i) (Australian Government, July 2010)

Where,

E, is the emissions of the respective gas type (kg CO_2-e).

Q, is the quantity of fuel type (GJ).

EF, is the Emissions Factor for each gas type as detailed in Table 2.2.

2.3 Global Warming and the Built Environment

Energy consumption in buildings is responsible for 26% of Australia's greenhouse gas emissions (CSIRO, 2010). Furthermore, the energy consumption associated with a buildings cooling and heating plant typically accounts for over 50% of the buildings total energy usage (CSIRO, 2010).

In 2006 Lishan Guan undertook a research project titled "The Implications of Global Warming on the Energy Performance and Indoor Thermal Environment of Air-Conditioned Office Buildings in Australia". Results of her research showed that there is a near linear relationship between the increase of ambient air temperatures and the increase of building energy use (Guan, 2006).

Figure 2.1 and 2.2, shows the effects of global warming on a buildings cooling load and the total building energy use in cities throughout Australia.

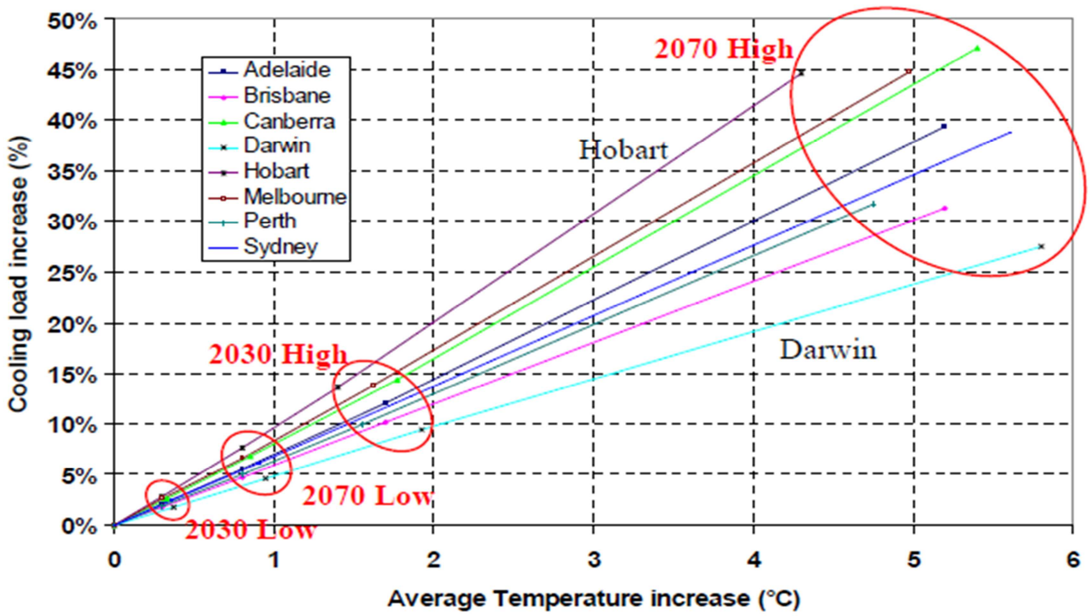

Figure 2.1: Building Cooling Load Increase versus Average Temperature Increase (Guan, 2006)

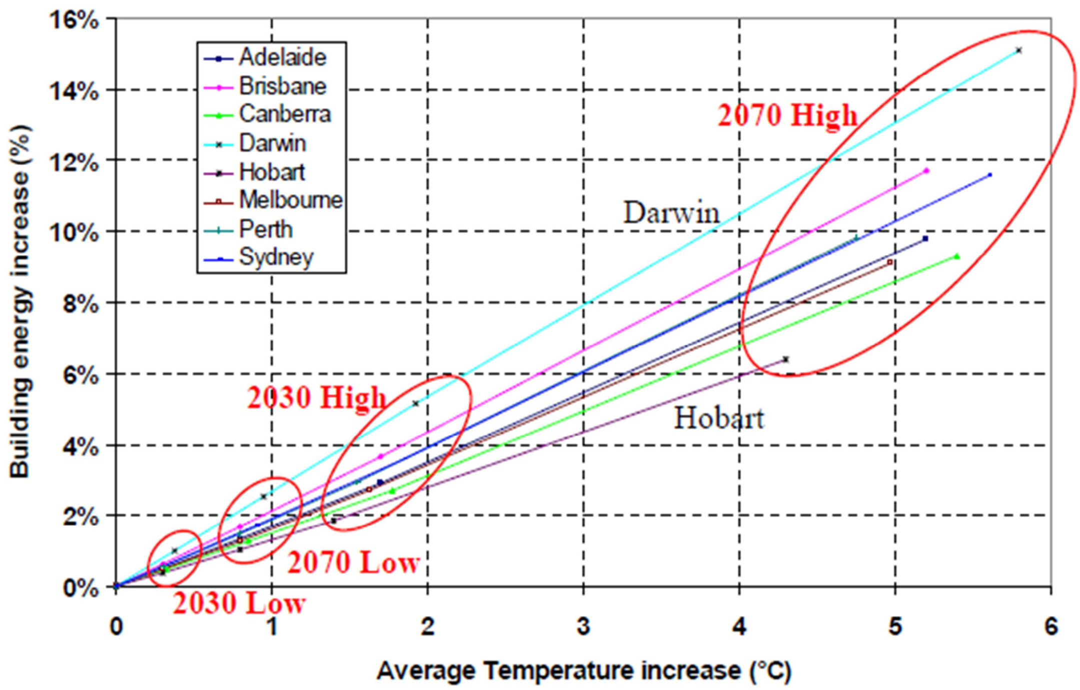

Figure 2.2: Building Energy Usage Increase versus Average Temperature Increase (Guan, 2006)

From Figures 2.1 and 2.2 it can be seen that building energy consumption is proportional to the ambient air temperature and global warming. As a result a cycling effect is evident. Global warming leads to greater building energy loads, which causes more greenhouse gas emissions, which leads to global warming. As building air conditioning systems account for a large proportion of greenhouse gas emissions, alternate energy efficient air conditioning systems should be investigated and analysed.

A recommendation for future research from "The Implications of Global Warming on the Energy Performance and Indoor Thermal Environment of Air-Conditioned Office Building in Australia" is to undertake a study of air conditioning systems selection and the energy efficiency associated with different systems (Guan, 2006).

2.4 Air Conditioning Systems

As detailed in Section 2.3, energy consumption in buildings is responsible for 26% of Australia's greenhouse gas emissions with 50% of the emissions associated with the air conditioning plant (CSIRO, 2010).

The cooling requirements of a building are dependent on a variety of factors which include but are not limited to the following:

- The climate zone the building is situated (Bhatia, 2011).
- The required space temperature (Bhatia, 2011).
- The type of construction and the thermal properties of the building fabric (Bhatia, 2011).
- The building orientation and how much shade is on the building (Bhatia, 2011).
- The physical size of the building to be conditioned (Bhatia, 2011).
- The quantity of ambient air infiltration into the building (Bhatia, 2011).
- The occupancy levels of the building (Bhatia, 2011).
- Activities undertaken within the building (Bhatia, 2011).
- Amount and type of lighting within the building (Bhatia, 2011).

Due to the wide variety of factors which affect the cooling requirements of a building it can be said that no two buildings are the same and each buildings has its own unique characteristics. As a result when determining heat loads and selecting the most energy efficient equipment it should be done on a case by case basis, as an appropriate selection for one building may not be the most appropriate for another.

The below subsections detail the air conditioning systems which are to be investigated in detail. The systems include:

- Variable air volume,
- Active Chilled beams,
- Trigeneration.

2.4.1 Variable Air Volume

A variable air volume (VAV) air conditioning system varies the quantity of supply air to meet the changing load conditions of the space (Trane, 2001). A VAV system is typically made up of the following main components:

- An air handling unit consisting of a variable speed supply air fan (Trane, 2001).
- A minimum of one variable air volume box downstream of the air handling unit. The primary components of the variable air volume box include an air modulation device such as a rotating blade damper, and control hardware (Trane, 2001).
- A thermostat dedicated to each variable air volume box (Trane, 2001).

There are two main control strategies for variable air volume boxes being pressure dependant and pressure independent control. Pressure dependant systems use the space temperature to control the position of the modulating device. The quantity of supply air delivered to the space is dependent on the static pressure within the duct and the position of the modulating device (Trane, 2001). A pressure independent unit controls the actual supply air delivered to the space utilising a velocity sensor in the supply air stream. Pressure independent variable air volume devices are the most popular form of control (Trane, 2001).

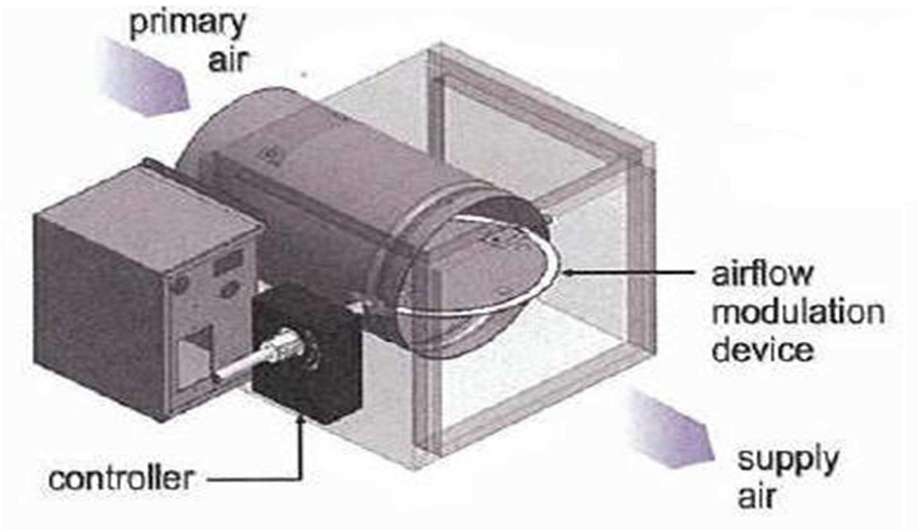

Figure 2.3: Pressure Independent Variable Air Volume Box Configuration (Trane, 2001)

There are two primary advantages associated with using a variable air volume system. The first is the system's ability to provide both fan and refrigeration part load energy savings. When the cooling demand is minimal within the space the damper modulates closed which creates an opportunity to reduce the speed of the fan which reduces fan energy. This reduced airflow across the cooling coil reduces the energy demand on the refrigeration system thus saving energy in the main cooling plant (Trane, 2001).

The second advantage associated with variable air volume systems is the improved comfort control. The system is capable of providing control to many spaces with varying cooling and heating requirements utilising one air handling unit fan and a variable air volume box to each individual space.

2.4.2 Chilled Beams

There are two main types of chilled beam air terminal devices namely active and passive (AIRAH, 2011). An active chilled beam utilises primary supply air for inducing room air over the chilled beam heat exchanger (AIRAH, 2011). It can be seen in Figure 2.4 that primary air is delivered to the mixing chamber through the primary air nozzles. This induces air from the conditioned space to rise through the secondary heat exchanger and mix with the primary air in the mixing chamber. The mixed air is then delivered to the space as supply air (AIRAH, 2011).

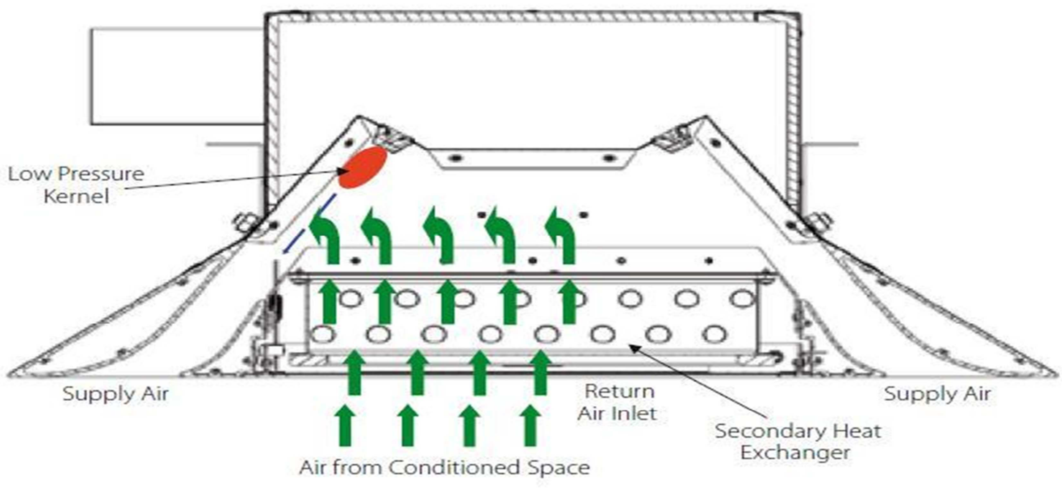

Figure 2.4, Active Chilled Beam Configuration (AIRAH, 2011)

A passive chilled beam has no direct supply air and relies on the room's natural air convection (Rumsey, Weale, 2011). Warm air rises to the beams coils, causing the air to cool and fall into the occupied zone (Rumsey, Weale, 2011). Passive chilled beams can handle low ventilation requirements and are less flexible than active technology (Rumsey, Weale, 2011). As a result active chilled beams will be used in this energy analysis.

The advantages associated with chilled beam technology include:

- Chilled beams use higher chilled water temperatures than conventional systems. A chiller dedicated to chilled beams has a lower temperature lift and can operate with a 15-20% higher efficiency (Roth, Dieckmann, Zogg, Brodrick, 2007).
- The combination of higher chilled water temperatures and the fact active chilled beams entrain large quantities of room air greatly reduces the need for energy consuming reheat of the cooled air (Roth, Dieckmann, Zogg, Brodrick, 2007).
- Chilled beams reduce ventilation fan energy consumption (Roth, Dieckmann, Zogg, Brodrick, 2007).

A study of the energy performance of active chilled beams and variable air volume systems for a building in Sydney found similar energy performances for the two buildings (Roth, Dieckmann, Zogg, Brodrick, 2007). During the summer months, the chilled beams system consumed less energy than the variable air volume system but during the winter months consumed more because of the reduced quantity of supply air precluded the use of an air side economizer (Roth, Dieckmann, Zogg, Brodrick, 2007). Studies of other buildings in Australia found that the energy impact varied appreciably depending on the specifics of the given project (Roth, Dieckmann, Zogg, Brodrick, 2007).

2.4.3 Trigeneration

Trigeneration also known as combined cooling, heating and power (CCHP) is the simultaneous production of electricity, heating and/or cooling from a single fuel source (Clinch, Selth, 2009). A gas turbine is used to simultaneously produce both electricity and useful heat (Australian Government, Feb 2010). With trigeneration the useful heat can be either used for heating or transformed into cooling energy by an absorption chiller (Australian Government, 2010).

Absorption chillers use heat in lieu of mechanical energy to provide cooling. A thermal compressor consists of an absorber, a generator, a pump and a throttling device and replaces the mechanical vapour compressor (REI, 2011). Absorption chillers have a low coefficient of performance (capacity output divided by the energy input) in comparison to typical mechanical chillers. Although they have a poor coefficient of performance they can substantially reduce operating costs because they are powered by low grade waste heat from the gas turbine (REI, 2011).

Figure 2.5, shows a typical trigeneration schematic. From this diagram it can be seen that natural gas supplies the generator and boiler. Electrical power is provided to the building from two sources being the electrical grid and the generator. Waste heat from the generator can be used for both heating and cooling as necessary.

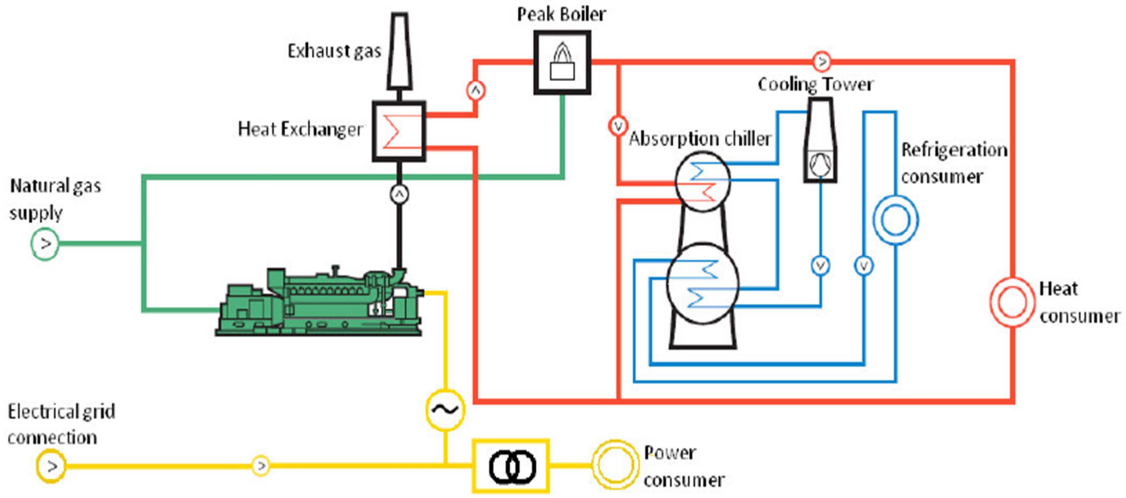

Figure 2.5: Trigeneration Process Schematic (Clinch, R, Selth, J, 2009)

The advantages of a trigeneration system is that it can make use of 70-75% of the energy in the original fuel, in comparison to a conventional coal fired power station which utilises approximately 25-30% (Australian Government, 2010). This is achieved by utilising the waste heat which would otherwise be wasted. A second advantage is that by producing the electricity on site, transmission and distribution losses are avoided which are often as high as 10% (Australian Government, 2010).

2.5 Building Code of Australia

The objective of Section J of the Building Code of Australia is to reduce building greenhouse gas emissions (Australian Building Codes Board, 2010). In order to reduce greenhouse gas emissions a building including its services must have features that facility the efficient use of energy (Australian Building Codes Board, 2010).

The Building Code of Australia (BCA) 2010 was effective from the 1 May 2010 and was superseded by the BCA2011 on the 1 May 2011 (Australian Building Codes Board, 2010). As this research project commenced prior to the 1 May 2011, the BCA2010 was adopted as the defining code for this research project.

For a building to comply with Section J of the BCA2010, it can be done so in one of two ways. The first is complying with the *Deemed-to-Satisfy Provisions* detailed within Parts J1 to J7. The title of each of these parts is listed below:

- Part J1: Building Fabric.
- Part J2: Glazing.
- Part J3: Building Sealing.
- Part J4: Not defined in BCA2010
- Part J5: Air-Conditioning and Ventilation Systems.
- Part J6: Artificial Lighting and Power.
- Part J7: Hot Water Supply and Swimming Pool and Spa Pool Plant.

Parts J1 to J7 can be categorised into two categories being building envelope requirements and building services requirements (Australian Building Codes Board, 2010). Parts J1, J2 and J3 make up the building envelope requirements while Parts J5, J6 and J7 make up the building services requirements.

The second alternative for compliance with the BCA2010 is verification using a reference building. Compliance using a reference building is verified when the annual energy consumption of the proposed building and its services is not more than the annual energy consumption of a reference building when:-

(i) The proposed building is modelled with the proposed services; and

(ii) The proposed building is modelled with the same services as the reference building (Australian Building Codes Board, 2010).

As detailed above verification using a reference building compares the annual energy consumptions of the proposed building with the annual energy consumption of the reference building. As the objective of the Building Code of Australia is to reduce greenhouse gas emissions, for this research project, annual greenhouse gas emissions will be compared instead of annual energy consumption. This will provide a more accurate analysis as to which upgrade is the most energy efficient in terms of which emits the least greenhouse gases. Gas and electrical energy consumptions will be converted to greenhouse gas emissions using the formulas described in Chapter 2.2 of this report.

As defined by the Building Code of Australia 2010, a reference building is a hypothetical building that is used to calculate the maximum allowable annual energy load, or maximum allowable annual energy consumption for the proposed building (Australian Building Codes Board, 2010). The *Deemed-to-Satisfy Provisions* from Parts J1 to J7 are to be used to model the reference buildings. A further description of these performance requirements are detailed later in this section.

As 295 Ann Street Brisbane is an existing building with an age of approximately 38 years, the existing building envelope and building services do not comply with the *Deemed-to-Satisfy Provisions*. Due to the size and age of the building it would be unfeasible to upgrade the building envelope to comply with the *Deemed-to-Satisfy Provisions.* This would involve replacing all the single pane glass with double pane glass, and insulating all external walls and roofs. For this reason verification using a reference building will be used to assess the compliance of the upgrade alternatives modelled throughout this research project.

The implications of not upgrading the building envelope result in the proposed building using more energy than the reference buildings when the proposed building is modelled with the same services as the reference building, as per requirement (ii).

This is due to the reference building being modelled with a *Deemed-to-Satisfy* envelope and services, while comparing this to the proposed building with a non-compliant envelope and *Deemed-to-Satisfy* services. For this reason, to determine BCA compliance for an existing building the proposed building will be modelled with the proposed services as per requirement (i).

The main performance requirements of the BCA2010 reference building are summarised below:

- Roof thermal resistance (R-Value) of 4.2 for a building in climate zone 2 (Australian Building Codes Board, 2010).
- Wall thermal resistance (R-Value) of 3.3 for a building in climate zone 2 (Australian Building Codes Board, 2010).
- Have an outdoor air economy cycle when the air conditioning unit capacity is over 50 kWr (Australian Building Codes Board, 2010).
- A gas boiler shall have a minimum gross thermal efficiency of 80% when the rated capacity is not more than 750 kW (Australian Building Codes Board, 2010).
- A Minimum energy efficiency ratio for refrigerant chillers of 4.2 under full load operation (Australian Building Codes Board, 2010).
- A solar absorptance of 0.6 for external walls and 0.7 for roofs (Australian Building Codes Board, 2010).
- For perimeter zones an air infiltration value of 1 air change per hour (Australian Building Codes Board, 2010).
- The aggregate air conditioning energy value attributable to the glazing must not exceed the allowance obtained by multiplying the facade area exposed to the conditioned space by the energy index (Australian Building Codes Board, 2010). The energy index for a building in climate zone 2 is 0.173. The aggregate air conditioning energy value is calculated using formula (2):

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

..... (2), (Australian Building Codes Board, 2010).

Where,

$A_{1,2}$= the area of each glazing element

$C_{A,\ B\ and\ C}$= the energy constants A, B and C for the specific orientation.

$SHGC_{\ 1,2,\ etc}$= the shading glass coefficient of each glazing element

$S_{H1,2,\ etc}$ = the heating shading multiplier for each glazing element obtained from the BCA2010.

$S_{C1,2,\ etc}$ = the cooling shading multiplier for each glazing element obtained from the BCA2010.

$U_{1,2}$= the area of each glazing element

The Building Code of Australia website provides an excel spread sheet to perform equation (2).

For consistency between the proposed building model and reference building model, section JV3, (d),(ii) of the Building Code of Australia 2010 details the features which are required to be kept consistent between the reference building and the proposed building model. One of the items includes the air conditioning system configuration and zones shall be kept consistent between the two models. As a result for each upgrade alternative a reference building shall be modelled with the same air conditioning system configurations and zones.

To ensure the results of the energy modelling are accurate, the Building Code of Australia requires that the energy consumption calculation method must comply with the Australian Building Codes Board, *Protocol for Building Energy Analysis Software* (Australian Building Codes Board, 2010). The protocol requires that evidence be produced to demonstrate the software is suitable. The evidence includes:

- The software has features and specific capabilities as detailed in section 3 and 4 of the Protocol for Building Energy Analysis Software (Australian Building Codes Board, 2010).
- The software has undergone appropriate testing and result analysis, and the process has undergone quality assurance (Australian Building Codes Board, 2010).
- A training program is available for users (Australian Building Codes Board, 2010).
- The status of the software such as whether it has been approved by any appropriate authority, must be clearly indicated (Australian Building Codes Board, 2010).

2.6 Modelling Software

The energy modelling software package being used for this analysis is TRACE 700 version 6.2. Trace 700 is a load, system, energy and economic analysis program. The software has the ability to analyse architectural features, heating, ventilation and air conditioning systems, building utilisation, scheduling and economic options (Trane, 2011).

As required by the Australian Building Codes Board (ABCB), TRACE 700 version 6.2.6 has been tested in compliance with ANSI/ASHRAE Standard 140-2007, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs* (Trane, 2011). To comply with this standard the software passed the BESTEST which compared the program with similar analysis programs. A letter verifying this compliance can be seen in Appendix B.

In order to gain a full appreciation of the software results it is necessary to understand the software's limitations. The limitations which have been identified include:

- The software does not provide detailed temperature profiles of each room. The software requires the user to input the required dry bulb and wet bulb temperatures of the room, however, when comparing between proposed systems it cannot be determined which system provides more consistent temperatures and air distribution, and which has a higher level of occupancy comfort.

- The energy calculations are based on average weather data for the location defined by the user. When comparing the theoretical energy usage with actual energy usage results will vary depending on how close the actual temperatures were to the average data built into the software.

3. PROJECT METHODOLOGY

This Chapter details the project methodology and tasks required to undertake this research. Each of the major tasks and milestones are detailed in the following sub headings.

3.1 Modelling the Existing Building and the Mechanical Services Systems

The first stage of the energy analyses was to model the existing building and the air conditioning systems within the building. This step determined the energy efficiency of the existing mechanical systems and provided a reference point to compare the upgrade alternatives to. Information used to model the existing building and its services was gathered from site audits, the buildings operation and maintenance manuals, as-installed drawings and the Building Management System (BMS). The below subsections detail the steps involved to model the existing systems. Appendix C contains screenshots of the TRACE 700 software for the existing building model.

3.1.1 Select Weather Information

As described in Section 2.4 climate greatly affects the energy consumption of buildings mechanical services. TRACE 700 has inbuilt weather files for a range of locations throughout the world. Information stored within these files includes:

- Maximum outside air dry bulb.
- Maximum outside air wet bulb.
- Humidity ratio.
- Cloud Cover Modifier.
- Wind speed.
- Barometric Pressure.

The building modelled is located at 295 Ann Street in the Brisbane CBD and as a result the Brisbane weather file was selected. Appendix D displays the Brisbane weather file which was used for this assessment.

3.1.2 Creation of Rooms

In order to model the existing building each floor was split into 18 individual rooms. Each level was assumed to be typical in terms of layout, construction and occupancy. The floor was divided into rooms by assuming one air mixing box was dedicated to each room thereby creating 18 rooms. Appendix E contains a typical floor plan which shows the segregation of the rooms. The subsections below detail the modelling associated with each room.

3.1.2.1 Rooms

The rooms sub-tab was used to define the following room properties:

- The length and width of the room.
- The height of the room including the slab to slab height and the ceiling plenum height.
- The cooling temperature set point.
- The heating temperature set point.
- Relative humidity set point.
- Cooling drift point which is the maximum range at which the temperature shall deviate from set point.
- The heating drift point which is the maximum range at which the temperature shall deviate from set point.
- The thermostat and CO_2 sensor positions.

Table 3.1 details the typical room properties for all rooms within the building. As seen in the table the room length and width are dependent on the respective room.

Table 3.1: Typical Room Properties at 295 Ann Street, Brisbane

Length of Room	Dependant on the room
Width of Room	Dependant on the room
Floor to Floor Height (slab to slab)	3.65m
Ceiling Plenum Height	0.95m
Cooling Set Point	22.5°C
Heating Set Point	21°C
Relative Humidity	50%
Cooling Drift Point	23.5°C
Heating Drift Point	20
Thermostat Sensor Location	Room, wall mounted
CO_2 Sensor Location	N/A

The set points detailed in Table 3.1 were obtained from the Building Management System.

3.1.2.2 Roofs

The roofs sub-tab was used to input the roof construction and the associated thermal properties. As the top floor of 295 Ann Street is a non air conditioned plant room the thermal properties of the roof does not affect the energy consumption within the building.

3.1.2.3 Walls

The walls sub-tab was used to define the wall construction, direction and thermal properties of all external walls. The following properties were defined within the walls tab:

- The direction of the wall.

- The length and height of the wall.
- The construction type of the wall.
- The heat transfer coefficient (U-Factor) of the wall.
- The length and height of glass within each wall.
- The type of glass.
- The heat transfer coefficient (U-Factor) of the glass.
- The shading coefficient of the glass.

Typical wall and glass properties within the building are detailed in Table 3.2.

Table 3.2: Typical Wall Properties at 295 Ann Street, Brisbane

Direction of Wall	Dependant on the room
The Length of Wall	Dependant on the room
Height of Wall	3.65m
External Wall Construction	200mm concrete lined with 20mm of plaster
Heat Transfer Coefficient (U-Factor) of External Walls	1.4479 $W/m^2°C$
Length of Glass Within Wall	Dependant on the room
Height of Glass	1.76m
Type of Glass	Single Clear 1/8"
Heat Transfer Coefficient (U-Factor) of Glass	5.9 $W/m^2°C$
Shading Coefficient of Glass	0.8

The TRACE 700 software contains heat transfer coefficients for a large range of wall, slab and glazing construction types. As a result the heat transfer coefficients detailed in Table 3.2 were obtained by selecting the appropriate wall construction and glass types. Wall and glazing construction types were identified during a site inspection.

3.1.2.4 Internal Loads

The internal loads sub-tab was used to define the internal loads within each room. These internal loads include:

- The occupancy levels and the activities being undertaken by occupants.
- Number of workstations per person.
- The type of lighting and the lighting heat gain within the room.
- Any miscellaneous loads within the room

The typical internal loads are detailed in Table 3.3.

Table 3.3: Typical Internal loads at 295 Ann Street, Brisbane

People Activity	Office
People Density	10 sq m/person
Workstation Density	1 workstation/person
Lighting Type	Fluorescent, 100% load to space
Heat Gain From Lighting	15 W/m^2

AS 1668.2-1991, The Use of Mechanical Ventilation and Air-Conditioning in Buildings states that for an office building the typical floor area per person is 1 person per $10m^2$ (Standards Australia, 1991). The people density in Table 3.3 is based on this standard. The lighting heat gain of 15 W/m^2 was an assumption made based on typical industry figures from the period the building was constructed.

3.1.2.5 Airflows

The outside air rates and the infiltration rates of each room were detailed in the airflows sub-tab. Table 3.4 details the outside air and infiltration rates used for the existing building model.

Table 3.4: Outside Air/Infiltration Rates at 295 Ann Street, Brisbane

Ventilation in Cooling Mode	10 L/s/person
Ventilation in Heating Mode	10 L/s/person
Infiltration in Cooling Mode	1 air change/hour
Infiltration in Heating Mode	1 air change/hour

The outside air rates detailed in Table 3.4 were obtained from the mechanical operation and maintenance manuals. The infiltration rate of 1 air change/hour was an assumption made and is consistent with the requirements of the BCA.

3.1.2.6 Partition/Floors

The Partition/Floors sub-tab was used to nominate partition walls and floors which affect the heat load of a space. A partition wall is a wall which divides an air conditioned space from a non air conditioned space thereby resulting in heat transfer from one room to another. A wall which divides a conditioned room from another conditioned room of same temperature is not deemed to be a partition as there will be no heat transfer between spaces.

For the 295 Ann Street model the only partition wall is that between the office space and the building core. On ground level the floor was modelled as a partition as it divides the air conditioned ground floor with the non air conditioned plant room level below. Similarly, the level 16 floor was modelled as a partition as it divides the air conditioned level 15 from the non air conditioned plant room on level 16. Details of each partition can be seen in Table 3.5.

Table 3.5: Partition/Floors Descriptions at 295 Ann Street, Brisbane

Partition Wall Construction	8” concrete block
Partition Wall Heat Transfer Coefficient (U-Factor)	2.288 W/m^2°C
Slab Construction	12” Concrete
Slab Heat Transfer Coefficient (U-Value)	0.515 W/m^2°C

The heat transfer coefficients detailed in Table 3.5 were obtained by selecting the appropriate construction type scheduled within the TRACE 700 program. These construction types were identified during a site inspection of the premises.

3.1.3 Create Systems

The create system tab was the location to select and define the air side system. As described earlier in this report the air distribution subsystem in the existing building consists of eight central air handling units. Each of the air handling units consists of a chilled water cooling coil and a hot water heating coil. A cold deck fan and a hot deck fan provide cold and hot supply air to the floor mixing boxes via individual ductwork reticulation systems. A return air fan draws air from the conditioned space and returns it back to the air handling unit. Here the return air mixes with outside air to repeat the process. A schematic of a zone mixing box system can be seen in Figure 3.1.

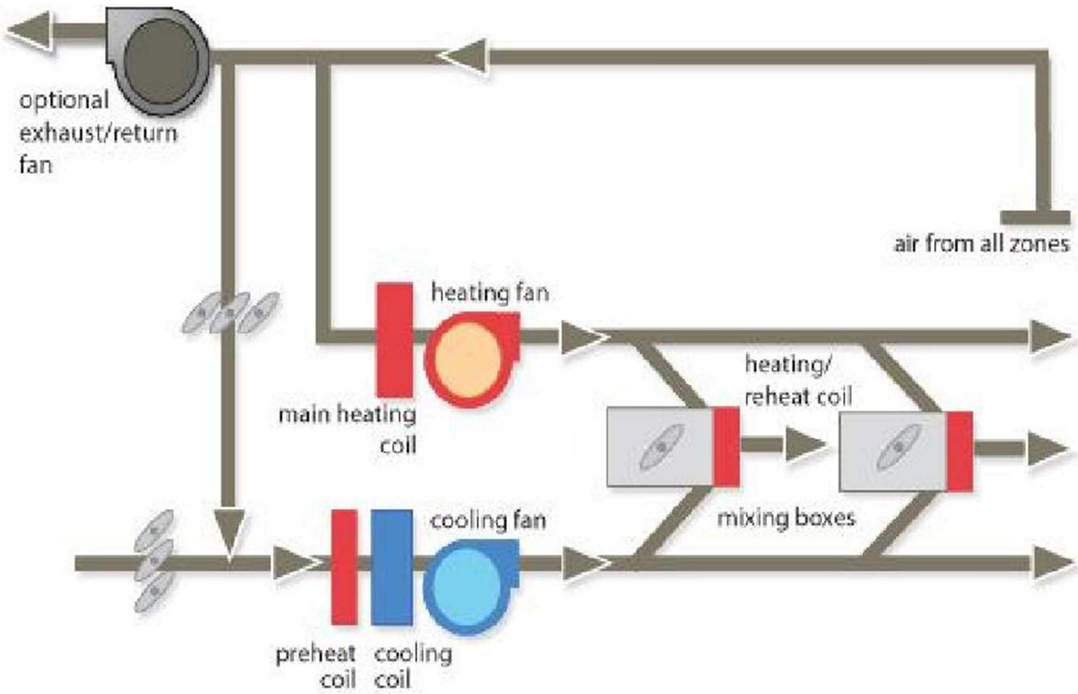

Figure 3.1: Zone Mixing Box Schematic

3.1.3.1 Fans

For each of the 8 air distribution systems, fan performance data was entered into the fans sub-tab. The fan information was obtained from the buildings operation and maintenance manuals. The performance data for the cooling, heating and return air fans for each system are summarised in Table 3.6.

Table 3.6: Fan Performance Data from Mechanical O&M Manuals

System Description	Fan	Fan Type	Static Pressure Drop
AHU NW (Level 1-7)	Cooling Supply	Centrifugal, variable speed motor	650 Pa
	Heating Supply	Axial fan, variable speed motor	650 Pa
	Return Air Fan	Axial fan, variable speed motor	395 Pa
AHU NE (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	450 Pa
	Heating Supply	Axial fan, variable speed motor	450 Pa
	Return Air Fan	Axial fan, variable speed motor	315 Pa
AHU SW (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	430 Pa
	Heating Supply	Axial fan, variable speed motor	430 Pa
	Return Air Fan	Axial fan, variable speed motor	320 Pa
AHU SE (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	440 Pa
	Heating Supply	Axial fan, variable speed motor	440 Pa
	Return Air Fan	Axial fan, variable speed motor	300 Pa
AHU NW (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	500 Pa
	Heating Supply	Axial fan, variable speed motor	500 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa
AHU NE (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	510 Pa
	Heating Supply	Axial fan, variable speed motor	510 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa

AHU SW (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	445 Pa
	Heating Supply	Axial fan, variable speed motor	445 Pa
	Return Air Fan	Axial fan, variable speed motor	390 Pa
AHU SE (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	520 Pa
	Heating Supply	Axial fan, variable speed motor	520 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa

3.1.4 Assign Rooms to Systems

The purpose of the assign rooms to system tab was to define the rooms each airside system serves. Table 3.7 details the room assignments used throughout this model.

Table 3.7: Room to System Assignment for the Existing Building Model

AIR SIDE SYSTEM	ROOM ASSIGNMENT
AHU NW (Levels 1-7)	Zones 15, 16, 17 & 18 from levels 1 to 7
AHU NE (Levels 1-7)	Zones 10, 11, 12, 13 & 14 from levels 1 to 7
AHU SW (Levels 1-7)	Zones 1, 2, 3, 4, & 5 from levels 1 to 7
AHU SE (Levels 1-7)	Zones 6, 7, 8 & 9 from levels 1 to 7
AHU NW (Levels 8-15)	Zones 15, 16, 17 & 18 from levels 8 to 15
AHU NE (Levels 8-15)	Zones 10, 11, 12, 13 & 14 from levels 8 to 15
AHU SW (Levels 8-15)	Zones 1, 2, 3, 4, & 5 from levels 8 to 15
AHU SE (Levels 8-15)	Zones 6, 7, 8 & 9 from levels 8 to 15

3.1.5 Create Plants

The main cooling and heating plants were created and defined in the create plants tab. A summary of the cooling and heating plants existing within the building are detailed in Table 3.8. This information was obtained from the buildings operation and maintenance manuals and mechanical as-installed drawings.

Table 3.8: Existing Building Cooling and Heating Plant

COOLING PLANT				
Equipment Description	**Equipment Type**	**Capacity**	**COP**	**Sequencing**
Water Cooled Chiller-1	Centrifugal 2 Stage with VSD	2110 kW	5.2	Parallel
Water Cooled Chiller-2	Centrifugal 2 Stage with VSD	1800 kW	5.2	
Water Cooled Chiller-3	Reciprocating	450 kW	3	
Water Cooled Chiller-4	Reciprocating	450 kW	3	
Cooling Tower 1	Single Speed Fans	2450 kW	N/A	Parallel
Cooling Tower 2	Single Speed Fans	2450 kW	N/A	
Chilled Water Pump 1	Constant Volume	40 kW	N/A	Single
Chilled Water Pump 2	Constant Volume	40 kW	N/A	Single
Chilled Water Pump 3	Constant Volume	22 kW	N/A	Single
Chilled Water Pump 4	Constant Volume	22 kW	N/A	Single
Condenser Water Pump 1	Constant Volume	20 kW	N/A	Single
Condenser Water Pump 2	Constant Volume	20 kW	N/A	Single
Condenser Water Pump 3	Constant Volume	11 kW	N/A	Single
Condenser Water Pump 4	Constant Volume	11 kW	N/A	Single
HEATING PLANT				
Boiler 1	Gas Fired	Calculated by TRACE	83.3%	Single
Heating Water Pump	Constant Volume	15 kW	N/A	Single

3.1.6 Assign Systems to Plants

The final stage in the modelling process was to assign the air side systems to the main cooling and heating plants. Systems were assigned to plants by assigning all the cooling coils to the main cooling plant and all heating coils to the heating plant.

3.2 Modelling the BCA 2010 Reference Buildings

As described in Section 2.5 of this report, in order to assess if a building is compliant with the Building Code of Australia 2010, its proposed greenhouse gas emissions must be compared with that of a reference building. A reference building is a hypothetical building that is used to calculate the maximum allowable greenhouse gas emissions for the proposed building. The following subsections detail the modelling of the reference buildings.

3.2.1 Wall Thermal Performance Values

Table 3.9 details the difference in the wall thermal performance values between the existing building and the reference building. The reference building performance values were obtained from Part J1 of the Building Code of Australia 2010, which is the Building Fabric *Deemed-to-Satisfy Provisions*.

Table 3.9: Reference Building Roof and Wall Thermal Performance

	Existing Building Value	Reference Building Value
Wall Heat Transfer Coefficient (U-Value)	1.4479 $W/m^2°C$	0.303 $W/m^2°C$
Wall Solar Absorptance	0.9	0.6
Infiltration Rates	1 air changes/hour	1 air change/hour
Heat from Lighting	15 W/m^2	9 W/m^2

3.2.2 Glazing

To determine the glazing performance of the reference building, the BCA2010 glazing calculator was used. The calculator performs equation (2) detailed in Section 2.5 of this report. The following data was required to be inputted into the spread sheet in order to perform the calculation:

- The facade area in each direction.
- The height and width of each glazing element.
- The thermal performance of the glass including the heat transfer coefficient and the glass shading coefficient.
- Dimensions of the physical shading around the windows including overhangs and reveals.
- The climate zone of which the building is located.

Appendix F contains the glazing calculator using the existing buildings glass properties. As all floors are typical the calculation has been performed for one level only. It can be seen in the far right hand column of the spread sheet that the glass does not comply due to:

- The aggregate air conditioning energy value attributed to the glazing in the north-western direction is 163% of the allowable quantity.
- The aggregate air conditioning energy value attributed to the glazing in the north-eastern direction is 201% of the allowable quantity.
- The aggregate air conditioning energy value attributed to the glazing in the south-western direction is 115% of the allowable quantity.
- The aggregate air conditioning energy value attributed to the glazing in the south-eastern direction is 131% of the allowable quantity.

As described earlier, the allowable energy value associated with the glazing is obtained by multiplying the facade area exposed to the conditioned space by the energy index. The energy index for a building in climate zone 2 is 0.173.

To determine the thermal performance of the glass which will comply with the BCA2010, the glazing calculator is used in an iterative process. The glass performance is increased until the aggregate air conditioning energy value is 100% of the allowable quantity. The glazing calculator is presented in Appendix G and the compliant glass properties detailed in Table 3.10.

Table 3.10: BCA2010 Compliant Glazing for 295 Ann Street, Brisbane

Aspect	Heat Transfer Coefficient (U-Value)	Shading Coefficient (SHGC)
North-West	3.4	0.48
North-East	3.4	0.4
South-West	3.4	0.69
South-East	3.4	0.61

3.2.3 System and Plant Level

Section JV3, d, (ii) of the BCA2010 requires that the proposed building and the reference building be modelled with the same air conditioning system configuration and zones. As a result, for this project a reference building was modelled for the following system configurations:

- Mixing box with central air handling plant.
- Variable air volume with central air handling plant.
- Variable air volume with floor air handling plant.
- Active chilled beams with central air handling plant.
- Active chilled beams with floor air handling plant.

As described in Section 2.4.3, trigeneration is an energy production plant rather than an air conditioning system. The trigeneration alternatives modelled as part of this research project are in combination with the air conditioning systems listed above. For this reason a separate reference building was not required to be modelled for the trigeneration alternatives as the reference buildings detailed above will be suitable.

The system and plant level differences between the existing model and the reference building models can be seen in Table 3.11 below.

Table 3.11: BCA2010 Reference Building Plant Performance

	Existing Building Value	Reference Building Value
Airside System Economiser	None	Outdoor air economy cycle
Boiler Efficiency	83%	80%
Chiller Coefficient of Performance (COP)	5.2 & 3	4.2

It can be seen in Table 3.11, that the existing building has chillers with better energy efficiency than that required by the reference building. The existing buildings chillers have a coefficient of performance (COP) of 5.2 & 3 in comparison to the reference building with a COP of 4.2.

3.3 Modelling the Proposed Upgrades

After modelling the existing building and the Building Code of Australia reference buildings the proposed upgrades were modelled. The below subsections describes the modelling of the proposed upgrades.

3.3.1 Variable Air Volume

The first system modelled was a variable air volume system. A schematic of a variable air volume system from the TRACE 700 software is presented in Figure 3.2.

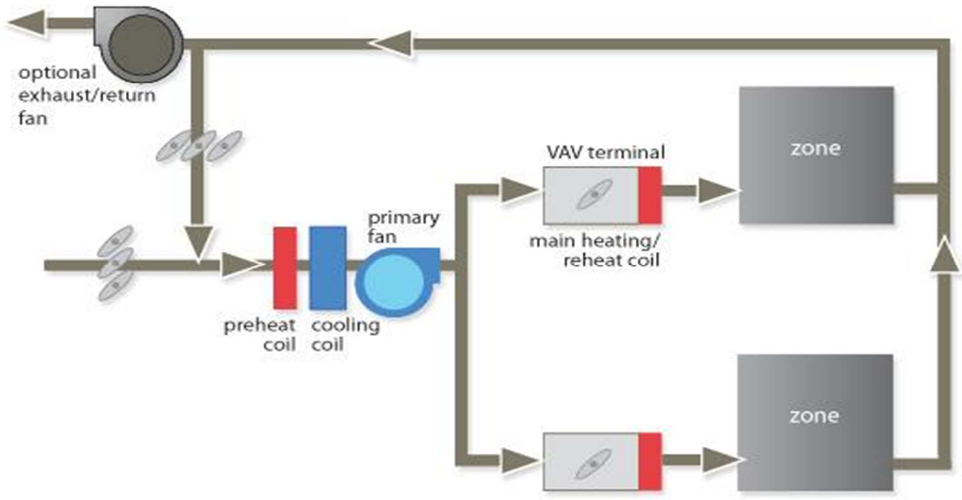

Figure 3.2: Variable Air Volume System Schematic

For a high rise application such as 295 Ann Street, a variable air volume system can be configured in two ways. The first configuration is central air handling plant. An air handling plant is made up of the primary fan, cooling coil and heating coil. The air handling plant shall be located in a centralised plant room and serve the same zones over a number of floors.

The second configuration is floor air handling plant. This configuration involves an air handling unit being located on each floor with one air handling unit serving the entire floor. The supply air fan on each floor shall provide supply air to the 18 variable air volume boxes on the respective floor. Both of these configurations have been modelled as part of this assessment and are detailed in the sub sections below.

3.3.1.1 Central Air Handling

Variable air volume combined with central air handling plant was the first variable air volume configuration modelled. Similar to the existing system, the system shall consist of eight central air handling units. Four central air handling units shall be located in the Level 16 plant room and be dedicated to the north-east, south-east, south-west and north-west zones on levels 8 to 15 inclusive. The remaining four central air handling units shall be located in the lower ground plant room and serve the north-east, south-east, south-west and north-west zones on levels ground to 7 inclusive.

In order to model this upgrade alternative the rooms and plants created in the existing building model were copied for continuity between the files. Eight variable air volume systems were then created under the systems tab as per Table 3.12.

Table 3.12: Fan Performance – Variable Air Volume Combined With Central Air Handling

System Description	Fan	Fan Type	Static Pressure Drop
AHU NW (Level 1-7)	Cooling Supply	Centrifugal, variable speed motor	650 Pa
	Return Air Fan	Axial fan, variable speed motor	395 Pa
AHU NE (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	450 Pa
	Return Air Fan	Axial fan, variable speed motor	315 Pa
AHU SW (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	430 Pa
	Return Air Fan	Axial fan, variable speed motor	320 Pa
AHU SE (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	440 Pa
	Return Air Fan	Axial fan, variable speed motor	300 Pa
AHU NW (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	500 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa
AHU NE (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	510 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa
AHU SW (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	445 Pa
	Return Air Fan	Axial fan, variable speed motor	390 Pa
AHU SE (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	520 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa

The fan static pressure drop used in this system was the same as that used in the existing building. This is assuming duct is sized efficiently and similar duct runs are used for the upgraded system. It can be seen in Table 3.12 that the variable air volume system contains only a cooling supply fan and a return air fan, in comparison to the existing mixing box system which also contains a heating supply fan.

3.3.1.2 Floor Air Handling

In order to model a variable air volume system with floor air handling plant the rooms and plants created in the existing building model were copied for continuity. As there shall be an air handling unit dedicated to each floor, sixteen variable air volume systems were created under the systems tab. Similar to the existing building model fan performances were detailed in the fans sub-tab and are summarised in Table 3.13.

Table 3.13: Fan Performance - Variable Air Volume Combined With Floor Air Handling

System Description	Fan	Fan Type	Static Pressure Drop
AHU Ground	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 1	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 2	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 3	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 4	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 5	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa

AHU Level 6	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 7	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 8	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 9	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 10	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 11	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 12	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 13	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 14	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 15	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa

To approximate the static pressure drop for the floor supply and return air fans it was assumed that the floor level supply and return air ductwork was configured and sized in the same arrangement as the existing ductwork. The supply and return air fan static pressure drop for the central air handling systems were averaged and the approximated riser losses were subtracted. Table 3.14 presents these calculations for both the supply and return air fan.

Table 3.14: Floor Air Handling Supply and Return Air Fan Pressure Drop Calculation

	Supply Air Fan	Return Air Fan
Average Cooling Supply Fan Pressure Drop from the Existing System	493	357
Approximate Riser Pressure Losses	50	50
Approximate Static Pressure Drop for Floor Air Handling Configuration	**448**	**312**

3.3.2 Active Chilled Beams

A schematic of an active chilled beams system from the TRACE 700 software can be seen in the Figure 3.3.

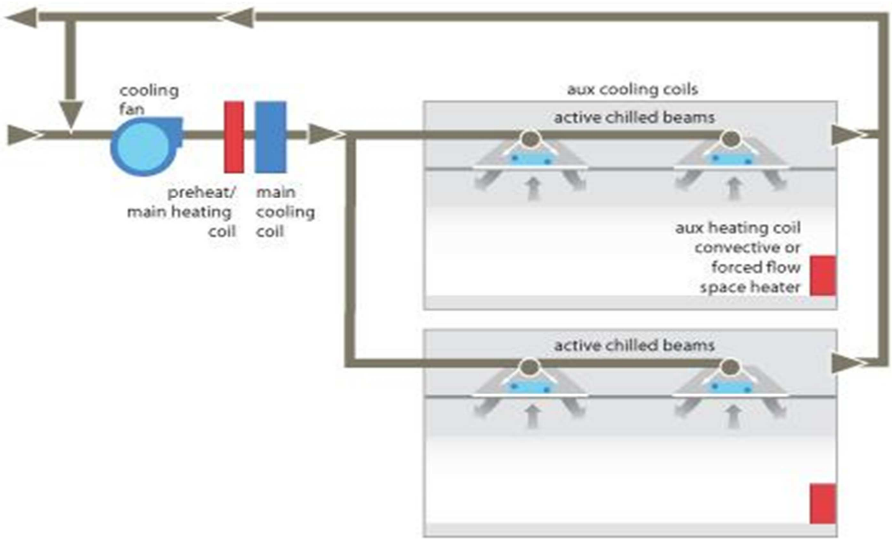

Figure 3.3: Active Chilled Beams System Schematic

Similar to a variable air volume system an active chilled beam system can be configured in two ways, being a central air handling system and a floor air handling system. Both of these configurations were modelled as detailed in the following sub-sections.

3.3.2.1 Central Air Handling

To ensure consistency between the files the rooms and main cooling and heating plants were copied from the existing building model. Eight active chilled beam systems were then created under the systems tab.

Similar to the existing system this upgrade alternative shall consist of eight central air handling plants. Four central air handling units shall be located in the Level 16 plant room and be dedicated to the north-east, south-east, south-west and north-west zones on levels 8 to 15 inclusive. The remaining four central air handling units shall be located in the lower ground plant room and serve the north-east, south-east, south-west and north-west zones on levels ground to 7 inclusive.

The static pressure drop used in this system was the same as that used in the existing building model. This was based on the assumption that the duct sizing and configuration will be the same as the existing. The fan performance details for the active chilled beam system with central air handling plant are presented in Table 3.15.

Table 3.15: Fan Performance - Active Chilled Beams With Central Air Handling Plant

System Description	Fan	Fan Type	Static Pressure Drop
AHU NW (Level 1-7)	Cooling Supply	Centrifugal, variable speed motor	650 Pa
	Return Air Fan	Axial fan, variable speed motor	395 Pa
AHU NE (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	450 Pa
	Return Air Fan	Axial fan, variable speed motor	315 Pa
AHU SW (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	430 Pa
	Return Air Fan	Axial fan, variable speed motor	320 Pa
AHU SE (Levels 1-7)	Cooling Supply	Centrifugal, variable speed motor	440 Pa
	Return Air Fan	Axial fan, variable speed motor	300 Pa
AHU NW (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	500 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa

AHU NE (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	510 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa
AHU SW (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	445 Pa
	Return Air Fan	Axial fan, variable speed motor	390 Pa
AHU SE (Levels 8-15)	Cooling Supply	Centrifugal, variable speed motor	520 Pa
	Return Air Fan	Axial fan, variable speed motor	380 Pa

Similar to the variable air volume system the active chilled beams system contains a cooling supply fan and a return air fan, in comparison to the existing mixing box system which also contains a heating supply fan.

3.3.2.2 Floor Air Handling Plant

To model the floor air handling active chilled beams system the rooms and main cooling and heating plants created in the existing building model were copied and reused to ensure consistency between the models. As there will be an air handling unit dedicated per floor sixteen active chilled beams systems were created under the systems tab. Fan performances were detailed in the fans sub-tab and are summarised in Table 3.16.

Table 3.16: Fan Performance - Active Chilled Beams With Floor Air Handling Plant

System Description	Fan	Fan Type	Static Pressure Drop
AHU Ground	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 1	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 2	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa

AHU Level 3	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 4	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 5	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 6	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 7	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 8	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 9	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 10	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 11	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 12	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 13	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 14	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa
AHU Level 15	Supply Air Fan	Centrifugal, variable speed motor	448 Pa
	Return Air Fan	Centrifugal, variable speed motor	312 Pa

The static pressure drops in Table 3.16 were calculated as detailed within Table 3.14. In order to approximate the static pressure drop for the floor supply and return air fans it was assumed that the floor level supply and return air ductwork was configured in the same arrangement as the existing ductwork. The supply and return air fan static pressure drops for the existing systems were averaged and the approximated riser losses were subtracted.

3.3.3 Trigeneration Combined With Zone Mixing Boxes

Trigeneration combined with zone mixing boxes was the next upgrade alternative to be modelled. Trigeneration forms part of the main plant and as such was modelled in the create plants tab within TRACE 700. As a zone mixing boxes system is used within the existing building, the rooms and systems from the existing building model were copied into this model. This ensures that all differences in energy usage between the alternatives are related to the different systems rather than errors in modelling.

As detailed in Section 2.4.3 of this report trigeneration utilises a gas turbine power generator to simultaneously produce electricity and useful heat. The useful heat can be used for either heating or transformed into cooling energy by an absorption chiller.

Table 3.17 details the equipment within the proposed trigeneration plant. A 500 kW gas fired generator shall produce electricity while also producing useful heat to power water cooled chiller 1, which is a two stage absorption chiller. It can be seen that the absorption chiller has a coefficient of performance (COP) of 1.23 which is much lower than that of the existing water cooled chiller which is 5.2. Although the absorption chiller has a lower energy efficiency it uses waste heat from the gas turbine which would otherwise be wasted.

Table 3.17: Trigeneration Equipment Schedule

COOLING PLANT				
Equipment Description	**Equipment Type**	**Capacity**	**COP**	**Sequencing**
Water Cooled Chiller-1	2 Stage Absorption	500 kW	1.23	Sidecar
Water Cooled Chiller-2	Centrifugal 2 Stage with VSD	2110 kW	5.2	Parallel
Water Cooled Chiller-3	Centrifugal 2 Stage with VSD	1800 kW	5.2	
Water Cooled Chiller-4	Reciprocating	450 kW	3	
Cooling Tower 1	Single Speed Fans	2450 kW	N/A	Parallel
Cooling Tower 2	Single Speed Fans	2450 kW	N/A	
Chilled Water Pump 1	Constant Volume	40 kW	N/A	Single
Chilled Water Pump 2	Constant Volume	40 kW	N/A	Single
Chilled Water Pump 3	Constant Volume	22 kW	N/A	Single
Chilled Water Pump 4	Constant Volume	22 kW	N/A	Single
Condenser Water Pump 1	Constant Volume	20 kW	N/A	Single
Condenser Water Pump 2	Constant Volume	20 kW	N/A	Single
Condenser Water Pump 3	Constant Volume	11 kW	N/A	Single
Condenser Water Pump 4	Constant Volume	11 kW	N/A	Single
GENERATOR PLANT				
Generator -1	Gas Fired	500 kW	N/A	Single
HEATING PLANT				
Boiler 1	Gas Fired	Calculated by TRACE	83.3%	Single
Heating Water Pump	Constant Volume	15 kW	N/A	Single

3.3.4 Trigeneration Combined with Floor Level Variable Air Volume System

Trigeneration combined with a floor level variable air volume system was the next upgrade alternative modelled. The trigeneration component was modelled in the create plants section of the TRACE 700 software while the variable air volume component was modelled in the create system section.

In order to model this system, the rooms were copied from the existing building model previously created. Furthermore the floor level variable air volume systems and the trigeneration plant were copied from the model detailed in Section 3.3.1.2 & 3.3.3 respectively.

3.3.5 Trigeneration Combined with Floor Level Active Chilled Beam System

The final system modelled was a combination of trigeneration and floor level active chilled beams. To model this system, the rooms were copied from the existing building model previously created. Furthermore the floor level active chilled beams system was copied from the previous model detailed in Section 3.3.2.2.

4. ANALYSIS OF RESULTS

This chapter will discuss and analyse the results of the modelling as detailed in the previous chapters. All energy consumption and greenhouse gas emissions data tabulated in this chapter are based on the mechanical equipment only. For each energy model, the energy associated with the lighting and miscellaneous equipment was subtracted from the total building energy consumption. The difference is the energy used by the mechanical services plant only.

4.1 Actual Usage During Baseline Year

A monthly NABERS tracking report prepared by EP&T in August 2010 details the electrical energy consumed by the buildings mechanical services equipment for a twelve month period between November 2008 and October 2009. The report does not detail the gas consumed by the gas fired boiler for heating purposes. Table 4.1 lists the electrical energy consumed during the baseline year of November 2008 to October 2009. Discussions with building management confirm the building was fully occupied during this period.

Table 4.1: Mechanical Plant Actual Electrical Energy Consumption During Baseline Year

Month, Year	Actual Monthly Electricity Consumption (kWh)
November, 2008	343969
December, 2008	432360
January, 2009	366973
February, 2009	350563
March, 2009	374136
April, 2009	333742
May, 2009	312809
June, 2009	230541

July, 2009	168221
August, 2009	216048
September, 2009	278952
October, 2009	382076
Annual Consumption	**3790390**

4.2 Existing Building Calculated Energy Usage

The first energy analysis undertaken was that of the existing building. Appendix H contains the TRACE 700 output file for this model. The calculated monthly energy usage associated with the mechanical services is summarised in Table 4.2. The total energy usage consists of both electrical energy and gas energy.

Table 4.2: Calculated Energy Consumption for the Existing Mechanical Plant

Month	Calculated Monthly Electricity Consumption (kWh)	Calculated Monthly Gas Consumption (kWh)
November	333204	13732
December	396020	9716
January	427776	4523
February	388048	1685
March	386994	7691
April	307441	27162
May	259710	88294
June	210165	151500
July	202278	184253
August	209937	154253
September	225749	87970
October	289788	44723
Annual	**3637110**	**775502**

The greenhouse gas emissions associated with the electrical and gas energy consumption were calculated using the formulas and emissions factors described in Section 2.2 of this report.

For the month of November the greenhouse gas emissions associated with the electrical energy consumption was calculated as follows:

$$E = EF \times kWh$$

From table 2.1, for Queensland EF=1.02

$$E = 1.02 \times 333204 = 339868 \text{ kg } CO_2\text{-e}$$

Likewise, the greenhouse gas emissions associated with the gas energy consumption for the month of November was calculated as follows:

$$E_{total} = E_{CO2} + E_{CH4} + E_{N20}$$

where,

$E_{CO2} = Q \times EF = 13732 \times .0036 \times 51.2 = 2531.1$ kg CO_2-e
$E_{CH4} = Q \times EF = 13732 \times .0036 \times 0.1 = 4.9$ kg CO_2-e
$E_{N2O} = Q \times EF = 13732 \times .0036 \times 0.03 = 1.5$ kg CO_2-e

Therefore,

$$E_{total} = 2531.1 + 4.9 + 1.5 = 2537.5 \text{ kg } CO_2\text{-e}$$

Table 4.3 details the calculated monthly emissions and the calculated annual emissions associated with the existing buildings mechanical services.

Table 4.3: Calculated Greenhouse Gas Emissions for the Existing Buildings Mechanical Plant.

Month	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Total Calculated Emissions (kg CO_2-e)
November	339868	2538	342406
December	403940	1795	405736
January	436332	836	437167
February	395809	311	396120
March	394734	1421	396155
April	313590	5019	318609
May	264904	16316	281220
June	214368	27995	242364
July	206324	34048	240371
August	214136	28504	242640
September	230264	16256	246520
October	295584	8264	303848
Annual Consumption	**3709852**	**143303**	**3853156**

4.3 Calculated Consumption versus Actual Consumption

In order to verify the results of the energy modelling, the calculated electricity consumption was compared with the actual electricity consumption from the baseline year. The baseline year is from November 2008 to October 2009, as detailed in Table 4.1.

Table 4.4 presents a comparison between the calculated electricity consumption and the actual electricity consumption from the baseline year. It can be seen that the calculated annual electricity consumption is 96% of the actual electricity consumed during the baseline year.

Table 4.4: Calculated Electrical Energy Consumption versus Actual Electrical Energy Consumption

Month	Calculated Monthly Electricity Consumption (kWh)	Actual Monthly Electricity Consumption (kWh)	Calculated Consumption Percentage of the Actual Consumption
November	333204	343969	96.9
December	396020	432360	91.6
January	427776	366973	116.6
February	388048	350563	110.7
March	386994	374136	103.4
April	307441	333742	92.1
May	259710	312809	83.0
June	210165	230541	91.2
July	202278	168221	120.2
August	209937	216048	97.2
September	225749	278952	80.9
October	289788	382076	75.8
Annual Consumption	**3637110**	**3790390**	**96.0**

Figure 4.2 shows a graph of the calculated electricity consumption versus the actual electricity consumption on a month by month basis.

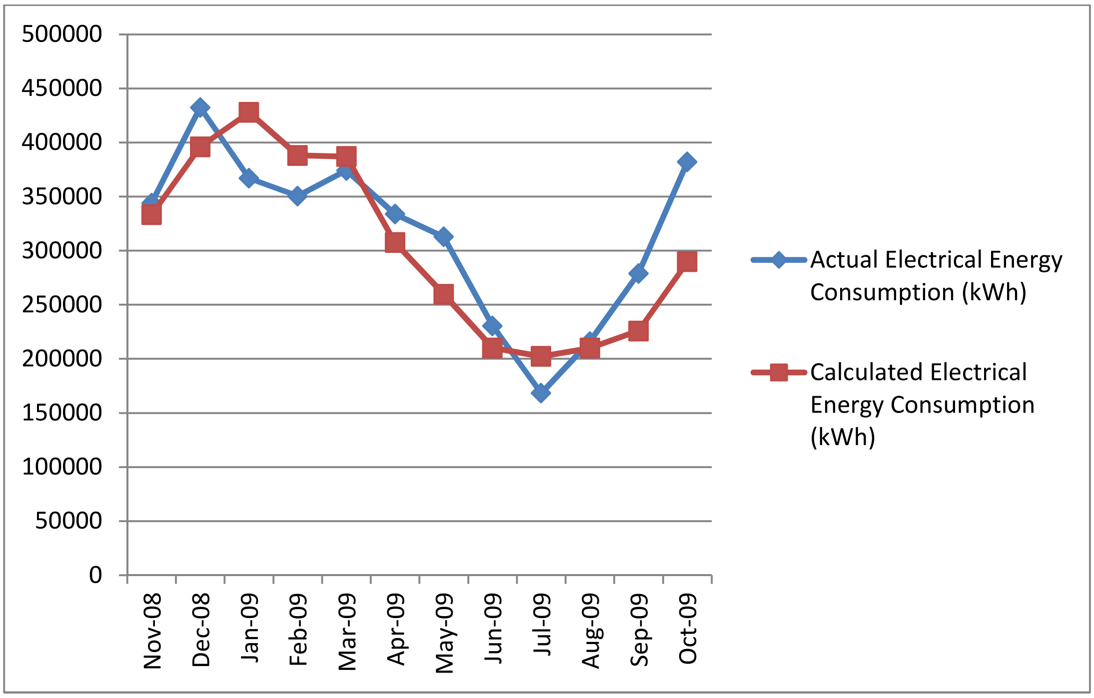

Figure 4.1: Actual Electrical Energy Consumption Versus Calculated Electrical Energy Usage

It can be seen within this graph that the trend of the calculated consumption is similar to that of the actual. The monthly calculated consumption percentage of the actual consumption tabulated in Table 4.4 has been depicted in Figure 4.2.

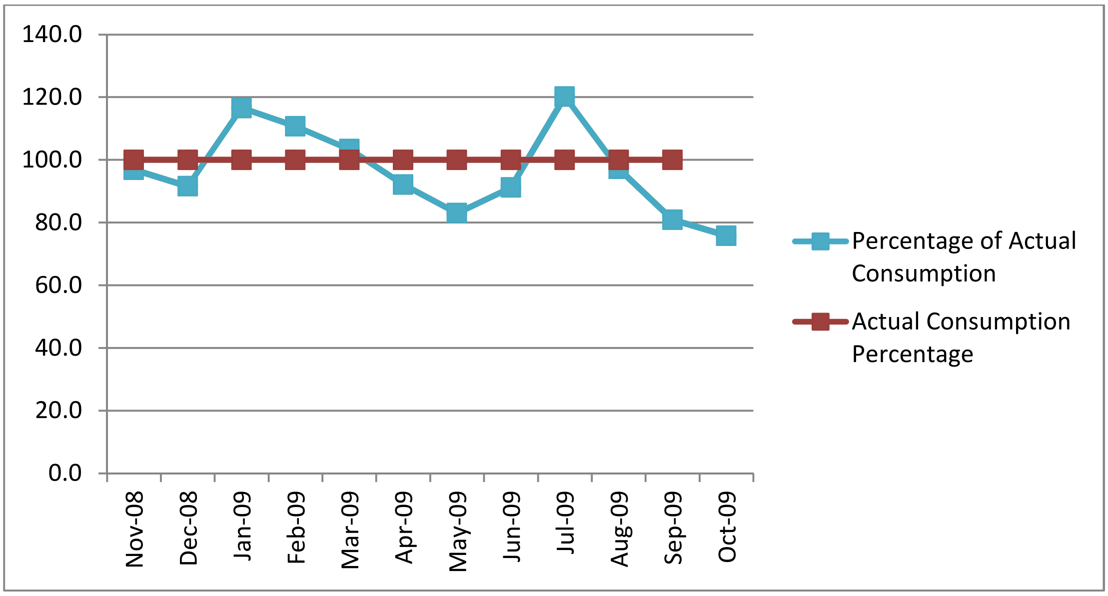

Figure 4.2: Calculated Percentage of Actual Consumption

For all months except October the calculated consumption is within 20% of the actual consumption. In October this increased out to 24%. Differences between the calculated consumption and actual consumption can be a result of the following:

- Ambient air temperatures above or below average for the particular month.
- Occupancy levels above or below the assumed levels.
- Outside air infiltration above or below the assumed levels.
- Activities undertaken within the space.

The comparison between the calculated electrical energy consumption and the actual electrical energy consumption validates the TRACE 700 software and proves the assumptions made during the modelling were accurate. This is due to:

- The calculated annual electricity consumption is 96% of the actual electricity consumed during the baseline year.
- Similar trending between the calculated monthly electricity consumption and the actual electricity consumption during the baseline year.

4.4 Existing Building BCA Compliance

To determine if the existing building and its systems is compliant with Building Code of Australia, the reference building was modelled as detailed in Chapter 3. As the Building Code of Australia requires that the reference building be modelled with the same systems and configuration as the proposed building, the reference building was modelled with zone mixing boxes and central air handling plant. Appendix I contains the TRACE 700 output file for this model.

Table 4.5 details the calculated energy usage and subsequent greenhouse gas emissions associated with the BCA 2010 reference building for a mixing box system with central air handling. Columns 2, 3 & 4 list the monthly electrical, gas and total calculated energy consumptions which are outputs from the TRACE 700 energy model. Using the emissions factors and formulas defined in Section 3.2 the greenhouse gas emissions were calculated and are listed in columns 5, 6 & 7 of Table 4.5.

Table 4.5: BCA 2010 Reference Building Calculated Energy Consumption and Greenhouse Gas Emissions for the Existing Mechanical Services

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	309358	5376	**314734**	315545	993	**316539**
Dec	369536	3834	**373370**	376927	708	**377635**
Jan	402352	1339	**403691**	410399	247	**410646**
Feb	364408	503	**364911**	371696	93	**371789**
March	356456	3261	**359717**	363585	603	**364188**
April	280076	12335	**292411**	285678	2279	**287957**
May	228087	44221	**272308**	232649	8172	**240820**
June	181142	81379	**262521**	184765	15038	**199803**
July	170077	108961	**279038**	173479	20135	**193613**
Aug	176509	83625	**260134**	180039	15453	**195492**
Sep	197552	41218	**238770**	201503	7617	**209120**
Oct	266773	22160	**288933**	272108	4095	**276203**
Annual Usage	3302326	408212	**3710538**	3368373	75433	**3443805**

It can be seen in Table 4.5 that for the existing building to be compliant with the Building Code of Australia 2010, its mechanical services annual emissions has to be less than 3443805 kg CO_2–e. As detailed in Table 4.3 the calculated annual emissions of the existing building is 3853156 kg CO_2–e which is 12% greater than that of the reference building. As a result the existing building in its current configuration is not compliant with the BCA 2010.

Figure 4.3 presents a graph of the existing buildings calculated greenhouse gas emissions versus the reference buildings calculated gas emissions on a month by month basis. It can be seen in the graph that the reference building is consistently more efficient over each month of the year.

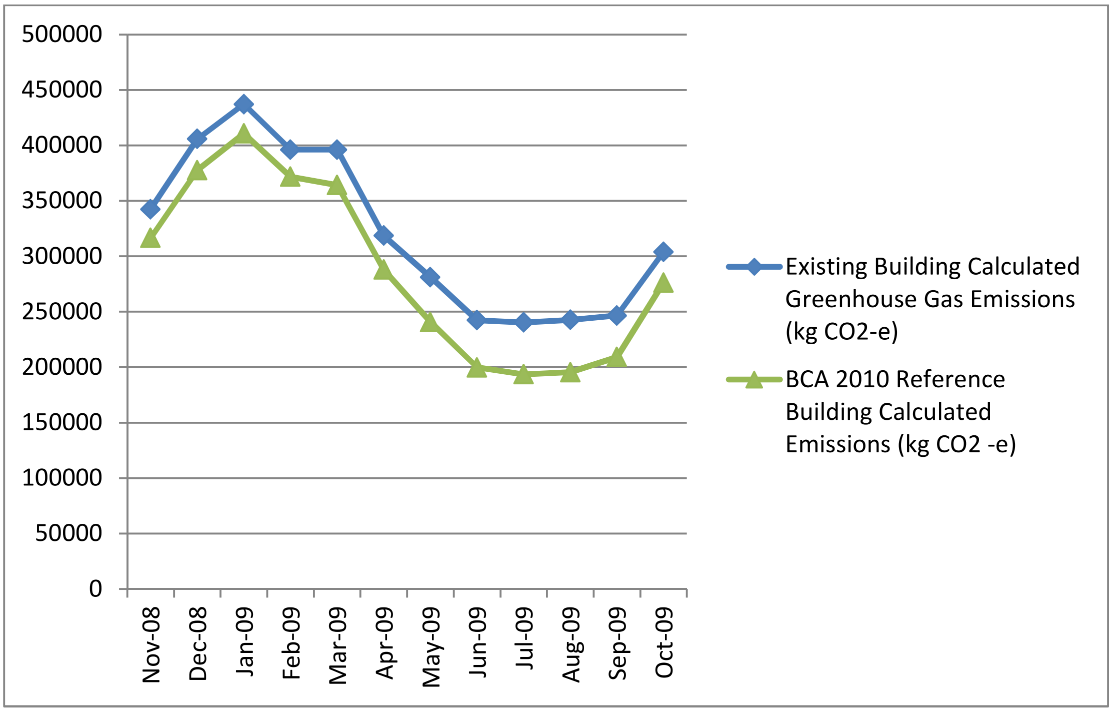

Figure 4.3: Existing Building Calculated Greenhouse Gas Emissions Versus BCA 2010 Reference Building Emissions

4.5 Upgrade Alternatives Energy Usage

4.5.1 Variable Air Volume with Central Air Handling Plant

The first upgrade alternative to be modelled was a variable air volume system with central air handling. The TRACE 700 output file for this system is presented in Appendix J. Similar to the previous model, Table 4.6 presents the calculated energy usage and subsequent greenhouse gas emissions associated with a variable air volume system with central air handling plant.

Table 4.6: Calculated Energy Consumption and Greenhouse Gas Emissions for a Variable Air Volume System with Central Air Handling

Month	Calculated Electricity Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	316818	0	**316818**	323154	0.0	**323154**
Dec	382657	0	**382657**	390310	0.0	**390310**
Jan	417752	0	**417752**	426107	0.0	**426107**
Feb	379378	0	**379378**	386966	0.0	**386966**
March	375742	0	**375742**	383257	0.0	**383257**
April	286314	0	**286314**	292040	0.0	**292040**
May	219897	0	**219897**	224295	0.0	**224295**
June	164780	2	**164782**	168076	0.4	**168076**
July	155936	1140	**157076**	159055	210.7	**159265**
Aug	167239	593	**167832**	170584	109.6	**170693**
Sep	194130	0	**194130**	198013	0.0	**198013**
Oct	262881	0	**262881**	268139	0.0	**268139**
Annual	3323524	1735	**3325259**	3389994	320.6	**3390315**

The calculated annual emissions associated with a variable air volume system with central air handling plant are 3390315 kg CO_2–e. Upgrading the building to this system would result in an annual greenhouse gas emissions savings of 12% compared with the existing buildings calculated emissions.

To determine if this system is compliant with the Building Code of Australia 2010, a reference building was modelled. The reference building was modelled with a variable air volume system and central air handling plant which is the same system and configuration as the proposed upgrade. The TRACE 700 output file for this system is presented in Appendix K. Similar to previous models, the calculated energy consumption and subsequent greenhouse gas emissions are presented in Table 4.7.

Table 4.7: BCA 2010 Reference Building Calculated Energy Consumption and Gas Emissions for a Variable Air Volume System with Central Air Handling

Month	Calculated Electricity Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	297700	0	**297700**	303654	0	**303654**
Dec	358911	0	**358911**	366089	0	**366089**
Jan	393749	0	**393749**	401624	0	**401624**
Feb	358355	0	**358355**	365522	0	**365522**
March	347134	0	**347134**	354077	0	**354077**
April	265038	0	**265038**	270339	0	**270339**
May	201874	0	**210874**	205911	0	**205911**
June	144555	1338	**145893**	147446	247	**147693**
July	135414	468	**135882**	138122	86	**138209**
Aug	146475	0	**146475**	149405	0	**149405**
Sep	177551	0	**177551**	181102	0	**181102**
Oct	249295	0	**249295**	254281	0	**254281**
Annual	3076051	1806	**3077857**	3137572	334	**3137906**

It can be seen in Table 4.7, that the calculated annual emissions of the reference building is 3137906 kg CO_2–e. As detailed in Table 4.6, the calculated annual emissions of the proposed upgrade is 3390315 kg CO_2–e which is 8% greater than that of the reference building. As a result the variable air volume system with central air handling plant is not compliant with the Building Code of Australia.

Figure 4.4 shows a graph which compares the calculated monthly greenhouse gas emissions of the variable air volume system with central air handling plant, the associated reference building and the existing building.

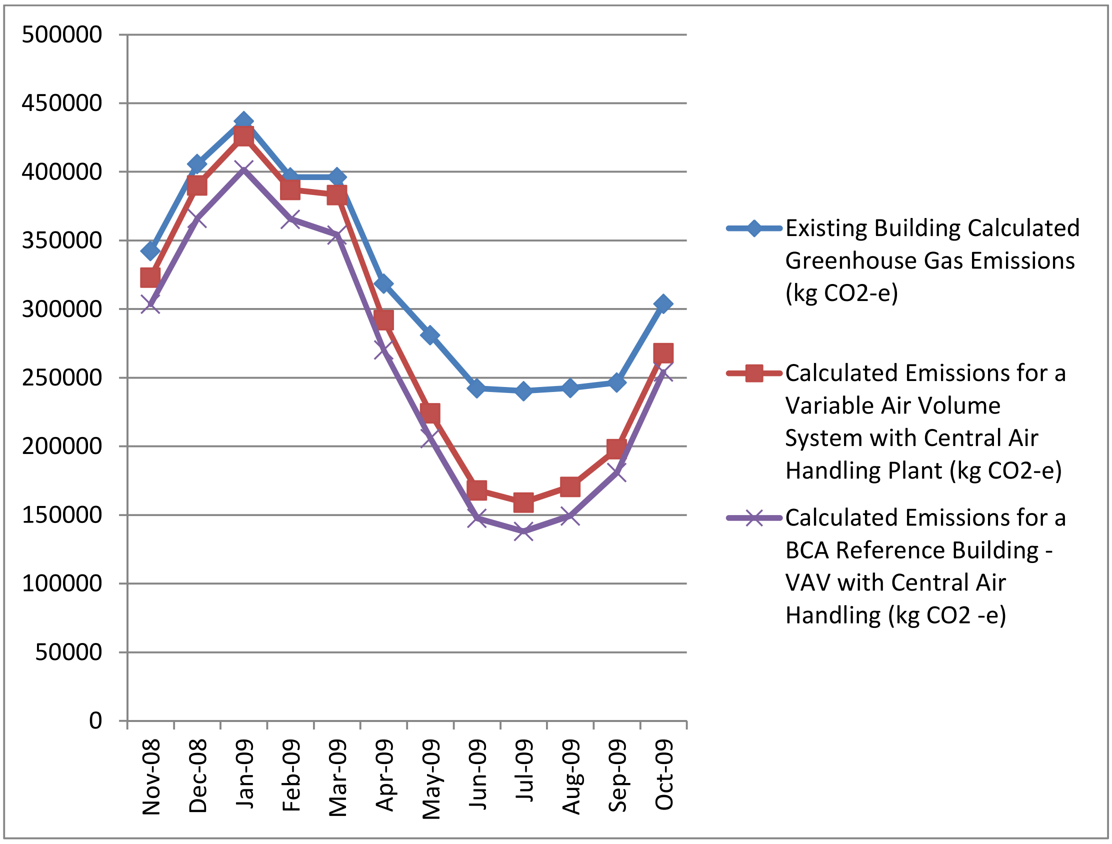

Figure 4.4: Calculated Monthly Emissions of a Variable Air Volume System with Central Air Handling, BCA 2010 Reference Building and Existing Building

It can be seen in Figure 4.4 that the majority of emissions savings associated with the variable air volume system occur in the winter months. As discussed in Section 2.4.1, this is a result of the variable air volume systems ability to provide both fan and refrigeration part load energy savings. When the cooling demand is minimal the variable air volume damper modulates closed which creates an opportunity to reduce the speed of the fan which reduces fan energy. This reduced airflow across the cooling coil reduces the energy demand on the refrigeration system thus saving energy in the main cooling plant (Trane, 2001).

4.5.2 Variable Air Volume System with Floor Air Handling Plant

The next system modelled was a variable air volume system with floor air handling. Appendix L contains the TRACE 700 output file for this alternative. Similar to the previous models, the calculated energy consumption and the associated greenhouse gas emissions are presented in Table 4.8.

Table 4.8: Calculated Energy Consumption and Gas Emissions Associated with a Variable Air Volume System with Floor Air Handling

Month	Calculated Electricity Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kgCO_2-e)
Nov	304976	0	**304976**	311076	0	311076
Dec	367453	0	**367453**	374802	0	374802
Jan	401650	0	**401650**	409683	0	409683
Feb	366316	0	**366316**	373642	0	373642
March	359853	0	**359853**	367050	0	367050
April	273143	0	**273143**	278606	0	278606
May	208317	0	**208317**	212483	0	212483
June	158620	139	**158759**	161792	26	161818
July	148226	844	**149070**	151191	156	151346
Aug	158704	362	**159066**	161878	67	161945
Sep	184968	0	**184968**	188667	0	188667
Oct	252015	0	**252015**	257055	0	257055
Annual	**3184241**	**1345**	**3185586**	**3247926**	**249**	**3248174**

The calculated greenhouse gas emissions associated with a variable air volume system with floor air handling plant is 3248174 kg CO_2–e. This is a savings of approximately 15.7% compared to the calculated emissions of the existing building.

Similar to previous models, Table 4.9 displays the calculated energy consumption and greenhouse gas emissions of the associated reference building. The reference building was modelled with a variable air volume system and floor air handling plant. The TRACE 700 output file for this system is presented in Appendix M.

Table 4.9: BCA 2010 Reference Building Calculated Energy Consumption and Gas Emissions for a Variable Air Volume System with Floor Air Handling

Month	Calculated Electricity Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	289887	0	**289887**	295685	0	**295685**
Dec	349873	0	**349873**	356870	0	**356870**
Jan	384196	0	**384196**	391880	0	**391880**
Feb	349275	0	**349275**	356261	0	**356261**
March	337572	0	**337572**	344323	0	**344323**
April	257060	0	**257060**	262201	0	**262201**
May	195205	0	**195205**	199109	0	**199109**
June	140897	0	**140897**	143715	0	**143715**
July	131445	42	**131487**	134074	8	**134082**
Aug	141234	16	**141250**	144059	3	**144062**
Sep	172311	0	**172311**	175757	0	**175757**
Oct	241886	0	**241886**	246724	0	**246724**
Annual	2990841	58	**2990899**	3050658	11	**3050669**

The calculated annual emissions associated with the reference building for this upgrade alternative is 3050669 kg CO_2-e. As detailed in Table 4.8 the calculated emissions associated with a variable air volume system with floor air handling plant is 3248174 kg CO_2 -e which is 6.5% greater than that of the reference building. As a result the variable air volume system with floor air handling plant is not compliant with the Building Code of Australia 2010.

Figure 4.5 shows a graph comparing the calculated monthly emissions of the variable air volume system with floor air handling plant, the associated reference building and the existing building.

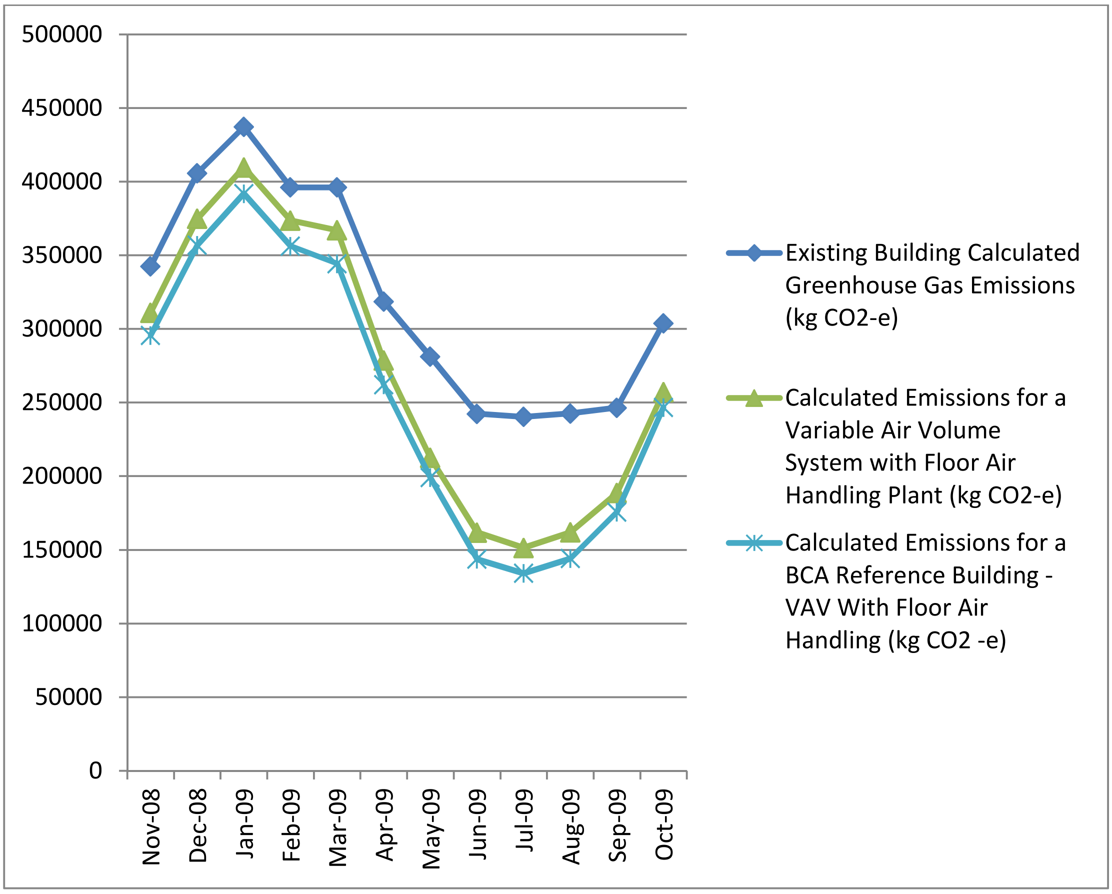

Figure 4.5: Calculated Monthly Emissions of a Variable Air Volume System With Floor Air Handling, BCA 2010 Reference Building and Existing Building

Similar to the variable air volume system with central air handling, the major emissions savings associated with the variable air volume systems occur in the winter months. This is due to the system's ability to provide both fan and refrigeration part load energy savings.

4.5.3 Active Chilled Beams with Central Air Handling Plant

Active chilled beams with central air handling plant was the next system modelled to determine the energy usage and subsequent greenhouse gas emissions. The TRACE 700 output file for this system is shown in Appendix N. As per the previous models, Table 4.10 details the calculated energy usage and subsequent gas emissions associated with an active chilled beams system with central air handling plant.

Table 4.10: Calculated Energy Consumption and Greenhouse Gas Emissions for Active Chilled Beams with Central Air Handling

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	320877	5178	**326055**	327295	957	**328251**
Dec	374969	3126	**378095**	382468	578	**383046**
Jan	400176	696	**400872**	408180	129	**408308**
Feb	363082	156	**363238**	370344	29	**370372**
March	366853	2410	**369263**	374190	445	**374635**
April	301312	15832	**317144**	307338	2926	**310264**
May	248897	19082	**267979**	253875	3526	**257401**
June	207561	24629	**232190**	211712	4551	**216263**
July	204681	46696	**251377**	208775	8629	**217403**
Aug	209280	29934	**239214**	213466	5531	**218997**
Sep	223455	2426	**225881**	227924	448	**228372**
Oct	279230	22987	**302217**	284815	4248	**289062**
Annual	3500373	173152	**3673525**	3570380	31996	**3602377**

The calculated annual greenhouse gas emissions associated with an active chilled beams system with central air handling plant is 3602377 kg CO_2-e. This results in a savings of approximately 6.5% compared to the calculated emissions of the existing building.

Table 4.11 displays the calculated energy consumption and greenhouse gas emissions of the associated reference building. The reference building was modelled with an active chilled beams system with central air handling plant which is the same system and configuration as the proposed. The TRACE 700 output file for this system is presented in Appendix O.

Table 4.11: BCA2010 Reference Building Calculated Energy Consumption and Gas Emissions for Active Chilled Beams with Central Air Handling

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	314140	3329	**317469**	320423	615	**321038**
Dec	367588	2654	**370242**	374940	490	**375430**
Jan	392012	1060	**393072**	399852	196	**400048**
Feb	352491	184	**352675**	359541	34	**359575**
March	356775	1898	**358673**	363911	351	**364261**
April	288768	11782	**300550**	294543	2177	**296721**
May	229145	3083	**232228**	233728	570	**234298**
June	183659	4790	**188449**	187332	885	**188217**
July	178904	18340	**197244**	182482	3389	**185871**
Aug	185190	9082	**194272**	188894	1678	**190572**
Sep	205528	0	**205528**	209639	0	**209639**
Oct	261460	12746	**274206**	266689	2355	**269045**
Annual	3315660	68948	**3384608**	3381973	12741	**3394714**

The calculated annual emissions associated with the reference building is 3394714 kg CO_2-e. As detailed in Table 4.10 the calculated emissions associated with the active chilled beams system with central air handling plant is 3602377 kg CO_2-e which is 6.1% greater than that of the reference building. As a result the active chilled beams system with central air handling is not compliant with the Building Code of Australia 2010.

Similar to previously, Figure 4.6 shows a graph which compares the calculated monthly emissions of the active chilled beams system with central air handling plant, the associated reference building and the existing building.

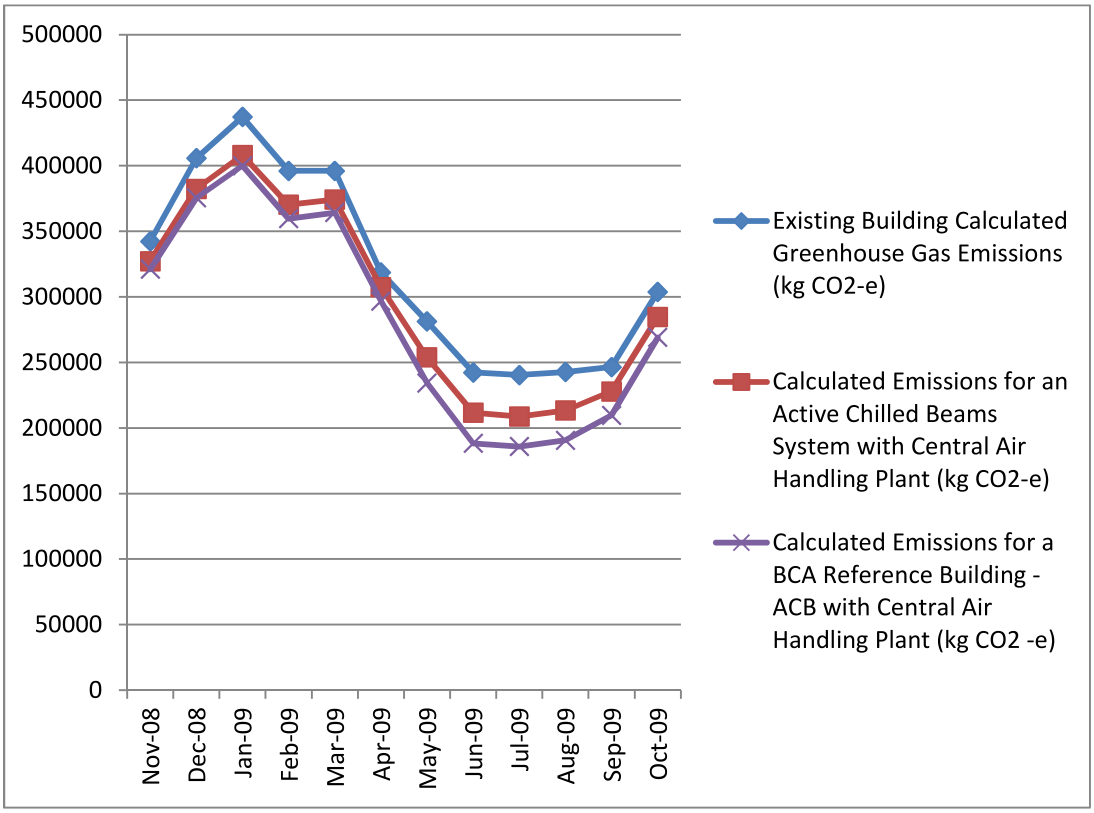

Figure 4.6: Calculated Monthly Emissions of an Active Chilled Beams System with Central Air Handling, BCA 2010 Reference Building and Existing Building.

From this graph it can be seen that the majority of the savings between the existing building and proposed upgrade occur in the middle of the summer and winter periods. In the summer months significant savings can be seen in the months of January and

February, while the winter months the major savings can be seen in June, July and August. In comparison the month of April has the lowest savings for this alternative.

4.5.4 Active Chilled Beams with Floor Air Handling Plant

An active chilled beams system with floor air handling plant was modelled as an upgrade alternative. The TRACE 700 output file for this system is shown in Appendix P. Similar to previous models, Table 4.12 details the calculated energy usage and greenhouse gas emissions associated with an active chilled beams system with floor air handling.

Table 4.12: Calculated Energy Consumption and Greenhouse Gas Emissions for Active Chilled Beams with Floor Air Handling Plant

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	312349	5650	**317999**	318596	1044	**319640**
Dec	366810	3475	**370285**	374146	642	**374788**
Jan	391278	994	**392272**	399104	184	**399287**
Feb	354809	202	**355011**	361905	37	**361943**
March	357701	2692	**360393**	364855	497	**365352**
April	291971	16107	**308078**	297810	2976	**300787**
May	239634	19202	**258836**	244427	3548	**247975**
June	198750	25496	**224246**	202725	4711	**207436**
July	195631	48346	**243977**	199544	8934	**208477**
Aug	200179	30930	**231109**	204183	5715	**209898**
Sep	214569	2595	**217164**	218860	480	**219340**
Oct	270298	23525	**293823**	275704	4347	**280051**
Annual	3393979	179214	**3573193**	3461859	33117	**3494975**

It can be seen in the table that the calculated annual emissions associated with this plant is 3494975 kg CO_2-e. This is a 9.3% savings compared to the existing system.

Table 4.13 displays the calculated energy consumption and greenhouse gas emissions of the associated reference building which was modelled with active chilled beams and floor air handling plant. Appendix Q contains the TRACE 700 output files for this system.

Table 4.13: BCA2010 Reference Building Calculated Energy Consumption and Gas Emissions for Active Chilled Beams with Floor Air Handling

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	307821	3809	**311630**	313977	704	**314681**
Dec	361181	2743	**363924**	368405	507	**368911**
Jan	384490	1211	**385701**	392180	224	**392404**
Feb	346208	138	**346346**	353132	26	**353158**
March	349879	1935	**351814**	356877	358	**357234**
April	281550	11633	**293183**	287181	2150	**289331**
May	221891	3080	**224971**	226329	569	**226898**
June	176722	4916	**181638**	180256	908	**181165**
July	171764	18740	**190504**	175199	3463	**178662**
Aug	178017	9262	**187279**	181577	1712	**183289**
Sep	198492	0	**198492**	202462	0	**202462**
Oct	254147	13033	**267180**	259230	2408	**261638**
Annual	3232162	70500	**3302662**	3296805	13028	**3309833**

The calculated greenhouse gas emissions associated with the reference building is 3309833 kg CO_2-e. The calculated emissions associated with the active chilled beams system with floor air handling plant is 3494975 kg CO_2-e which is 5.6% greater than that of the reference building. As the upgrade alternative emits more greenhouse gases than the reference building the system is not compliant with the Building Code of Australia 2010.

Figure 4.7 below shows a graph which compares the calculated monthly emissions of the active chilled beams system with floor air handling, the reference building and the existing building.

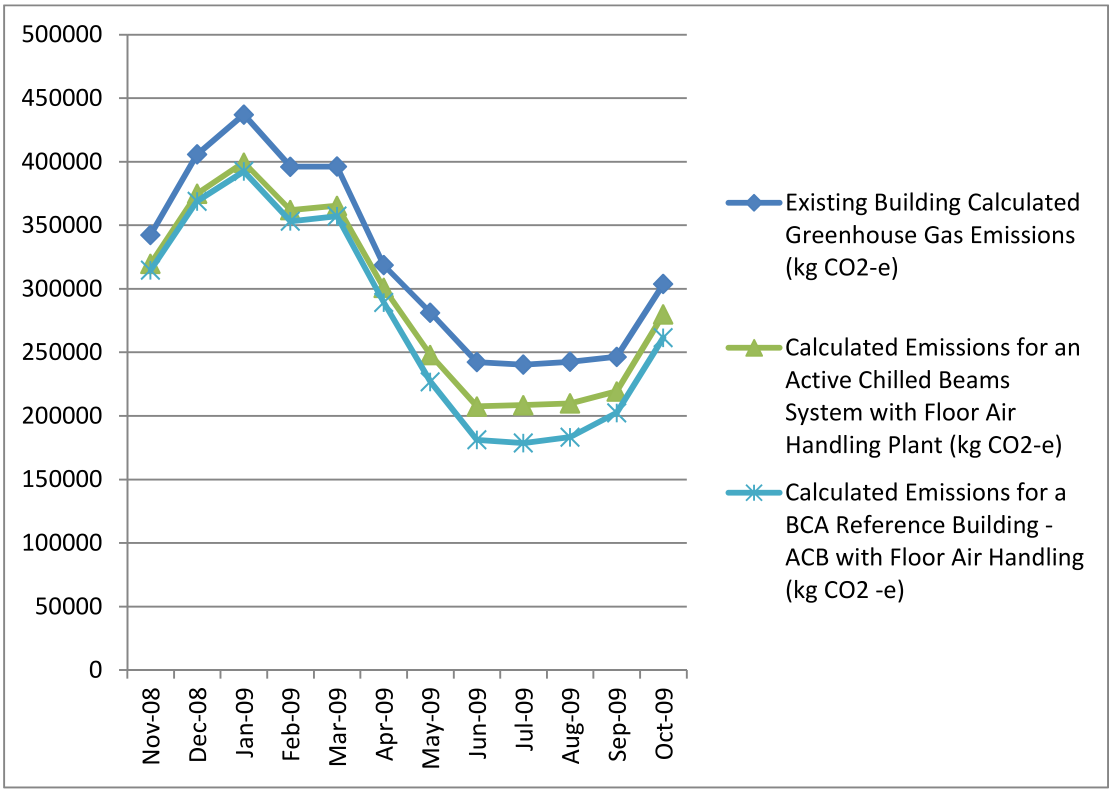

Figure 4.7: Calculated Monthly Emissions of an Active Chilled Beams System with Floor Air Handling, BCA 2010 Reference Building and Existing Building.

Similar to the previous active chilled beams system, the majority of emissions savings between the existing building and proposed upgrade occurs in the middle of the summer and winter periods. In the summer months significant savings can be seen in the months of January and February while the winter months the major savings can be seen in June, July and August. In comparison the month of April results in the lowest savings for this alternative.

4.5.5 Trigeneration Combined With Mixing Boxes

Trigeneration combined with mixing boxes and central air handling was the next upgrade to be modelled. The TRACE 700 output file for this system is shown in Appendix R. Similar to the previous models, the energy usage and gas emissions of the system are detailed in Table 4.14.

Table 4.14: Calculated Energy Consumption and Greenhouse Gas Emissions for Trigeneration Combined with Mixing Boxes

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	-43824	1247837	**1204013**	-44700	230585	**185885**
Dec	-6740	1284958	**1278218**	-6875	237445	**230570**
Jan	17255	1279765	**1297020**	17600	236485	**254085**
Feb	18399	1153517	**1171916**	18767	213156	**231923**
March	-14087	1282933	**1268846**	-14369	237071	**222702**
April	-63579	1261267	**1197688**	-64851	233067	**168216**
May	-110193	1363536	**1253343**	-112397	251965	**139568**
June	-143617	1385605	**1241988**	-146489	256043	**109554**
July	-186934	1459495	**1272561**	-190673	269697	**79024**
Aug	-172250	1429495	**1257245**	-175695	264154	**88459**
Sep	-126099	1322075	**1195976**	-128621	244304	**115683**
Oct	-86696	1319965	**1233269**	-88430	243914	**155484**
Annual	-918365	15790448	**14872083**	-936732	2917885	**1981153**

It can be seen that the calculated annual emissions associated with this plant is 1981153 kg CO_2-e, which results in a savings of 48.6% compared to the existing building.

As described in Section 3.2.3 of this report a separate reference building was not required to be modelled for this alternative. As trigeneration is an energy production plant it is combined with an air conditioning system previously modelled. For this reason the reference building modelled with mixing boxes and central air handling is suitable.

As per Table 4.5, the annual greenhouse gas emissions of the reference building modelled with zone mixing boxes and central air handling plant is 3443805 kg CO_2-e. The proposed system emissions are 42.5% less than the reference building emissions and as a result trigeneration combined with zone mixing boxes and central air handling plant is compliant with the Building Code of Australia. Figure 4.8 below is a graph which compares the calculated monthly emissions of the trigeneration system combined with mixing boxes and central air handling, the associated reference building and the existing building.

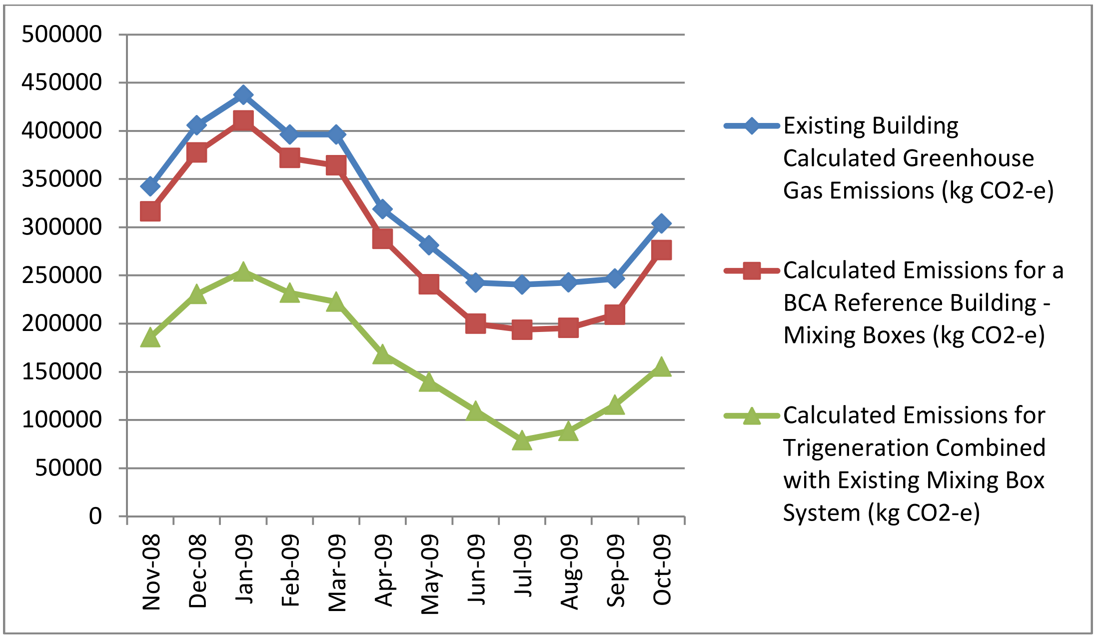

Figure 4.8: Calculated Monthly Emissions of Trigeneration Combined with Mixing Boxes and Central Air Handling, BCA 2010 Reference Building and Existing Building

The graph within Figure 4.8 highlights that this upgrade is significantly more efficient than the existing mechanical system.

4.5.6 Trigeneration Combined With Variable Air Volume Boxes and Floor Air Handling Plant

Trigeneration combined with variable air volume boxes and floor air handling plant was the next upgrade to be modelled. Appendix S contains the output file for this system. Similar to the previous models the calculated energy usage and greenhouse gas emissions associated with a trigeneration system combined with mixing boxes and floor air handling plant is detailed in Table 4.15.

Table 4.15: Calculated Energy Consumption and Greenhouse Gas Emissions for Trigeneration Combined with Variable Air Volume and Floor Air Handling

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	-71423	1234105	**1162682**	-72851	228048	**155196**
Dec	-35430	1275242	**1239812**	-36139	235649	**199511**
Jan	-8869	1275242	**1266373**	-9046	235649	**226603**
Feb	-3517	1151831	**1148314**	-3587	212845	**209257**
March	-41351	1275242	**1233891**	-42178	235649	**193471**
April	-95577	1234105	**1138528**	-97489	228048	**130559**
May	-179575	1275242	**1095667**	-183167	235649	**52483**
June	-233236	1234244	**1001008**	-237901	228073	**-9827**
July	-259538	1276086	**1016548**	-264729	235805	**-28923**
Aug	-250053	1275603	**1025550**	-255054	235716	**-19338**
Sep	-205200	1234105	**1028905**	-209304	228048	**18744**
Oct	-131137	1275242	**1144105**	-133760	235649	**101890**
Annual	-1514906	15016289	**13501383**	-1545204	2774830	**1229626**

The calculated annual emissions associated with a Trigeneration system combined with variable air volume boxes and floor air handling plant is 1229626 kg CO_2-e. This is a 68% savings compared to the existing system.

As described in Section 3.2.3 a separate reference building was not required to be modelled for this alternative. As trigeneration is an energy production plant it is combined with an air conditioning system previously modelled. For this reason the reference building modelled with a variable air volume system and floor air handling plant is suitable.

As detailed in Table 4.9, the annual greenhouse gas emissions of the reference building modelled with variable air volume boxes and floor air handling plant is 3050669 kg CO_2-e. The calculated emissions of the proposed system are 59.7% less than the reference building emissions and as a result trigeneration combined with variable air volume boxes and floor air handling plant is compliant with the Building Code of Australia.

Figure 4.9 below shows a graph which compares the calculated monthly emissions of the trigeneration system combined with variable air volume boxes and floor air handling plant, the associated reference building and the existing building.

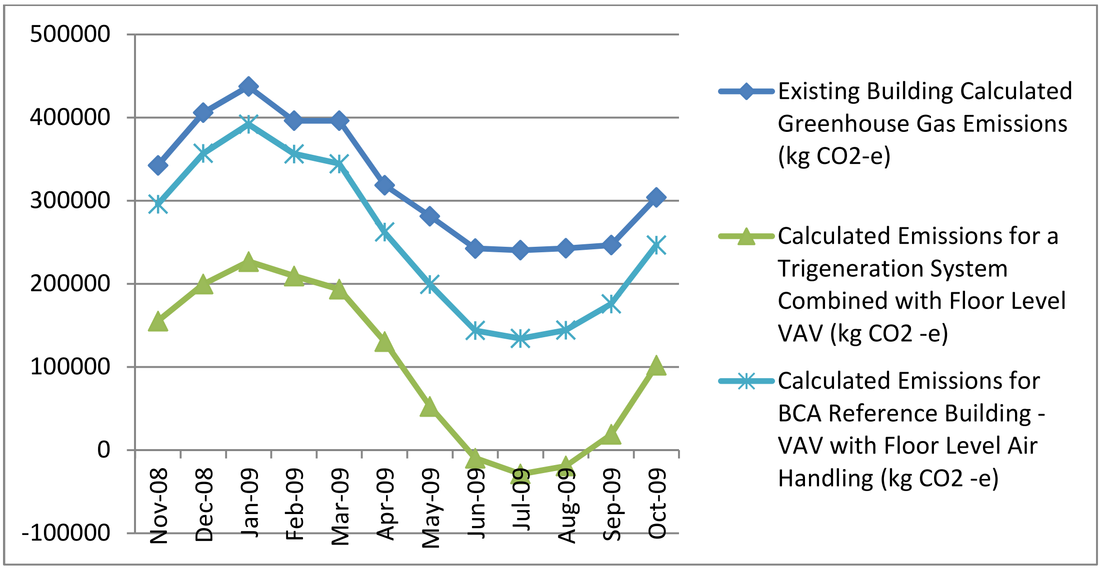

Figure 4.9: Calculated Monthly Emissions for Trigeneration Combined with Variable Air Volume Boxes and Floor Air Handling, BCA 2010 Reference Building and Existing Building.

It can be seen in Figure 4.9 that for the months of June, July & August the proposed system uses negative emissions. As the trigeneration system contains a gas fired turbine to create energy on site any remaining energy not consumed by the mechanical plant can be used for other services within the building such as lighting or if not required returned to the grid. The gas fired turbine reduces the building dependants on mains electricity which has high emissions factors in comparison to energy produced from the gas fired turbine. The savings in emissions between the two energy sources results in the negative gas emissions seen in Figure 4.9.

4.5.7 Trigeneration Combined With Active Chilled Beams and Floor Air Handling

The final system modelled was trigeneration combined with active chilled beams and floor air handling. The TRACE 700 output file for this system is shown in Appendix T. Table 4.16 details the calculated energy usage and greenhouse gas emissions associated with a trigeneration system combined with active chilled beams and floor air handling plant.

Table 4.16: Calculated Energy Consumption and Greenhouse Gas Emissions for Trigeneration Combined with Active Chilled Beams and Floor Air Handling

Month	Calculated Electrical Energy Usage (kWh)	Calculated Gas Energy Usage (kWh)	Calculated Total Energy Usage (kWh)	Calculated Electricity Consumption Emissions (kg CO_2-e)	Calculated Gas Consumption Emissions (kg CO_2-e)	Calculated Total Emissions (kg CO_2-e)
Nov	-62224	1239755	**1177531**	-63468	229092	**165623**
Dec	-33704	1278717	**1245013**	-34378	236292	**201913**
Jan	-17159	1276236	**1259077**	-17502	235833	**218331**
Feb	-15448	1152034	**1136586**	-15757	212882	**197125**
March	-41326	1277933	**1236607**	-42153	236147	**193994**
April	-78152	1250214	**1172062**	-79715	231025	**151310**
May	-137614	1294444	**1156830**	-140366	239198	**98831**

June	-193013	1259601	**1066588**	-196873	232759	**35886**
July	-214652	1323587	**1108935**	-218945	244583	**25638**
Aug	-205221	1306172	**1100951**	-209325	241365	**32039**
Sep	-165040	1236700	**1071660**	-168341	228527	**60187**
Oct	-101719	1298766	**1197047**	-103753	239996	**136243**
Annual	-1265272	15194159	**13928887**	-1290577	2807698	**1517121**

The calculated annual emissions associated with a Trigeneration system combined with active chilled beams and floor air handling plant is 1517121 kg CO_2-e. This is a 60.6% savings compared to the existing systems.

Similar to the previous trigeneration systems a separate reference building was not required to be modelled for this alternative. The reference building previously modelled with active chilled beams and floor air handling plant is suitable for this alternative.

As detailed in Table 4.13 the annual greenhouse gas emissions of the reference building modelled with active chilled beams and floor air handling plant is 3309833 kg CO_2-e. The proposed system emissions are 54% less than the reference building emissions, and as a result trigeneration combined with active chilled beams and floor air handling plant is compliant with the Building Code of Australia. Figure 4.10 below contains a graph which compares the monthly emissions of the trigeneration system combined with active chilled beams and floor air handling plant, the reference building and the existing building.

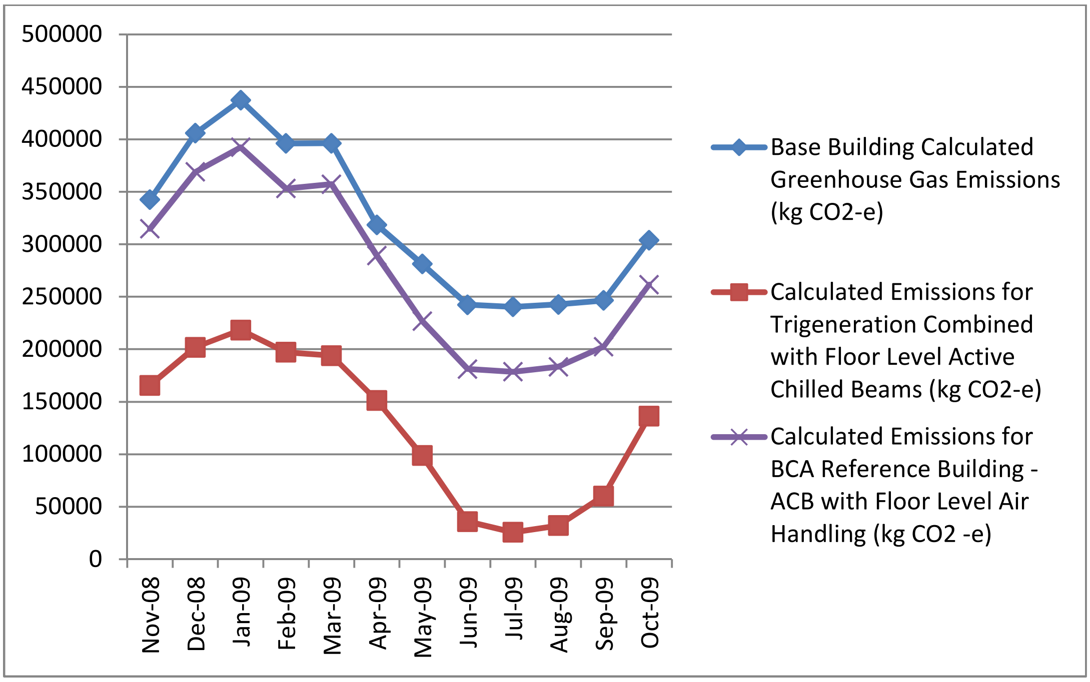

Figure 4.10: Calculated Monthly Emissions of Trigeneration Combined with Active Chilled Beams and Floor Air Handling Plant, BCA 2010 Reference Building and Existing Building.

The graph highlights that the trigeneration system combined with active chilled beams is significantly more efficient than the existing system over every month of the year.

4.6 Building Code of Australia Compliance

As discussed in Section 2.5 of this report, the Building Code of Australia 2010 requires that the annual energy consumption of the proposed building is not more than the annual energy consumption of the reference building. As the objective of this research project is to reduce greenhouse gas emissions, the annual greenhouse gas emissions of the proposed building were compared with that of the reference building. Table 4.17 details the Building Code of Australia compliance if annual energy consumption was compared instead of annual greenhouse gas emissions.

Table 4.17: BCA2010 Compliance Based on the Calculated Annual Energy Consumption

Upgrade Alternative	Calculated Energy Usage (kWh)	Reference Building Calculated Energy Usage (kWh)	Building Code of Australia 2010 Compliance
Existing Building	4412612	3710538	No
VAV - Central Air Handling	3325259	3077857	No
VAV - Floor Air Handling	3185586	2990899	No
Active Chilled Beams - Central Air Handling	3673525	3384608	No
Active Chilled Beams - Floor Air Handling	3573193	3302662	No
Trigeneration Combined with Mixing Boxes	148720083	3710538	No
Trigeneration Combined with VAV and Floor Air Handling	13501383	2990899	No
Trigeneration Combined with Active Chilled Beams and Floor Air Handling	13928887	3302662	No

It can be seen in Table 4.17 that when the annual energy consumption is used to determine compliance with the Building Code of Australia none of the upgrades triggered compliance. When the annual greenhouse gas emissions were used to determine compliance with the Building Code of Australia, the three trigeneration upgrades were compliant.

The trigeneration system utilises a gas turbine to power the site. As discussed in Section 2.2.1 the emissions factors for the consumption of natural gas distributed in a pipeline is approximately 0.185 kg CO_2-e/kWh while the emissions factor for the consumption of electrical energy from the electrical grid in Queensland is 1.02 kg CO_2-e/kWh. These emissions factors suggest gas energy is a cleaner energy source than electricity from the grid in Queensland. Although this is the case, for this application a gas turbine is used to create electricity for the site. For a gas turbine the electrical energy output is less than the gas energy input which suggests the gas turbine consumes more gas energy than the electrical energy it produces.

This explains why the trigeneration systems are compliant with the Building Code of Australia when based on the annual greenhouse gas emissions and not when based on the annual energy consumption. As the gas turbine consumes more gas energy than the electrical energy it produces the annual energy consumption of the proposed upgrade was greater than that of the associated reference building. As the consumption of gas is much cleaner than consumption of electricity from the grid the greenhouse gas emissions of the trigeneration systems were lower than their associated reference building even though they consumed more energy.

4.7 Active Chilled Beams versus Variable Air Volume

Figure 4.11 below shows a comparative graph of the two chilled beams systems versus the two variable air volume systems for each month of the year.

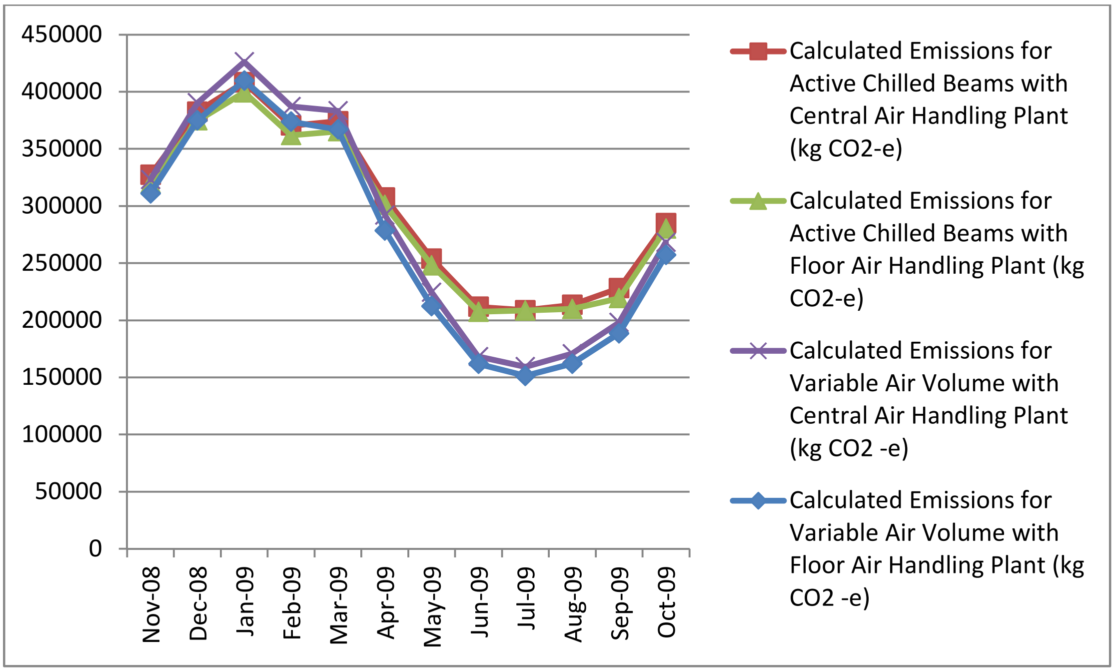

Figure 4.11: Calculated Monthly Emissions Comparison Between the Variable Air Volume Systems and Chilled Beams Systems

As discussed in Section 2.4.2 of this report, a study of the energy performance of active chilled beams and variable air volume for a building in Sydney found similar energy performances for the two buildings (Roth, Dieckmann, Zogg, Brodrick, 2007). During the summer months, the chilled beams system consumed less energy than the VAV system but during the winter months consumed more because of the reduced quantity of supply air precluded the use of an air side economizer (Roth, Dieckmann, Zogg, Brodrick, 2007).

This has proven correct for the analysis undertaken at 295 Ann Street Brisbane. It can be seen in Figure 4.11 that for the summer months the variable air volume systems have slightly greater greenhouse gas emissions. In the winter months the variable air volume systems have a considerably more efficient performance in terms of gas emissions.

4.8 Floor Air Handling Plant Compared to Central Air Handling Plant

For both the active chilled beams system and the variable air volume system floor air handling proved to be slightly more efficient than central air handling over all months of the year. Figure 4.12 below shows the calculated monthly greenhouse gas emissions of the variable air volume alternatives. The annual greenhouse gas emissions of the floor air handling plant is 4.2% less than the emissions of the central air handling. As seen in Figure 4.12, the savings between the central air handling and floor air handling were consistent over each month of the year.

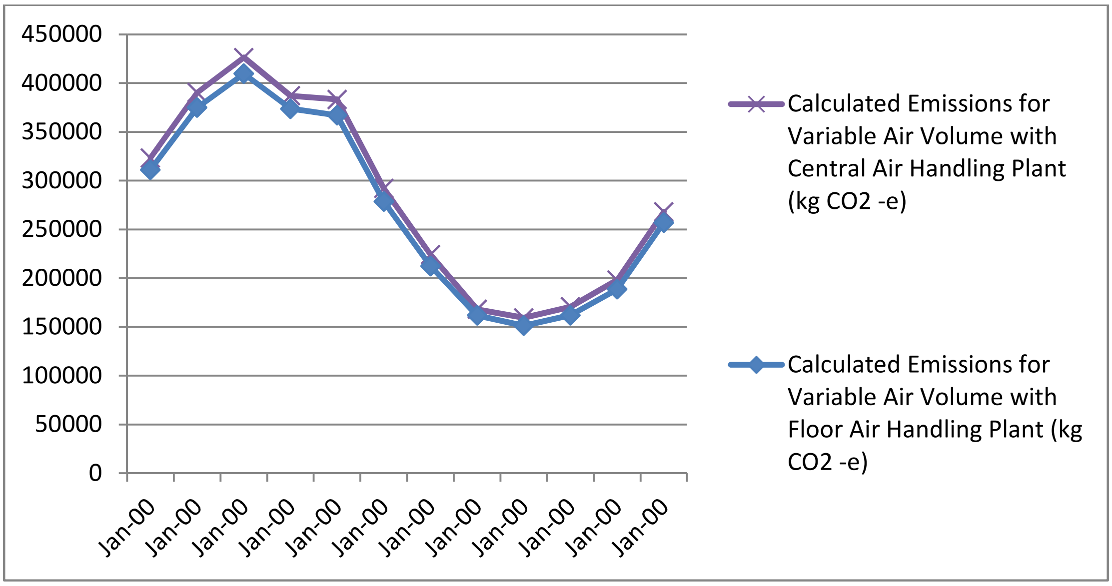

Figure 4.12: Calculated Monthly Emissions Comparison Between the VAV Alternatives

In relation to the active chilled beams systems, Figure 4.13 compares the calculated monthly greenhouse gas emissions of the two active chilled beams alternatives. For these systems the annual greenhouse gas emissions of the floor air handling plant was 3% less than the emissions of the central air handling plant and was consistent over each month of the year.

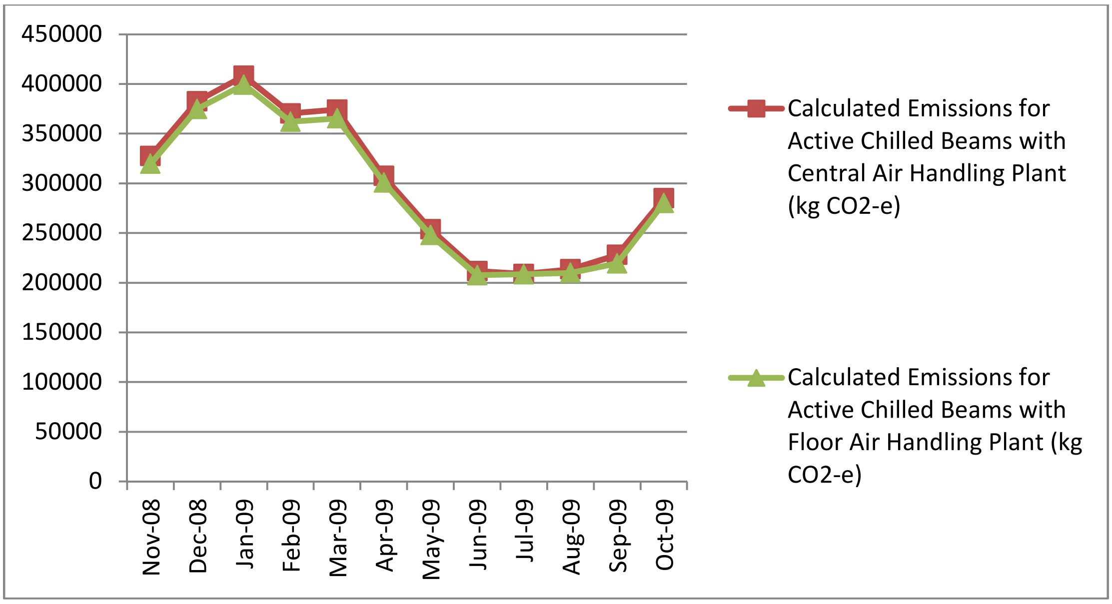

Figure 4.13: Calculated Monthly Emissions Comparison Between the Active Chilled Beams Alternatives

5. CONCLUSION

5.1 Greenhouse Gas Emissions Saving

It was demonstrated that significant greenhouse gas emissions savings can be achieved by upgrading a buildings mechanical services plant. Table 5.1 below summarises the annual greenhouse gas emissions savings associated with each upgrade alternatives as compared to the existing buildings calculated emissions.

Table 5.1: Summary of Upgrade Alternatives Calculated Emissions

Upgrade Alternatives	Calculated Greenhouse Gas Emissions (kg CO_2-e)	Percentage Savings
Zone Mixing Boxes with Central Air Handling Plan	3853156	N/A
Active Chilled Beams with Central Air Handling Plant	3602377	6.5
Active Chilled Beams with Floor Air Handling	3494975	9.3
Variable Air Volume With Central Air Handling Plant	3390315	12
Variable Air Volume with Floor Air Handling	3248174	15.7
Trigeneration Combined with Zone Mixing Boxes and Central Air Handling Plant	1981153	48.6
Trigeneration Combined with Active Chilled Beams and Floor Air Handling	1517121	60.6
Trigeneration Combined with Variable Air Volume and Floor Air Handling	1229626	68

Out of the seven upgrade alternatives, Trigeneration combined with a variable air volume system and floor air handling proved to have the lowest greenhouse gas emissions. This system has a 68% savings in total greenhouse gas emissions, in comparison to the existing building calculated emissions.

Out of the upgrades that aren't combined with trigeneration, variable air volume combined with floor air handling has the lowest greenhouse gas emissions. This system results in a 15.7% saving compared to the existing system. An active chilled beams system with central air handling plant has a 6.5% savings of greenhouse gas emissions which is the lowest of the upgrade alternatives. The results of this work are specific to 295 Ann Street, Brisbane, however, they can be used as guidelines for upgrade projects of other buildings of similar style.

5.2 Building Code of Australia Compliance

To determine compliance with the Building Code of Australia the greenhouse gas emissions associated with the proposed upgrades were compared to that of a reference building. As discussed in Chapter 4, the variable air volume systems and the active chilled beams systems on their own did not comply with the Building Code of Australia. As the reference building is required to be modelled with the same air-conditioning systems and configuration as the reference building, upgrading the air conditioning system alone did not trigger compliance.

When these air conditioning systems were combined with trigeneration the buildings were compliant with the Building Code of Australia. As trigeneration is an energy production plant it is not an air conditioning system and as a result is not required to be modelled within the reference building.

5.3 Buildings of Similar Style and Usage

For a new construction of similar style and usage as 295 Ann Street, Brisbane, it is expected that the building envelope is compliant with the Building Code of Australia. A trigeneration system would not be required as it would not need to offset a poor performing envelope. Based on the results of this research a variable air volume system with floor air handling plant would be suitable as it was the best performing non trigeneration system.

For an existing building of similar style it is assumed that the building envelope is non-compliant with the Building Code of Australia. In this situation a trigeneration system is required to offset the poor performing building envelope.

5.4 Opportunities for Further Studies

Throughout this project a number of opportunities for further studies have been identified. This research project has investigated the most energy efficient upgrade alternative however the cost of each system has not been considered. To determine if the upgrade alternatives are feasible a complete cost analysis is required. The cost analysis should be undertaken to determine the capital cost, operational cost and maintenance cost for each system. These costs can then be compared with the greenhouse gas emissions savings to determine which option will provide the greatest emissions savings per dollar spent. It would be good to perform the experiment and compare the experimental results with the current model predictions.

Another option for further studies is to model the building and the upgrade alternatives in a range of climate zones around Australia. This study can be used to identify how the climate affects greenhouse gas emissions. It can also be used to determine in what parts of Australia does upgrading buildings mechanical services provide the greatest savings in greenhouse gas emissions.

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APPENDIX A - PROJECT SPECIFICATION

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: JOSHUA SEARLE

TOPIC: The efficient use of BUILDING MECHANICAL SERVICES for saving energy.

SUPERVISOR: Dr Sourish Banerjee, Lecturer, USQ

PROJECT AIM: To analyse and compare a range of air conditioning upgrade alternatives to determine which will provide the greatest energy savings for the building.

PROGRAMME: **Issue A, 22 March 2011**

1. Research the background information relating to building energy efficiency.
2. Collect data in relation to the existing air conditioning system at a building located at 295 Ann Street, including reviewing as-installed drawings, Operation & Maintenance Manuals and a physical survey of the site.
3. Model the existing air conditioning system serving 295 Ann Street using Trace 700 Energy Load software.
4. Validate the software predictions by comparing with actual energy data.
5. Explore air conditioning upgrade alternatives suitable for 295 Ann Street Brisbane.
6. Model the air conditioning upgrade alternatives using Trace 700 Energy Load software.
7. Compare the results for each air conditioning system to determine which would provide the greatest energy savings for the building.
8. Submit an academic dissertation on the research.

As time permits:

9. Further analyse the building to determine how the orientation of the building can affect the air conditioning energy load.

AGREED:

_______________(Student) _______________ (Supervisor)

Date: __/__/__ Date: __/__/__

Examiner / Co-examiner: ________________________

APPENDIX B – TRACE 700 COMPLIANCE LETTER

Trane C.D.S.
3600 Pammel Creek Rd
La Crosse, WI 54601 USA
Tel (608)787-3926 Fax (608)787-3005
http://www.tranecds.com

TRANE

September 8, 2010

Subject: TRACE™ 700 v6.2.6 Compliance with ANSI/ASHRAE Standard 140-2007

Dear TRACE User:

We are pleased to inform you that TRACE 700 v6.2.6 was tested in compliance with ANSI/ASHRAE Standard 140–2007, *Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs*. Test results, supplemented by graphs and explanatory notes, accompany this letter.

As you may know, ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings, Except Low-Rise Residential Buildings*, stipulates that any computer program that is used to demonstrate code compliance via the performance path's Energy Cost Budget Method must be tested in accordance with Standard 140. TRACE 700 v6.2.6 has completed the BESTEST validation for calculation and comparison with similar analysis programs as required by ASHRAE Standard 140.

Standard 90.1 defines minimum requirements for the design of energy-efficient buildings and is used by many state and local code-writing bodies as the "standard of care" in their jurisdictions. Building-energy simulation programs, such as TRACE 700, are used to estimate the difference in energy costs between the design- and budget-building models specified in Section 11 of Standard 90.1.

If you have questions about the testing documentation that accompanies this letter, or about any of Trane's design and analysis tools, please contact our C.D.S. Support Center by phoning (608) 787-3926 or e-mailing cdshelp@trane.com.

Best regards,

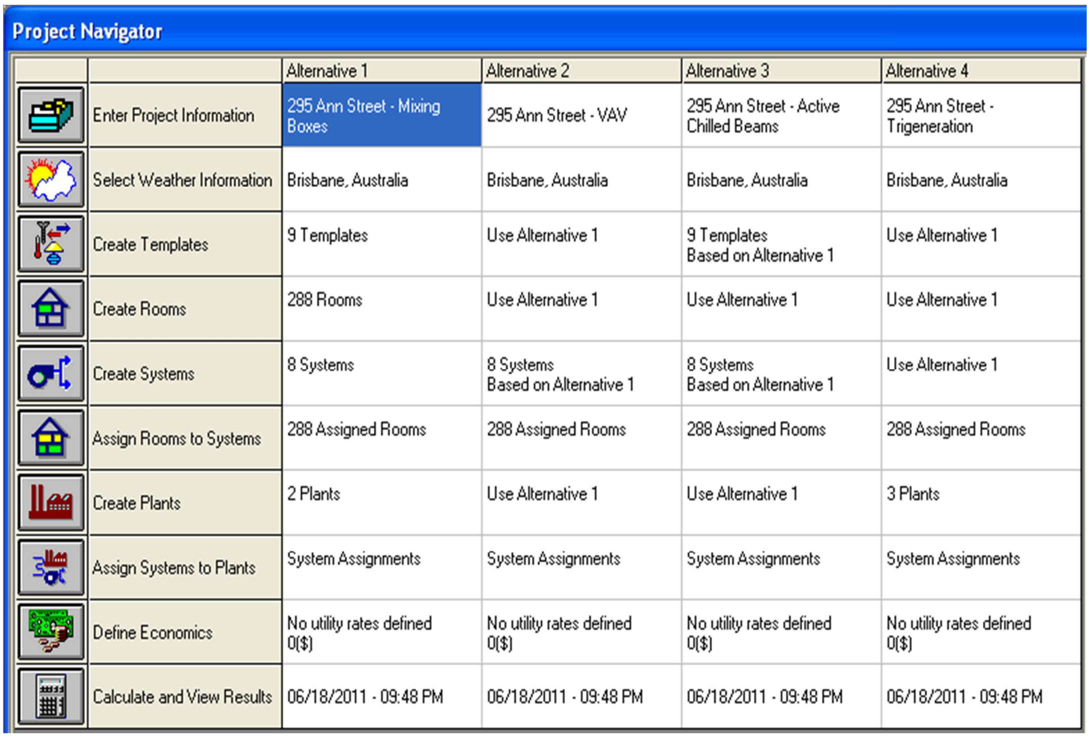
Eric Sturm

Eric Sturm
ASHRAE Standard 140 Coordinator
Trane C.D.S.

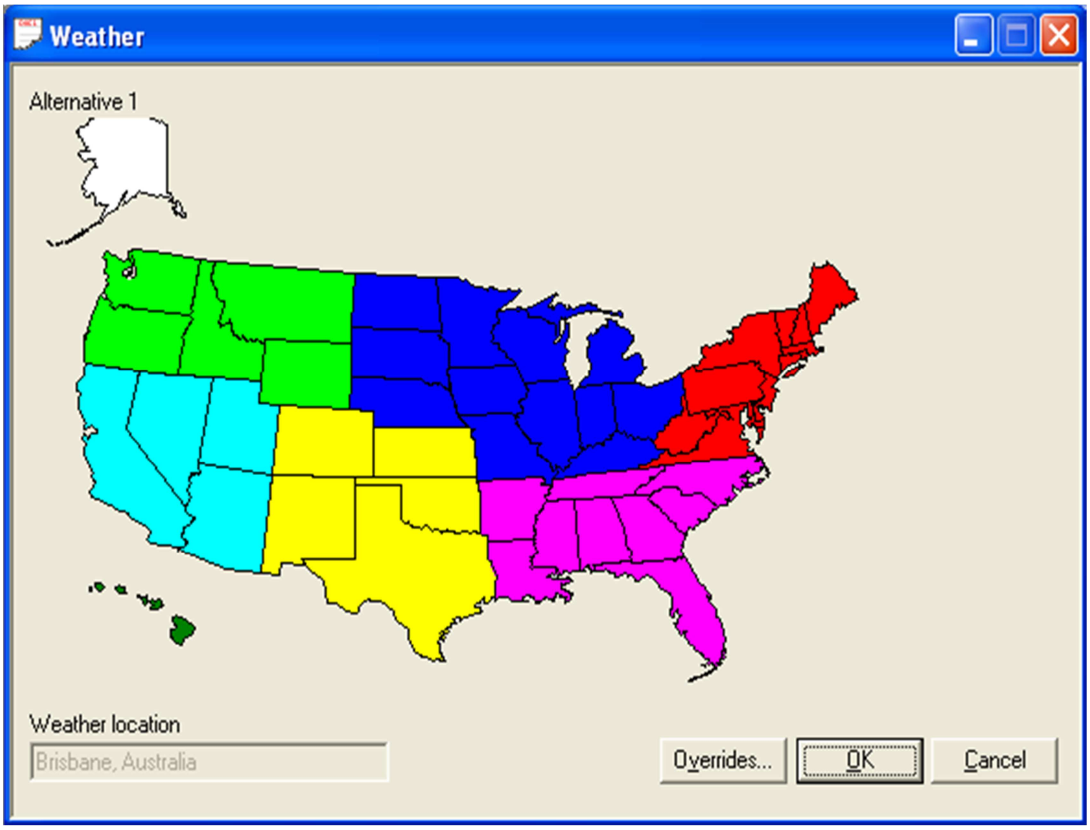
Attachments: Results and modeling notes from Standard 140 testing of TRACE 700

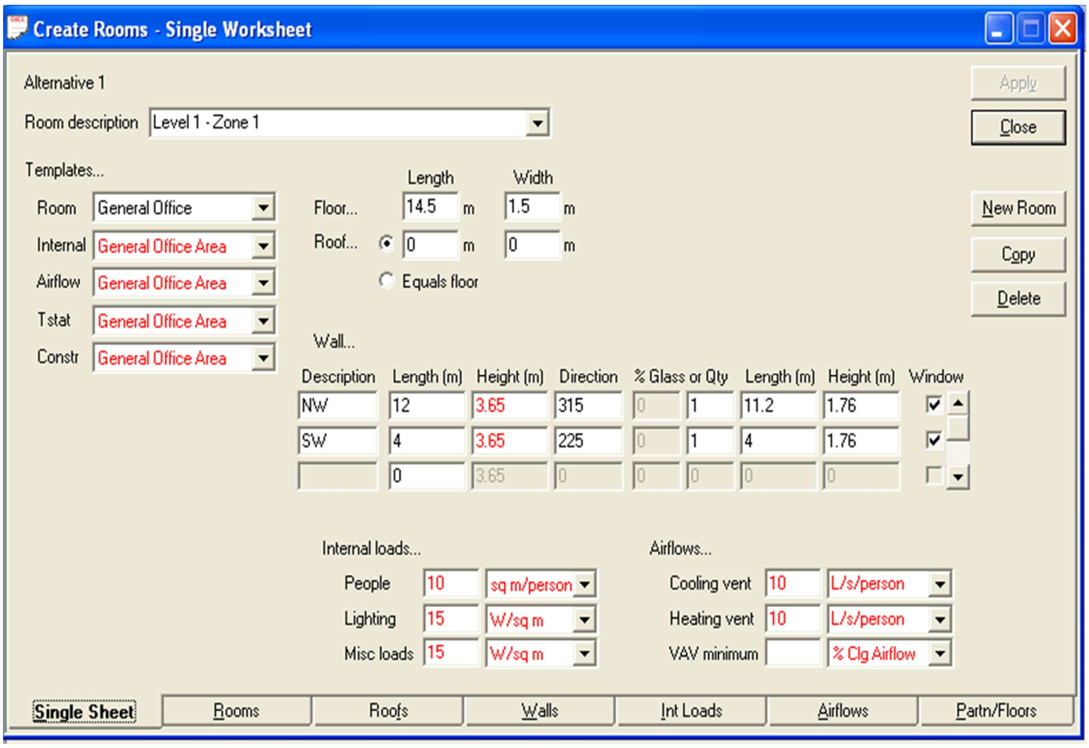
Ingersoll Rand

APPENDIX C –TRACE700 MODELLING SCREEN SHOTS

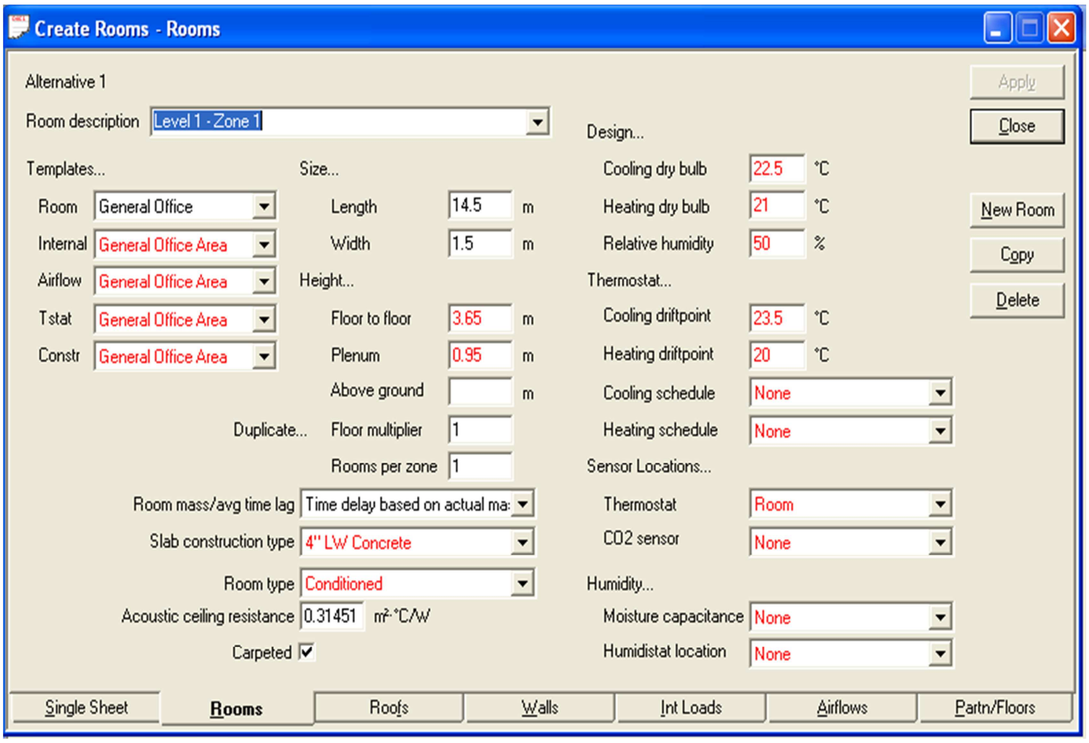

Project Navigator

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Enter Project Information	295 Ann Street - Mixing Boxes	295 Ann Street - VAV	295 Ann Street - Active Chilled Beams	295 Ann Street - Trigeneration
Select Weather Information	Brisbane, Australia	Brisbane, Australia	Brisbane, Australia	Brisbane, Australia
Create Templates	9 Templates	Use Alternative 1	9 Templates Based on Alternative 1	Use Alternative 1
Create Rooms	288 Rooms	Use Alternative 1	Use Alternative 1	Use Alternative 1
Create Systems	8 Systems	8 Systems Based on Alternative 1	8 Systems Based on Alternative 1	Use Alternative 1
Assign Rooms to Systems	288 Assigned Rooms	288 Assigned Rooms	288 Assigned Rooms	288 Assigned Rooms
Create Plants	2 Plants	Use Alternative 1	Use Alternative 1	3 Plants
Assign Systems to Plants	System Assignments	System Assignments	System Assignments	System Assignments
Define Economics	No utility rates defined 0($)	No utility rates defined 0($)	No utility rates defined 0($)	No utility rates defined 0($)
Calculate and View Results	06/18/2011 - 09:48 PM	06/18/2011 - 09:48 PM	06/18/2011 - 09:48 PM	06/18/2011 - 09:48 PM

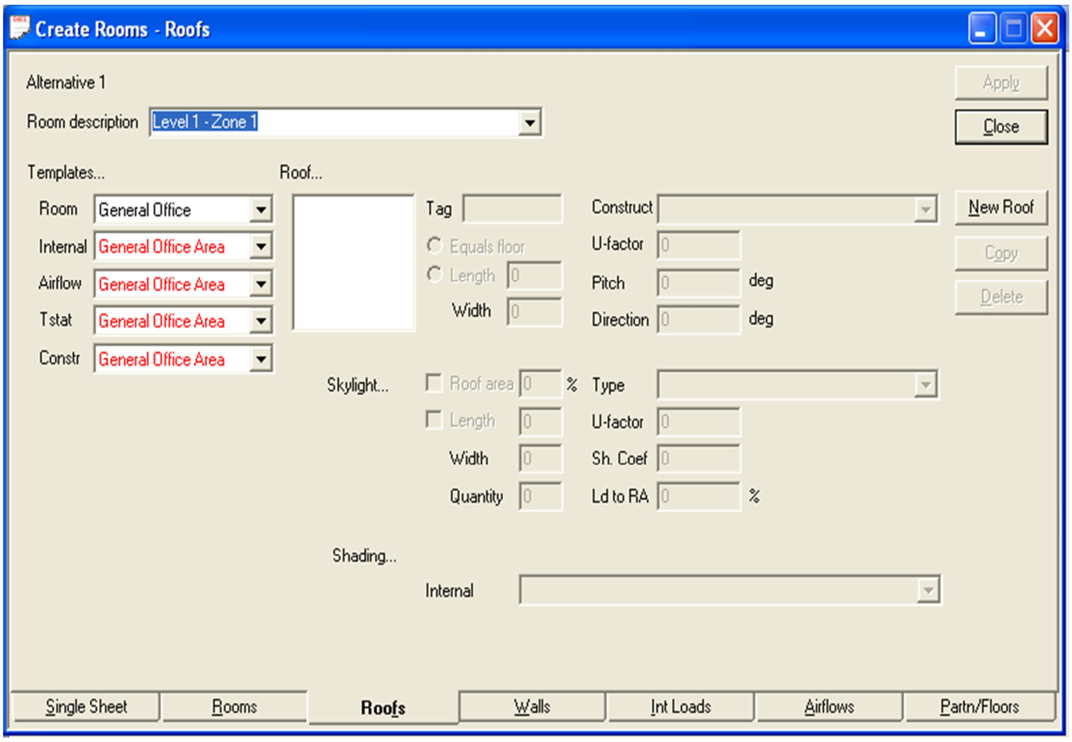


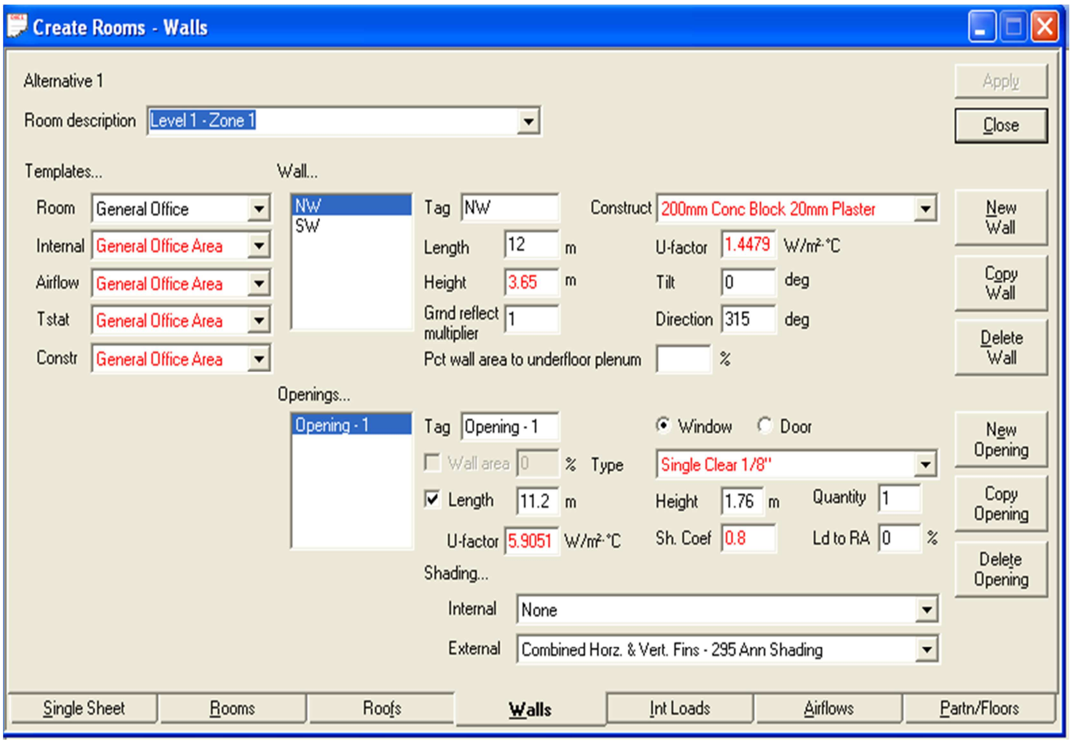


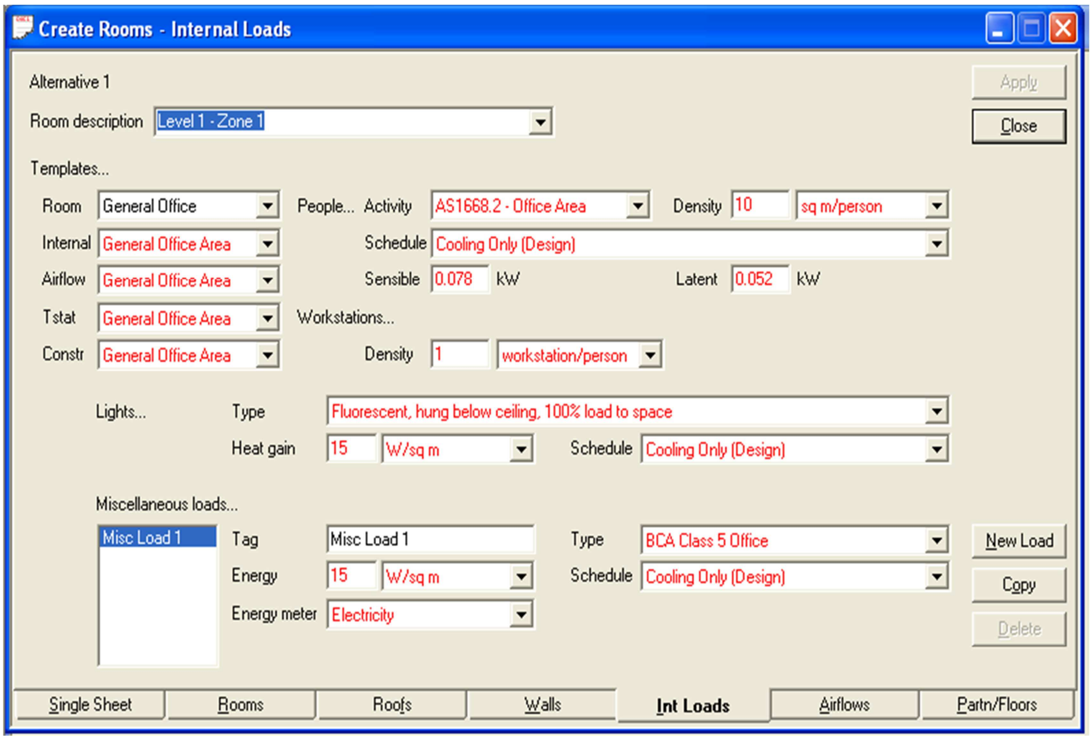
Create Rooms - Single Worksheet
Alternative 1
Room description Level 1 - Zone 1
Apply
Close
Templates...
Room General Office
Internal General Office Area
Airflow General Office Area
Tstat General Office Area
Constr General Office Area
Length
Width
Floor... 14.5 m 1.5 m
Roof... 0 m 0 m
Equals floor
New Room
Copy
Delete
Wall...
Description Length (m) Height (m) Direction % Glass or Qty Length (m) Height (m) Window
NW 12 3.65 315 0 1 11.2 1.76
SW 4 3.65 225 0 1 4 1.76
0 3.65 0 0 0 0 0
Internal loads...
People 10 sq m/person
Lighting 15 W/sq m
Misc loads 15 W/sq m
Airflows...
Cooling vent 10 L/s/person
Heating vent 10 L/s/person
VAV minimum % Clg Airflow
Single Sheet
Rooms
Roofs
Walls
Int Loads
Airflows
Partn/Floors

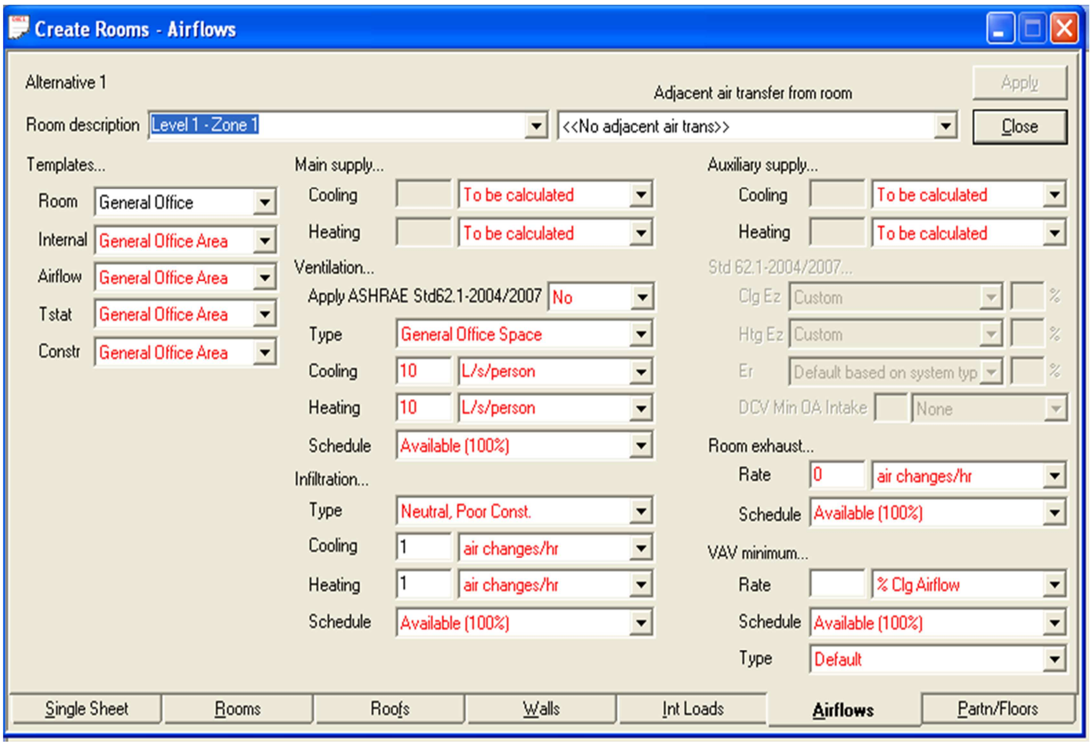


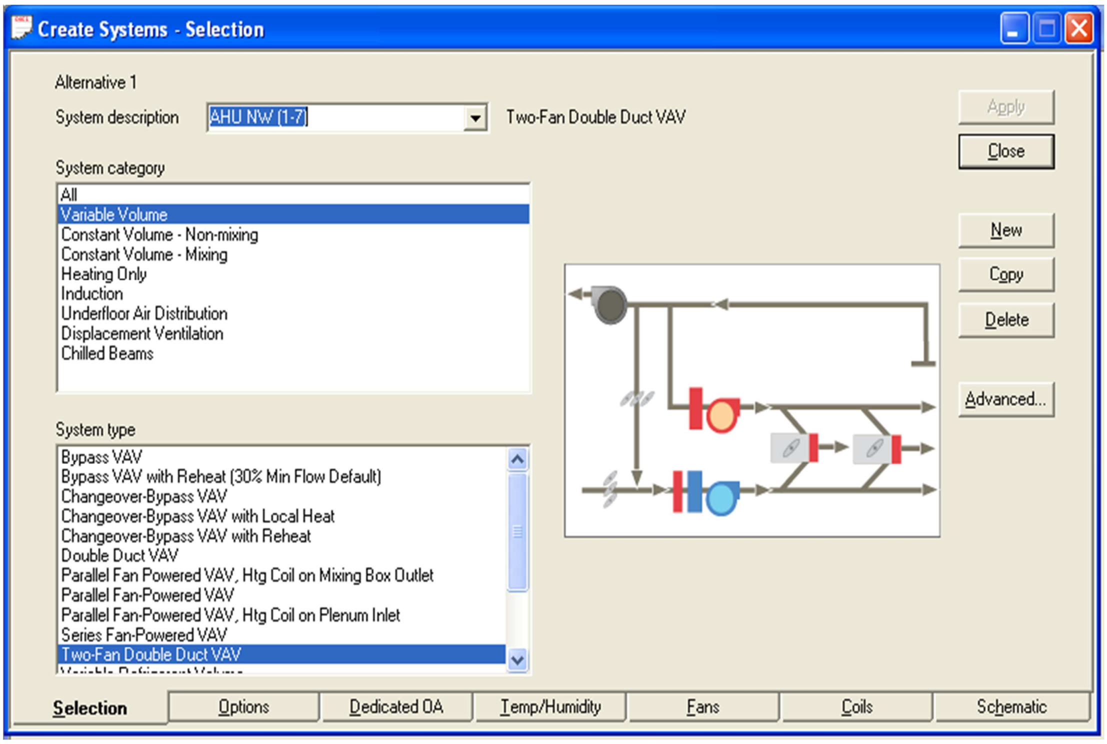
Create Rooms - Rooms
Alternative 1
Room description Level 1 - Zone 1
Apply
Close
Design...
Templates...
Room General Office
Internal General Office Area
Airflow General Office Area
Tstat General Office Area
Constr General Office Area
Size...
Length 14.5 m
Width 1.5 m
Height...
Floor to floor 3.65 m
Plenum 0.95 m
Above ground m
Duplicate...
Floor multiplier 1
Rooms per zone 1
Cooling dry bulb 22.5 °C
Heating dry bulb 21 °C
Relative humidity 50 %
Thermostat...
Cooling driftpoint 23.5 °C
Heating driftpoint 20 °C
Cooling schedule None
Heating schedule None
Sensor Locations...
Thermostat Room
CO2 sensor None
Humidity...
Moisture capacitance None
Humidistat location None
New Room
Copy
Delete
Room mass/avg time lag Time delay based on actual ma
Slab construction type 4" LW Concrete
Room type Conditioned
Acoustic ceiling resistance 0.31451 m²·°C/W
Carpeted
Single Sheet
Rooms
Roofs
Walls
Int Loads
Airflows
Partn/Floors


Create Rooms - Roofs
Alternative 1
Room description
Level 1 - Zone 1
Apply
Close
Templates...
Roof...
Room
General Office
Internal
General Office Area
Airflow
General Office Area
Tstat
General Office Area
Constr
General Office Area
Tag
Equals floor
Length
Width
Construct
U-factor
Pitch
deg
Direction
deg
New Roof
Copy
Delete
Skylight...
Roof area
%
Type
Length
U-factor
Width
Sh. Coef
Quantity
Ld to RA
%
Shading...
Internal
Single Sheet
Rooms
Roofs
Walls
Int Loads
Airflows
Partn/Floors

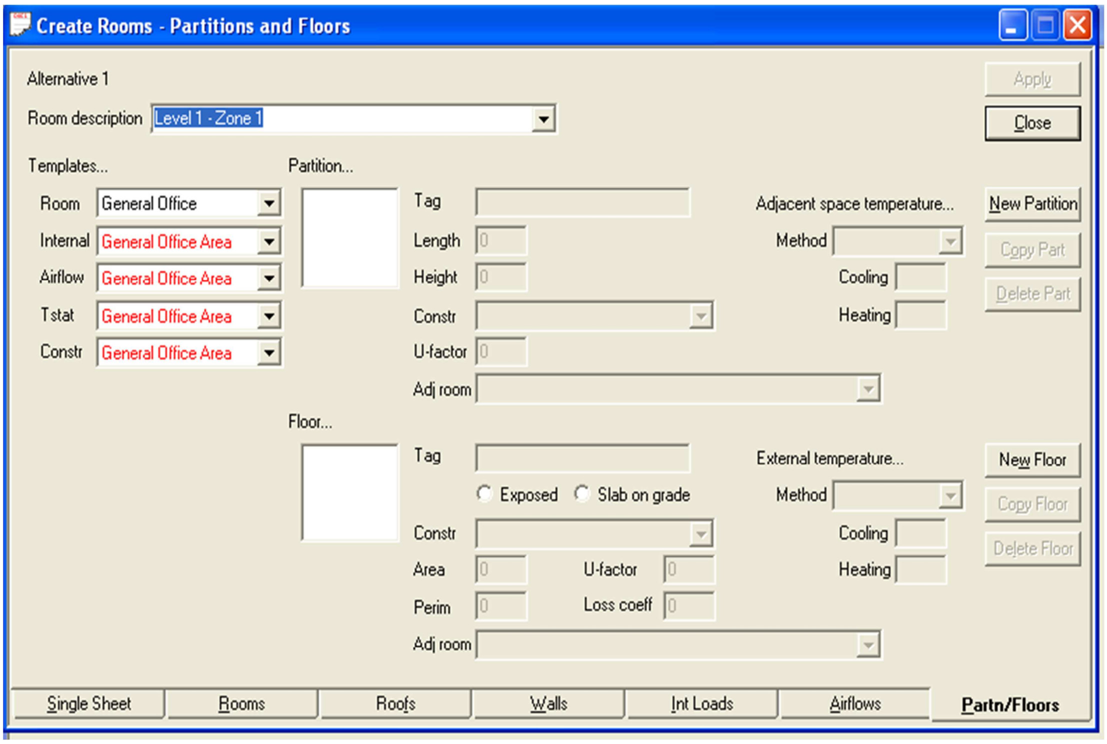

Create Rooms - Walls
Alternative 1
Room description
Level 1 - Zone 1
Apply
Close
Templates...
Wall...
Room
General Office
Internal
General Office Area
Airflow
General Office Area
Tstat
General Office Area
Constr
General Office Area
NW
SW
Tag
NW
Length
12
m
Height
3.65
m
Grnd reflect multiplier
1
Pct wall area to underfloor plenum
%
Construct
200mm Conc Block 20mm Plaster
U-factor
1.4479
W/m²·°C
Tilt
0
deg
Direction
315
deg
New Wall
Copy Wall
Delete Wall
Openings...
Opening - 1
Tag
Opening - 1
Wall area
0
%
Type
Single Clear 1/8"
Length
11.2
m
U-factor
5.9051
W/m²·°C
Window
Door
Height
1.76
m
Quantity
1
Sh. Coef
0.8
Ld to RA
0
%
New Opening
Copy Opening
Delete Opening
Shading...
Internal
None
External
Combined Horz. & Vert. Fins - 295 Ann Shading
Single Sheet
Rooms
Roofs
Walls
Int Loads
Airflows
Partn/Floors


Create Rooms - Internal Loads
Alternative 1
Room description
Level 1 - Zone 1
Apply
Close
Templates...
Room
General Office
Internal
General Office Area
Airflow
General Office Area
Tstat
General Office Area
Constr
General Office Area
People...
Activity
AS1668.2 - Office Area
Density
10
sq m/person
Schedule
Cooling Only (Design)
Sensible
0.078
kW
Latent
0.052
kW
Workstations...
Density
1
workstation/person
Lights...
Type
Fluorescent, hung below ceiling, 100% load to space
Heat gain
15
W/sq m
Schedule
Cooling Only (Design)
Miscellaneous loads...
Misc Load 1
Tag
Misc Load 1
Type
BCA Class 5 Office
New Load
Energy
15
W/sq m
Schedule
Cooling Only (Design)
Copy
Energy meter
Electricity
Delete
Single Sheet
Rooms
Roofs
Walls
Int Loads
Airflows
Partn/Floors

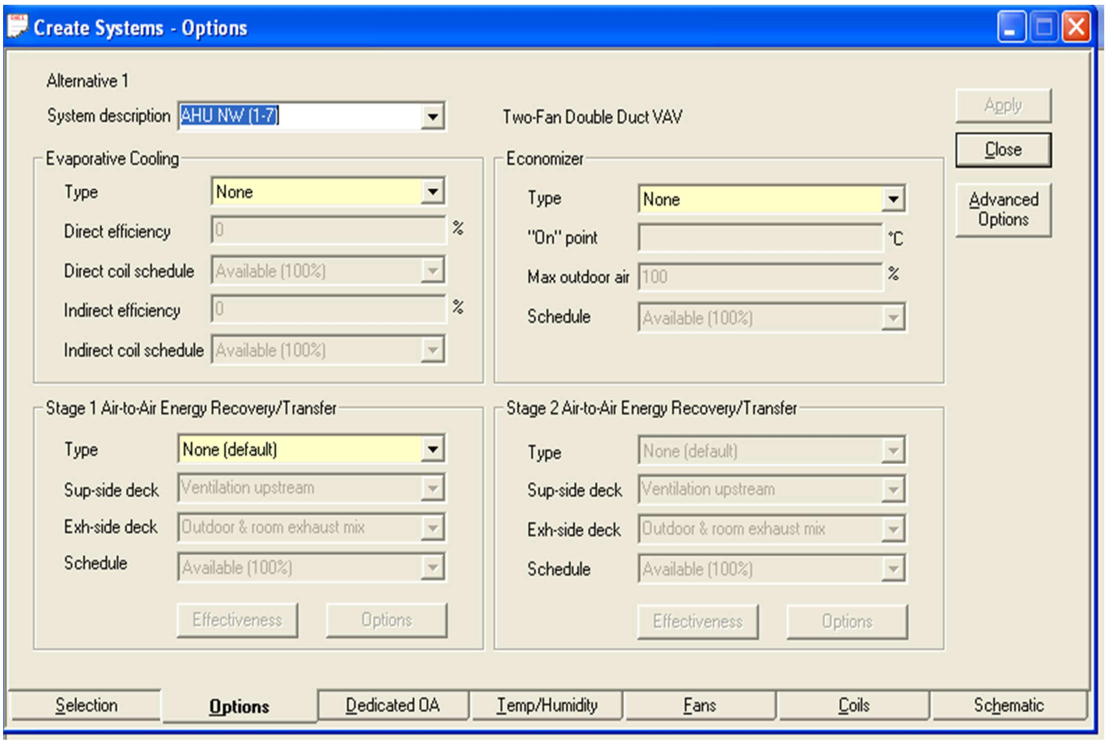

Create Rooms - Airflows
Alternative 1
Adjacent air transfer from room
Apply
Room description
Level 1 - Zone 1
<<No adjacent air trans>>
Close
Templates...
Room
General Office
Internal
General Office Area
Airflow
General Office Area
Tstat
General Office Area
Constr
General Office Area
Main supply...
Cooling
To be calculated
Heating
To be calculated
Ventilation...
Apply ASHRAE Std62.1-2004/2007
No
Type
General Office Space
Cooling
10
L/s/person
Heating
10
L/s/person
Schedule
Available (100%)
Infiltration...
Type
Neutral, Poor Const.
Cooling
1
air changes/hr
Heating
1
air changes/hr
Schedule
Available (100%)
Auxiliary supply...
Cooling
To be calculated
Heating
To be calculated
Std 62.1-2004/2007...
Clg Ez
Custom
%
Htg Ez
Custom
%
Er
Default based on system typ
%
DCV Min OA Intake
None
Room exhaust...
Rate
0
air changes/hr
Schedule
Available (100%)
VAV minimum...
Rate
% Clg Airflow
Schedule
Available (100%)
Type
Default
Single Sheet
Rooms
Roofs
Walls
Int Loads
Airflows
Partn/Floors

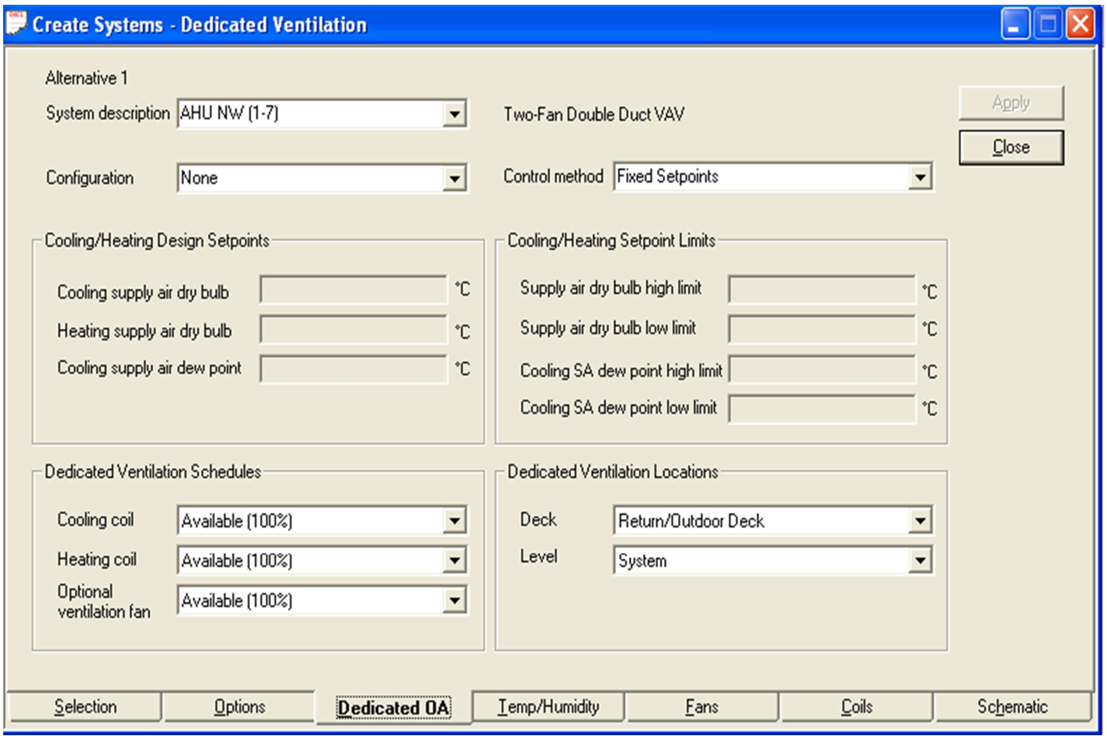


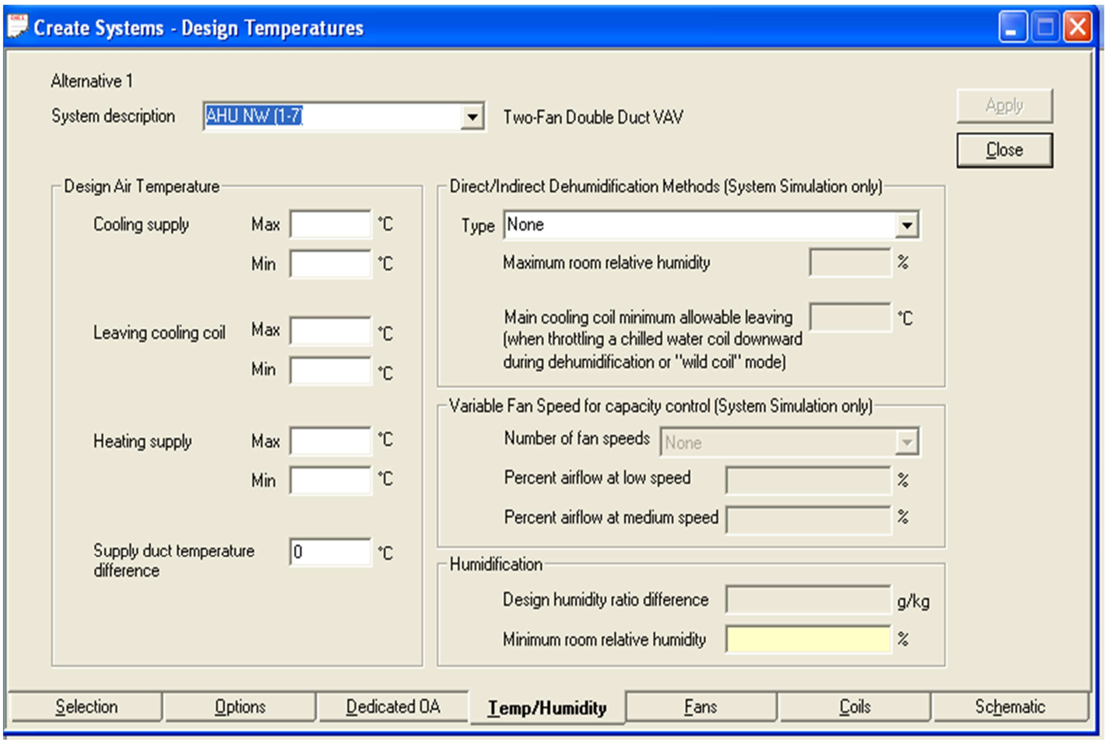
Create Systems - Selection
Alternative 1
System description
AHU NW (1-7)
Two-Fan Double Duct VAV
Apply
Close
New
Copy
Delete
Advanced...
System category
All
Variable Volume
Constant Volume - Non-mixing
Constant Volume - Mixing
Heating Only
Induction
Underfloor Air Distribution
Displacement Ventilation
Chilled Beams
System type
Bypass VAV
Bypass VAV with Reheat (30% Min Flow Default)
Changeover-Bypass VAV
Changeover-Bypass VAV with Local Heat
Changeover-Bypass VAV with Reheat
Double Duct VAV
Parallel Fan Powered VAV, Htg Coil on Mixing Box Outlet
Parallel Fan-Powered VAV
Parallel Fan-Powered VAV, Htg Coil on Plenum Inlet
Series Fan-Powered VAV
Two-Fan Double Duct VAV
Selection
Options
Dedicated OA
Temp/Humidity
Fans
Coils
Schematic

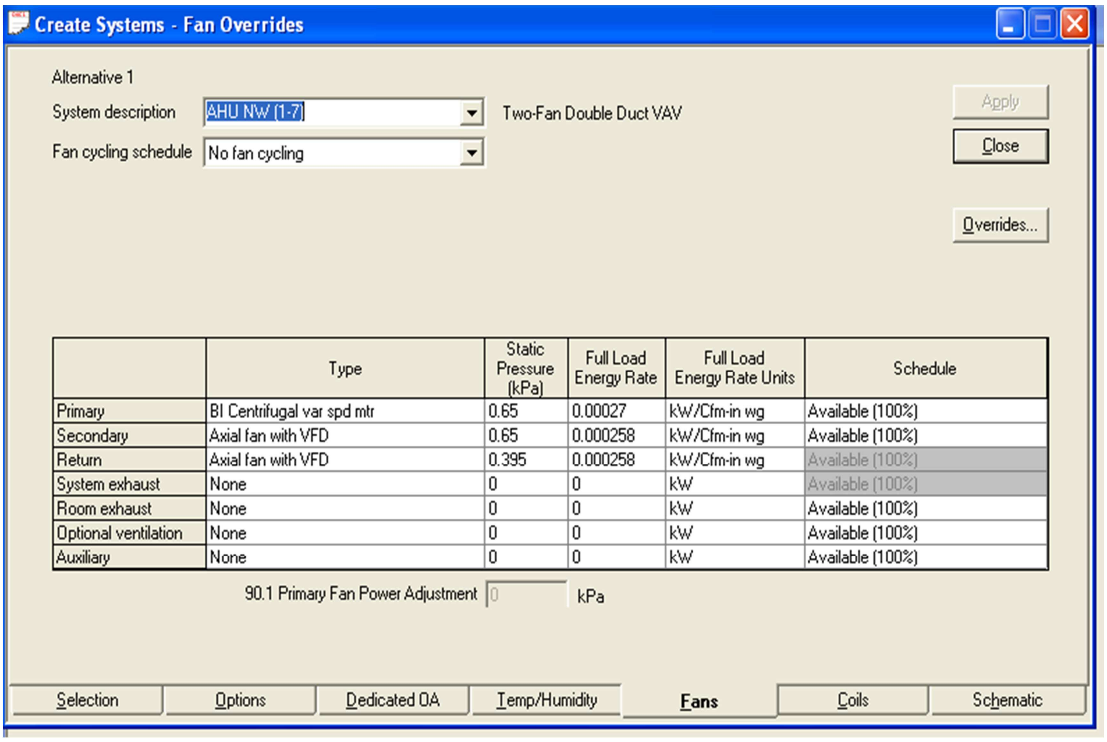


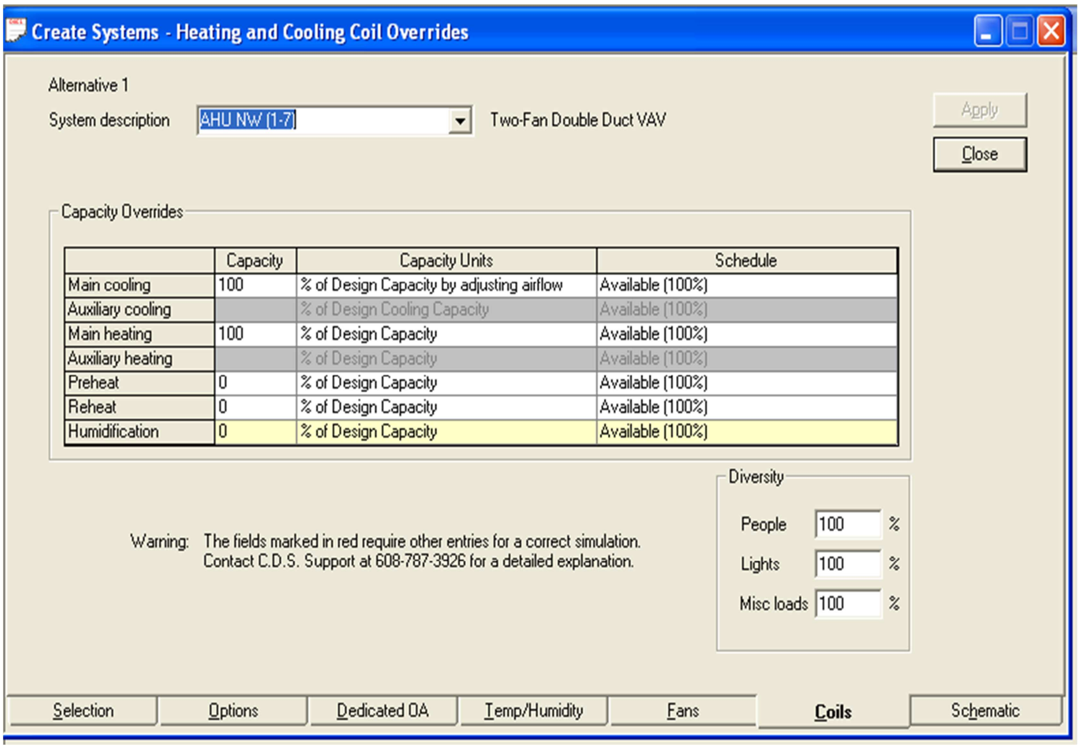
Create Rooms - Partitions and Floors
Alternative 1
Room description
Level 1 - Zone 1
Apply
Close
Templates...
Room
General Office
Internal
General Office Area
Airflow
General Office Area
Tstat
General Office Area
Constr
General Office Area
Partition...
Tag
Length
Height
Constr
U-factor
Adj room
Adjacent space temperature...
Method
Cooling
Heating
New Partition
Copy Part
Delete Part
Floor...
Tag
Exposed
Slab on grade
Constr
Area
U-factor
Perim
Loss coeff
Adj room
External temperature...
Method
Cooling
Heating
New Floor
Copy Floor
Delete Floor
Single Sheet
Rooms
Roofs
Walls
Int Loads
Airflows
Partn/Floors


Create Systems - Options
Alternative 1
System description
AHU NW (1-7)
Two-Fan Double Duct VAV
Apply
Close
Advanced Options
Evaporative Cooling
Type
None
Direct efficiency
0
%
Direct coil schedule
Available (100%)
Indirect efficiency
0
%
Indirect coil schedule
Available (100%)
Economizer
Type
None
"On" point
°C
Max outdoor air
100
%
Schedule
Available (100%)
Stage 1 Air-to-Air Energy Recovery/Transfer
Type
None (default)
Sup-side deck
Ventilation upstream
Exh-side deck
Outdoor & room exhaust mix
Schedule
Available (100%)
Effectiveness
Options
Stage 2 Air-to-Air Energy Recovery/Transfer
Type
None (default)
Sup-side deck
Ventilation upstream
Exh-side deck
Outdoor & room exhaust mix
Schedule
Available (100%)
Effectiveness
Options
Selection
Options
Dedicated OA
Temp/Humidity
Fans
Coils
Schematic

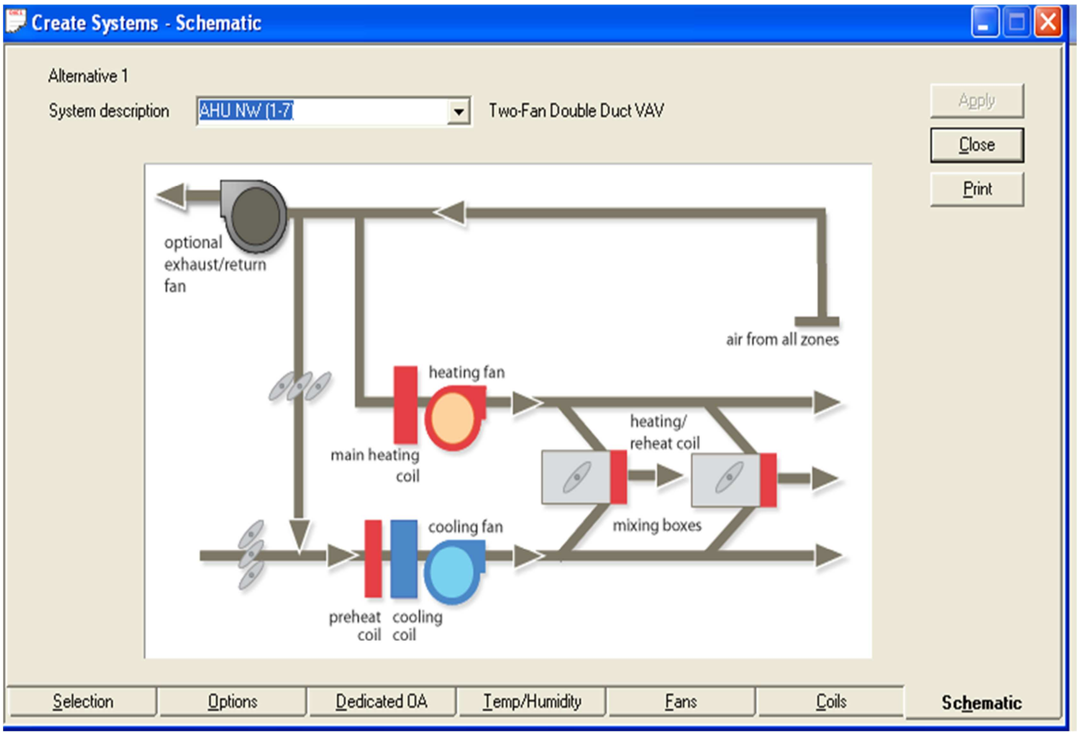

Create Systems - Dedicated Ventilation
Alternative 1
System description
AHU NW (1-7)
Two-Fan Double Duct VAV
Apply
Close
Configuration
None
Control method
Fixed Setpoints
Cooling/Heating Design Setpoints
Cooling supply air dry bulb
°C
Heating supply air dry bulb
°C
Cooling supply air dew point
°C
Cooling/Heating Setpoint Limits
Supply air dry bulb high limit
°C
Supply air dry bulb low limit
°C
Cooling SA dew point high limit
°C
Cooling SA dew point low limit
°C
Dedicated Ventilation Schedules
Cooling coil
Available (100%)
Heating coil
Available (100%)
Optional ventilation fan
Available (100%)
Dedicated Ventilation Locations
Deck
Return/Outdoor Deck
Level
System
Selection
Options
Dedicated OA
Temp/Humidity
Fans
Coils
Schematic

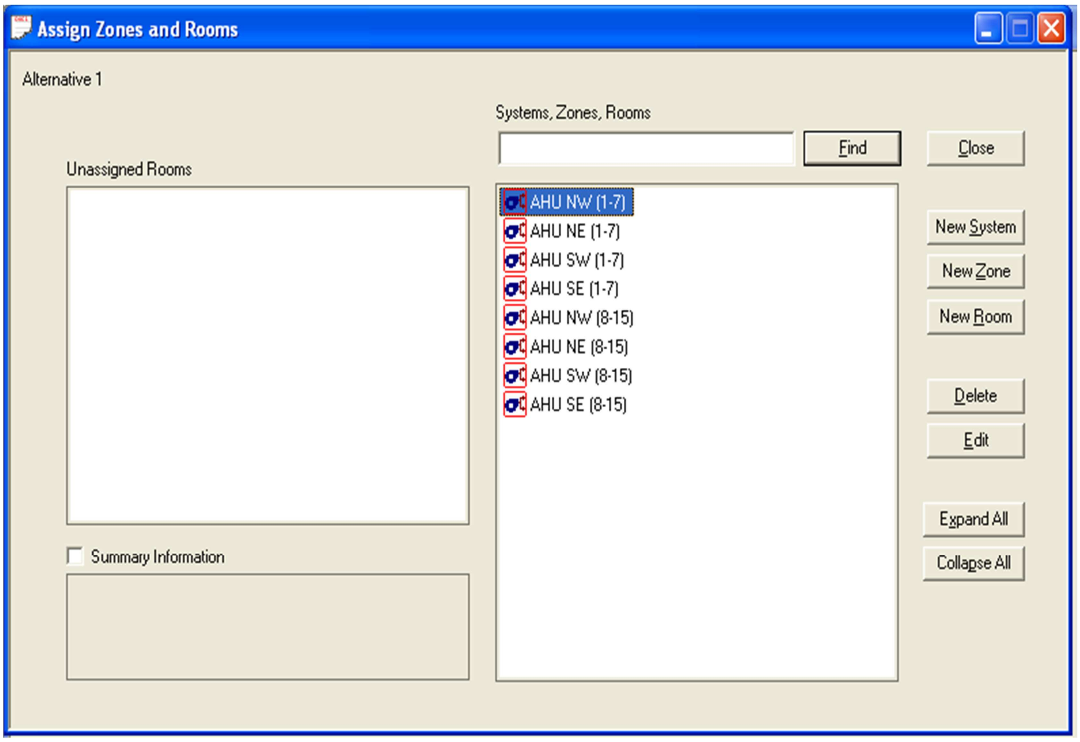

Create Systems - Design Temperatures
Alternative 1
System description
AHU NW (1-7)
Two-Fan Double Duct VAV
Apply
Close
Design Air Temperature
Cooling supply
Max
°C
Min
°C
Leaving cooling coil
Max
°C
Min
°C
Heating supply
Max
°C
Min
°C
Supply duct temperature difference
0
°C
Direct/Indirect Dehumidification Methods (System Simulation only)
Type
None
Maximum room relative humidity
%
Main cooling coil minimum allowable leaving (when throttling a chilled water coil downward during dehumidification or "wild coil" mode)
°C
Variable Fan Speed for capacity control (System Simulation only)
Number of fan speeds
None
Percent airflow at low speed
%
Percent airflow at medium speed
%
Humidification
Design humidity ratio difference
g/kg
Minimum room relative humidity
%
Selection
Options
Dedicated OA
Temp/Humidity
Fans
Coils
Schematic

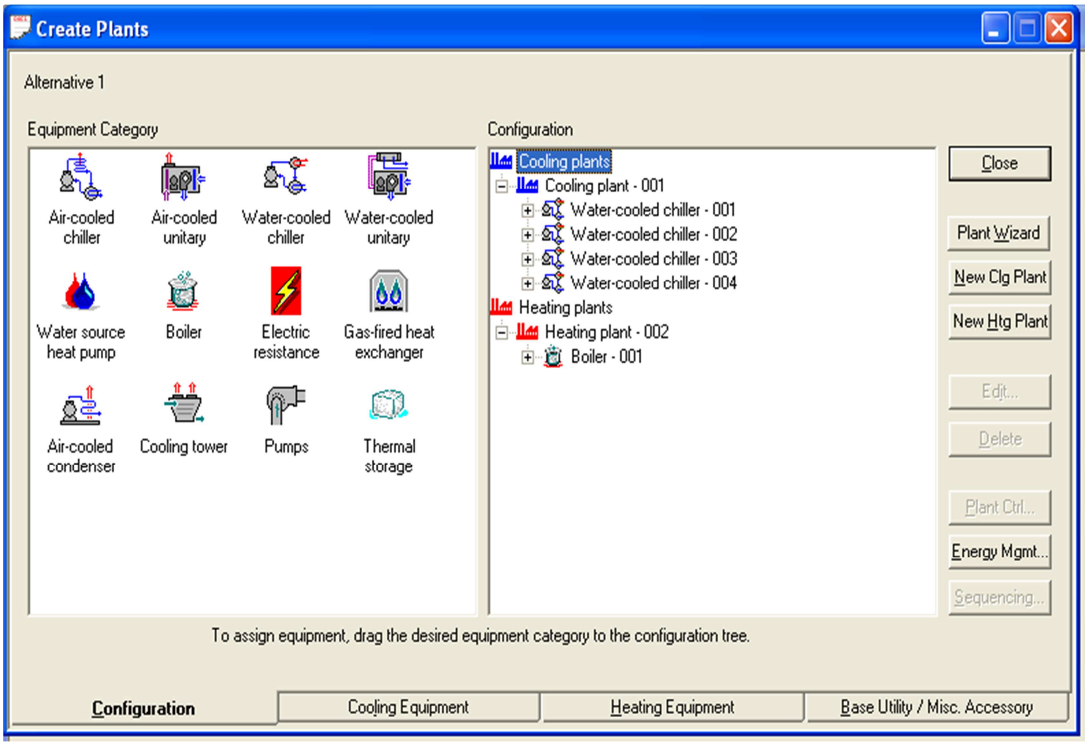

Create Systems - Fan Overrides
Alternative 1
System description
AHU NW (1-7)
Two-Fan Double Duct VAV
Fan cycling schedule
No fan cycling
Apply
Close
Overrides...
Type
Static Pressure (kPa)
Full Load Energy Rate
Full Load Energy Rate Units
Schedule
Primary
Bl Centrifugal var spd mtr
0.65
0.00027
kW/Cfm-in wg
Available (100%)
Secondary
Axial fan with VFD
0.65
0.000258
kW/Cfm-in wg
Available (100%)
Return
Axial fan with VFD
0.395
0.000258
kW/Cfm-in wg
Available (100%)
System exhaust
None
0
0
kW
Available (100%)
Room exhaust
None
0
0
kW
Available (100%)
Optional ventilation
None
0
0
kW
Available (100%)
Auxiliary
None
0
0
kW
Available (100%)
90.1 Primary Fan Power Adjustment
0
kPa
Selection
Options
Dedicated OA
Temp/Humidity
Fans
Coils
Schematic

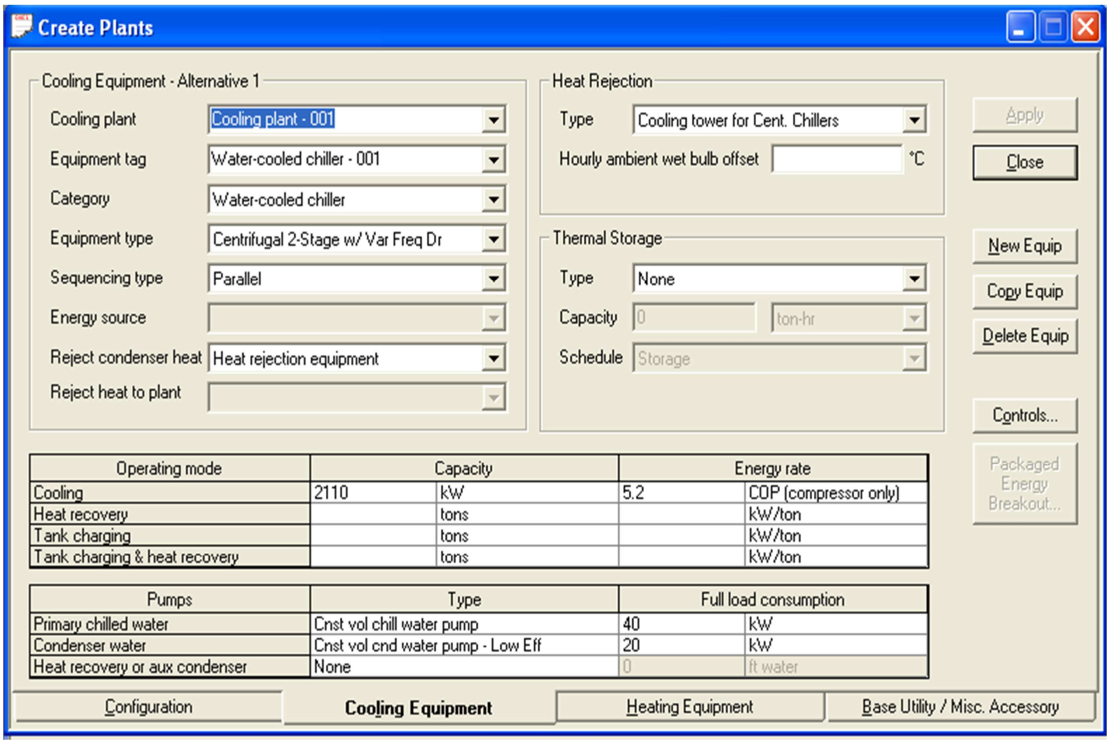


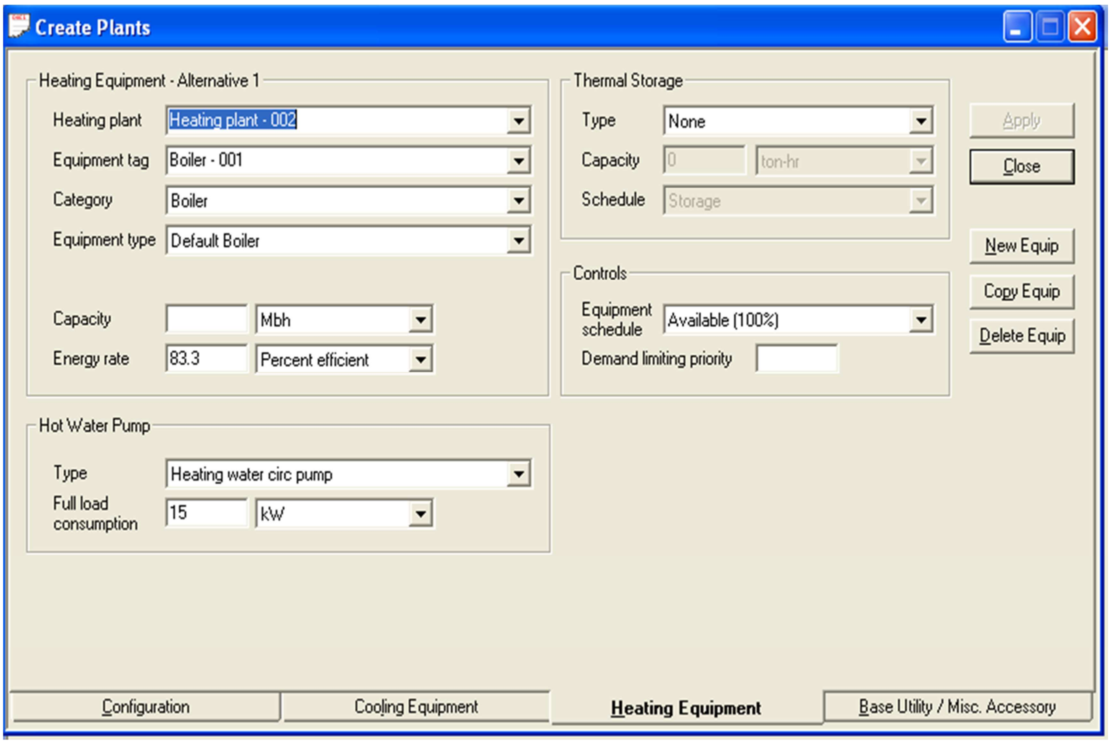
	Capacity	Capacity Units	Schedule
Main cooling	100	% of Design Capacity by adjusting airflow	Available (100%)
Auxiliary cooling		% of Design Cooling Capacity	Available (100%)
Main heating	100	% of Design Capacity	Available (100%)
Auxiliary heating		% of Design Capacity	Available (100%)
Preheat	0	% of Design Capacity	Available (100%)
Reheat	0	% of Design Capacity	Available (100%)
Humidification	0	% of Design Capacity	Available (100%)

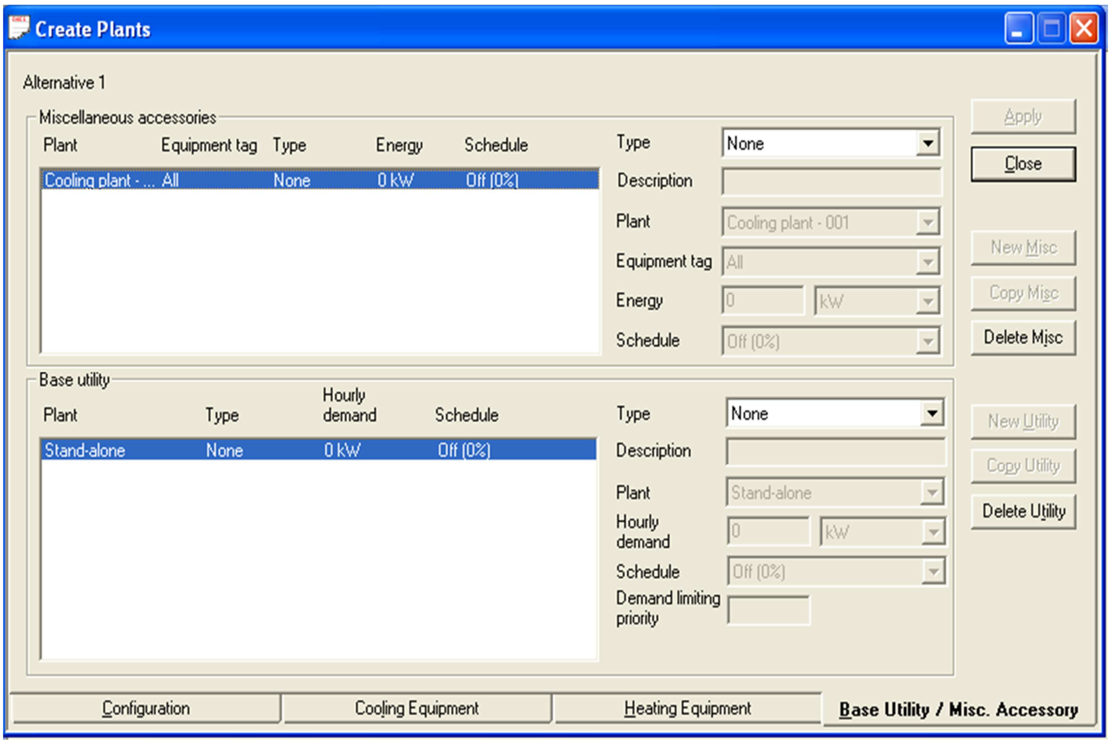



Assign Zones and Rooms
Alternative 1
Systems, Zones, Rooms
Find
Close
Unassigned Rooms
AHU NW (1-7)
AHU NE (1-7)
AHU SW (1-7)
AHU SE (1-7)
AHU NW (8-15)
AHU NE (8-15)
AHU SW (8-15)
AHU SE (8-15)
New System
New Zone
New Room
Delete
Edit
Expand All
Collapse All
Summary Information


Create Plants
Alternative 1
Equipment Category
Configuration
Air-cooled chiller
Air-cooled unitary
Water-cooled chiller
Water-cooled unitary
Water source heat pump
Boiler
Electric resistance
Gas-fired heat exchanger
Air-cooled condenser
Cooling tower
Pumps
Thermal storage
Cooling plants
Cooling plant - 001
Water-cooled chiller - 001
Water-cooled chiller - 002
Water-cooled chiller - 003
Water-cooled chiller - 004
Heating plants
Heating plant - 002
Boiler - 001
Close
Plant Wizard
New Clg Plant
New Htg Plant
Edit...
Delete
Plant Ctrl...
Energy Mgmt...
Sequencing...
To assign equipment, drag the desired equipment category to the configuration tree.
Configuration
Cooling Equipment
Heating Equipment
Base Utility / Misc. Accessory


Create Plants
Cooling Equipment - Alternative 1
Cooling plant
Cooling plant - 001
Equipment tag
Water-cooled chiller - 001
Category
Water-cooled chiller
Equipment type
Centrifugal 2-Stage w/ Var Freq Dr
Sequencing type
Parallel
Energy source
Reject condenser heat
Heat rejection equipment
Reject heat to plant
Heat Rejection
Type
Cooling tower for Cent. Chillers
Hourly ambient wet bulb offset
°C
Thermal Storage
Type
None
Capacity
0
ton-hr
Schedule
Storage
Apply
Close
New Equip
Copy Equip
Delete Equip
Controls...
Packaged Energy Breakout...
Operating mode
Capacity
Energy rate
Cooling
2110
kW
5.2
COP (compressor only)
Heat recovery
tons
kW/ton
Tank charging
tons
kW/ton
Tank charging & heat recovery
tons
kW/ton
Pumps
Type
Full load consumption
Primary chilled water
Cnst vol chill water pump
40
kW
Condenser water
Cnst vol cnd water pump - Low Eff
20
kW
Heat recovery or aux condenser
None
0
ft water
Configuration
Cooling Equipment
Heating Equipment
Base Utility / Misc. Accessory


Create Plants
Heating Equipment - Alternative 1
Heating plant
Heating plant - 002
Equipment tag
Boiler - 001
Category
Boiler
Equipment type
Default Boiler
Capacity
Mbh
Energy rate
83.3
Percent efficient
Thermal Storage
Type
None
Capacity
0
ton-hr
Schedule
Storage
Controls
Equipment schedule
Available (100%)
Demand limiting priority
Apply
Close
New Equip
Copy Equip
Delete Equip
Hot Water Pump
Type
Heating water circ pump
Full load consumption
15
kW
Configuration
Cooling Equipment
Heating Equipment
Base Utility / Misc. Accessory


Create Plants
Alternative 1
Miscellaneous accessories
Plant
Equipment tag
Type
Energy
Schedule
Cooling plant - ... All None 0 kW Off (0%)
Type
None
Description
Plant
Cooling plant - 001
Equipment tag
All
Energy
0
kW
Schedule
Off (0%)
Apply
Close
New Misc
Copy Misc
Delete Misc
Base utility
Plant
Type
Hourly demand
Schedule
Stand-alone None 0 kW Off (0%)
Type
None
Description
Plant
Stand-alone
Hourly demand
0
kW
Schedule
Off (0%)
Demand limiting priority
New Utility
Copy Utility
Delete Utility
Configuration
Cooling Equipment
Heating Equipment
Base Utility / Misc. Accessory

APPENDIX D – TRACE 700 BRISBANE WEATHER FILES

Date	OADB	OAWB	Humidity Ratio	Cloud Cover Modifier	Wind Speed m/s	Barometric Pressure (kPa)
1 January,	23.7	21.6	15.41	1	3.3	100.99
2 January,	23.3	21.5	15.41	1	3.3	100.99
3 January,	22.9	21.4	15.41	1	3.3	100.99
4 January,	22.7	21.3	15.41	1	3.3	100.99
5 January,	22.6	21.3	15.41	1	3.3	100.99
6 January,	22.8	21.3	15.41	1	3.3	100.99
7 January,	23.2	21.5	15.41	1	3.3	100.99
8 January,	23.9	21.7	15.41	1	3.3	100.99
9 January,	25	22	15.41	1	3.3	100.99
10 January,	26.2	22.3	15.41	1	3.3	100.99
11 January,	27.6	22.7	15.41	1	3.3	100.99
12 January,	28.9	23.1	15.41	1	3.3	100.99
13 January,	29.9	23.4	15.41	1	3.3	100.99
14 January,	30.6	23.5	15.41	1	3.3	100.99
15 January,	30.8	23.6	15.41	1	3.3	100.99
16 January,	30.6	23.5	15.41	1	3.3	100.99
17 January,	30	23.4	15.41	1	3.3	100.99
18 January,	29.1	23.1	15.41	1	3.3	100.99
19 January,	28	22.8	15.41	1	3.3	100.99
20 January,	26.9	22.5	15.41	1	3.3	100.99
21 January,	26	22.3	15.41	1	3.3	100.99
22 January,	25.2	22	15.41	1	3.3	100.99
23 January,	24.6	21.9	15.41	1	3.3	100.99
24 January,	24.1	21.7	15.41	1	3.3	100.99
1 February,	23.5	21.5	15.42	1	3.3	100.99
2 February,	23	21.4	15.42	1	3.3	100.99
3 February,	22.7	21.3	15.42	1	3.3	100.99
4 February,	22.5	21.3	15.42	1	3.3	100.99
5 February,	22.4	21.2	15.42	1	3.3	100.99
6 February,	22.6	21.3	15.42	1	3.3	100.99
7 February,	23	21.4	15.42	1	3.3	100.99
8 February,	23.7	21.6	15.42	1	3.3	100.99
9 February,	24.7	21.9	15.42	1	3.3	100.99
10 February,	26	22.3	15.42	1	3.3	100.99
11 February,	27.3	22.7	15.42	1	3.3	100.99
12 February,	28.6	23	15.42	1	3.3	100.99
13 February,	29.6	23.3	15.42	1	3.3	100.99

14 February,	30.3	23.5	15.42	1	3.3	100.99
15 February,	30.5	23.5	15.42	1	3.3	100.99
16 February,	30.3	23.5	15.42	1	3.3	100.99
17 February,	29.7	23.3	15.42	1	3.3	100.99
18 February,	28.8	23.1	15.42	1	3.3	100.99
19 February,	27.7	22.8	15.42	1	3.3	100.99
20 February,	26.7	22.5	15.42	1	3.3	100.99
21 February,	25.8	22.2	15.42	1	3.3	100.99
22 February,	25	22	15.42	1	3.3	100.99
23 February,	24.3	21.8	15.42	1	3.3	100.99
24 February,	23.9	21.7	15.42	1	3.3	100.99
1 March,	22.2	20.5	14.45	1	3.3	100.99
2 March,	21.8	20.3	14.45	1	3.3	100.99
3 March,	21.4	20.2	14.45	1	3.3	100.99
4 March,	21.2	20.2	14.45	1	3.3	100.99
5 March,	21.1	20.1	14.45	1	3.3	100.99
6 March,	21.3	20.2	14.45	1	3.3	100.99
7 March,	21.7	20.3	14.45	1	3.3	100.99
8 March,	22.5	20.6	14.45	1	3.3	100.99
9 March,	23.6	20.9	14.45	1	3.3	100.99
10 March,	24.9	21.3	14.45	1	3.3	100.99
11 March,	26.3	21.7	14.45	1	3.3	100.99
12 March,	27.7	22.1	14.45	1	3.3	100.99
13 March,	28.8	22.4	14.45	1	3.3	100.99
14 March,	29.4	22.6	14.45	1	3.3	100.99
15 March,	29.7	22.7	14.45	1	3.3	100.99
16 March,	29.4	22.6	14.45	1	3.3	100.99
17 March,	28.8	22.4	14.45	1	3.3	100.99
18 March,	27.9	22.2	14.45	1	3.3	100.99
19 March,	26.8	21.8	14.45	1	3.3	100.99
20 March,	25.7	21.5	14.45	1	3.3	100.99
21 March,	24.7	21.2	14.45	1	3.3	100.99
22 March,	23.9	21	14.45	1	3.3	100.99
23 March,	23.2	20.8	14.45	1	3.3	100.99
24 March,	22.6	20.6	14.45	1	3.3	100.99
1 April,	19.8	18.1	12.34	1	3.3	100.99
2 April,	19.4	18	12.34	1	3.3	100.99
3 April,	19	17.8	12.34	1	3.3	100.99
4 April,	18.7	17.7	12.34	1	3.3	100.99
5 April,	18.6	17.7	12.34	1	3.3	100.99
6 April,	18.8	17.8	12.34	1	3.3	100.99
7 April,	19.3	17.9	12.34	1	3.3	100.99
8 April,	20.1	18.2	12.34	1	3.3	100.99

9 April,	21.3	18.6	12.34	1	3.3	100.99
10 April,	22.7	19.1	12.34	1	3.3	100.99
11 April,	24.3	19.6	12.34	1	3.3	100.99
12 April,	25.8	20	12.34	1	3.3	100.99
13 April,	27	20.4	12.34	1	3.3	100.99
14 April,	27.7	20.6	12.34	1	3.3	100.99
15 April,	28	20.7	12.34	1	3.3	100.99
16 April,	27.7	20.6	12.34	1	3.3	100.99
17 April,	27.1	20.4	12.34	1	3.3	100.99
18 April,	26	20.1	12.34	1	3.3	100.99
19 April,	24.8	19.7	12.34	1	3.3	100.99
20 April,	23.6	19.3	12.34	1	3.3	100.99
21 April,	22.5	19	12.34	1	3.3	100.99
22 April,	21.6	18.7	12.34	1	3.3	100.99
23 April,	20.9	18.5	12.34	1	3.3	100.99
24 April,	20.3	18.3	12.34	1	3.3	100.99
1 May,	16.7	15	9.96	1	6.6	100.99
2 May,	16.2	14.8	9.96	1	6.6	100.99
3 May,	15.8	14.7	9.96	1	6.6	100.99
4 May,	15.5	14.5	9.96	1	6.6	100.99
5 May,	15.4	14.5	9.96	1	6.6	100.99
6 May,	15.6	14.6	9.96	1	6.6	100.99
7 May,	16.1	14.8	9.96	1	6.6	100.99
8 May,	17	15.1	9.96	1	6.6	100.99
9 May,	18.2	15.6	9.96	1	6.6	100.99
10 May,	19.7	16.1	9.96	1	6.6	100.99
11 May,	21.3	16.7	9.96	1	6.6	100.99
12 May,	22.9	17.2	9.96	1	6.6	100.99
13 May,	24	17.6	9.96	1	6.6	100.99
14 May,	24.8	17.9	9.96	1	6.6	100.99
15 May,	25.1	18	9.96	1	6.6	100.99
16 May,	24.8	17.9	9.96	1	6.6	100.99
17 May,	24.1	17.6	9.96	1	6.6	100.99
18 May,	23.1	17.3	9.96	1	6.6	100.99
19 May,	21.8	16.8	9.96	1	6.6	100.99
20 May,	20.5	16.4	9.96	1	6.6	100.99
21 May,	19.5	16	9.96	1	6.6	100.99
22 May,	18.5	15.7	9.96	1	6.6	100.99
23 May,	17.7	15.4	9.96	1	6.6	100.99
24 May,	17.1	15.2	9.96	1	6.6	100.99
1 June,	13.9	12.2	8.13	1	6.6	100.99
2 June,	13.4	12	8.13	1	6.6	100.99
3 June,	13	11.8	8.13	1	6.6	100.99

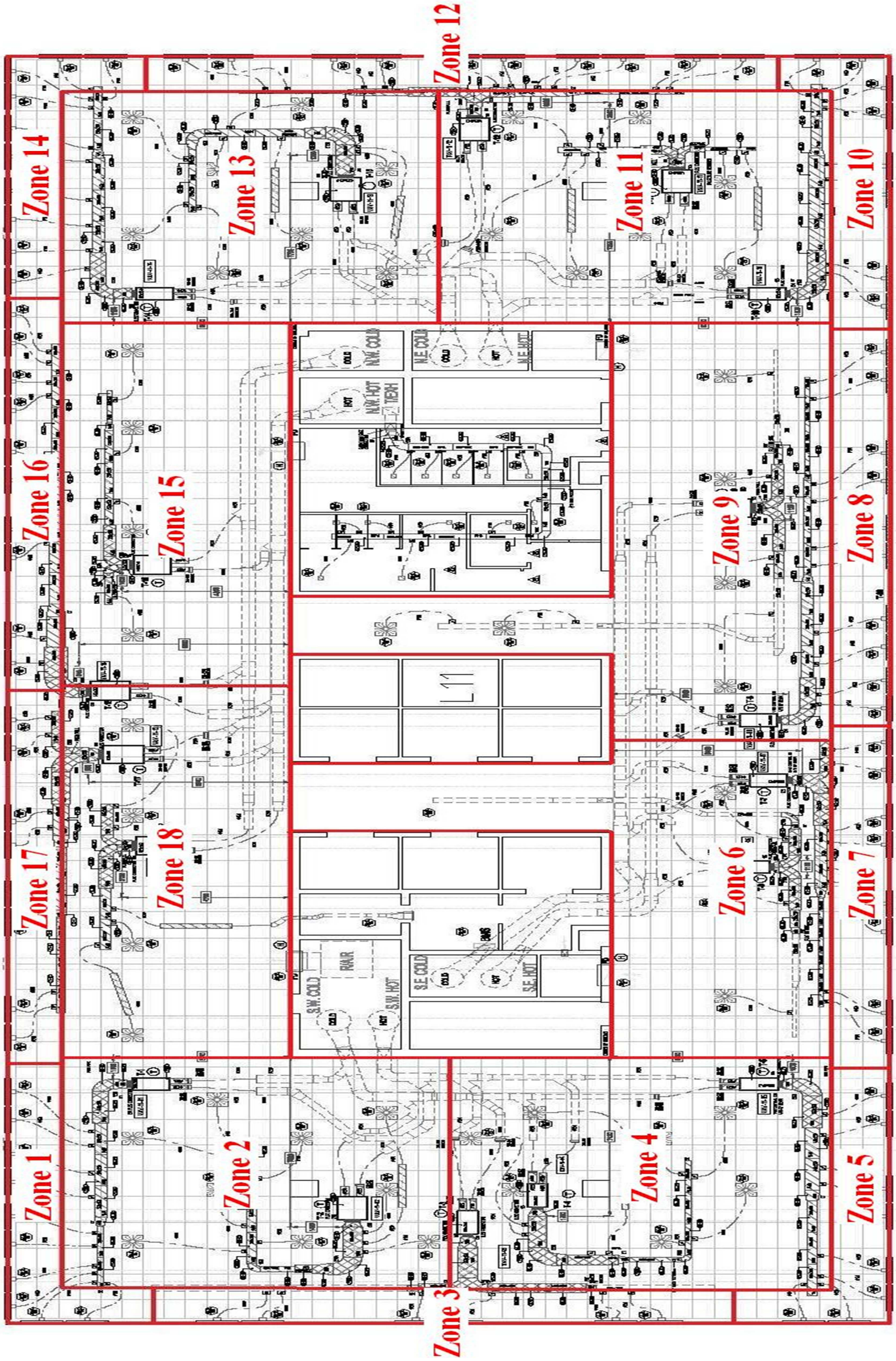
4 June,	12.7	11.7	8.13	1	6.6	100.99
5 June,	12.6	11.6	8.13	1	6.6	100.99
6 June,	12.8	11.7	8.13	1	6.6	100.99
7 June,	13.3	11.9	8.13	1	6.6	100.99
8 June,	14.2	12.3	8.13	1	6.6	100.99
9 June,	15.6	12.8	8.13	1	6.6	100.99
10 June,	17.1	13.5	8.13	1	6.6	100.99
11 June,	18.8	14.1	8.13	1	6.6	100.99
12 June,	20.5	14.8	8.13	1	6.6	100.99
13 June,	21.7	15.2	8.13	1	6.6	100.99
14 June,	22.5	15.5	8.13	1	6.6	100.99
15 June,	22.8	15.6	8.13	1	6.6	100.99
16 June,	22.5	15.5	8.13	1	6.6	100.99
17 June,	21.8	15.3	8.13	1	6.6	100.99
18 June,	20.7	14.8	8.13	1	6.6	100.99
19 June,	19.3	14.3	8.13	1	6.6	100.99
20 June,	18	13.8	8.13	1	6.6	100.99
21 June,	16.9	13.4	8.13	1	6.6	100.99
22 June,	15.9	13	8.13	1	6.6	100.99
23 June,	15	12.6	8.13	1	6.6	100.99
24 June,	14.4	12.4	8.13	1	6.6	100.99
1 July,	12.5	10.6	7.16	1	6.6	100.99
2 July,	11.9	10.3	7.16	1	6.6	100.99
3 July,	11.4	10.1	7.16	1	6.6	100.99
4 July,	11.1	10	7.16	1	6.6	100.99
5 July,	11	9.9	7.16	1	6.6	100.99
6 July,	11.2	10	7.16	1	6.6	100.99
7 July,	11.8	10.3	7.16	1	6.6	100.99
8 July,	12.8	10.7	7.16	1	6.6	100.99
9 July,	14.2	11.3	7.16	1	6.6	100.99
10 July,	15.9	12	7.16	1	6.6	100.99
11 July,	17.8	12.8	7.16	1	6.6	100.99
12 July,	19.6	13.5	7.16	1	6.6	100.99
13 July,	21	14.1	7.16	1	6.6	100.99
14 July,	21.9	14.4	7.16	1	6.6	100.99
15 July,	22.2	14.5	7.16	1	6.6	100.99
16 July,	21.9	14.4	7.16	1	6.6	100.99
17 July,	21.1	14.1	7.16	1	6.6	100.99
18 July,	19.8	13.6	7.16	1	6.6	100.99
19 July,	18.4	13	7.16	1	6.6	100.99
20 July,	16.9	12.5	7.16	1	6.6	100.99
21 July,	15.7	11.9	7.16	1	6.6	100.99
22 July,	14.6	11.5	7.16	1	6.6	100.99

23 July,	13.7	11.1	7.16	1	6.6	100.99
24 July,	13	10.8	7.16	1	6.6	100.99
1 August,	13.1	10.8	7.12	1	6.6	100.99
2 August,	12.5	10.6	7.12	1	6.6	100.99
3 August,	12.1	10.4	7.12	1	6.6	100.99
4 August,	11.7	10.2	7.12	1	6.6	100.99
5 August,	11.6	10.1	7.12	1	6.6	100.99
6 August,	11.8	10.2	7.12	1	6.6	100.99
7 August,	12.4	10.5	7.12	1	6.6	100.99
8 August,	13.5	11	7.12	1	6.6	100.99
9 August,	15	11.6	7.12	1	6.6	100.99
10 August,	16.7	12.3	7.12	1	6.6	100.99
11 August,	18.7	13.1	7.12	1	6.6	100.99
12 August,	20.6	13.9	7.12	1	6.6	100.99
13 August,	22	14.4	7.12	1	6.6	100.99
14 August,	22.9	14.8	7.12	1	6.6	100.99
15 August,	23.3	14.9	7.12	1	6.6	100.99
16 August,	22.9	14.8	7.12	1	6.6	100.99
17 August,	22.1	14.5	7.12	1	6.6	100.99
18 August,	20.8	14	7.12	1	6.6	100.99
19 August,	19.3	13.4	7.12	1	6.6	100.99
20 August,	17.8	12.8	7.12	1	6.6	100.99
21 August,	16.5	12.2	7.12	1	6.6	100.99
22 August,	15.3	11.8	7.12	1	6.6	100.99
23 August,	14.4	11.4	7.12	1	6.6	100.99
24 August,	13.7	11.1	7.12	1	6.6	100.99
1 September,	15.6	13.2	8.5	1	6.6	100.99
2 September,	15	13	8.5	1	6.6	100.99
3 September,	14.6	12.8	8.5	1	6.6	100.99
4 September,	14.2	12.7	8.5	1	6.6	100.99
5 September,	14.1	12.6	8.5	1	6.6	100.99
6 September,	14.3	12.7	8.5	1	6.6	100.99
7 September,	14.9	12.9	8.5	1	6.6	100.99
8 September,	15.9	13.3	8.5	1	6.6	100.99
9 September,	17.4	13.9	8.5	1	6.6	100.99
10 September,	19.1	14.6	8.5	1	6.6	100.99
11 September,	21	15.3	8.5	1	6.6	100.99
12 September,	22.8	15.9	8.5	1	6.6	100.99
13 September,	24.2	16.4	8.5	1	6.6	100.99
14 September,	25.1	16.8	8.5	1	6.6	100.99
15 September,	25.4	16.9	8.5	1	6.6	100.99
16 September,	25.1	16.8	8.5	1	6.6	100.99
17 September,	24.3	16.5	8.5	1	6.6	100.99

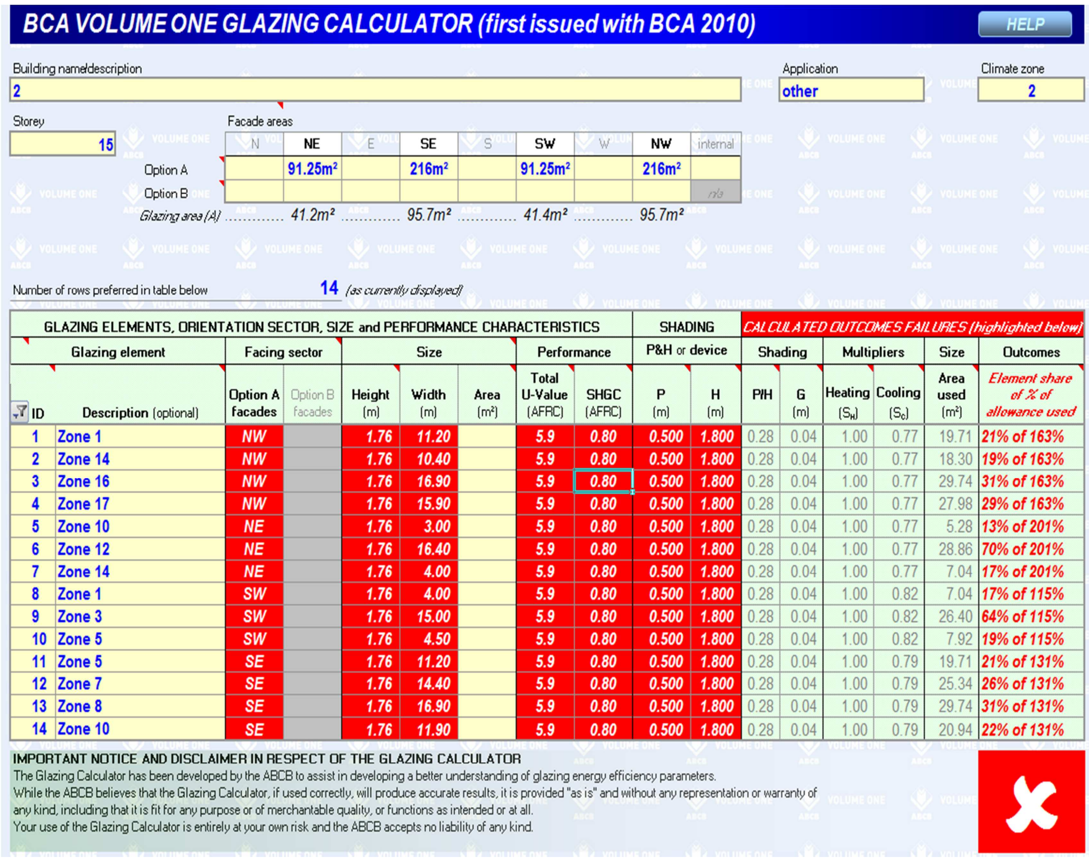
18 September,	23	16	8.5	1	6.6	100.99
19 September,	21.6	15.5	8.5	1	6.6	100.99
20 September,	20.1	15	8.5	1	6.6	100.99
21 September,	18.8	14.5	8.5	1	6.6	100.99
22 September,	17.7	14	8.5	1	6.6	100.99
23 September,	16.8	13.7	8.5	1	6.6	100.99
24 September,	16.1	13.4	8.5	1	6.6	100.99
1 October,	18.5	16.5	10.91	1	6.6	100.99
2 October,	18	16.3	10.91	1	6.6	100.99
3 October,	17.6	16.2	10.91	1	6.6	100.99
4 October,	17.3	16.1	10.91	1	6.6	100.99
5 October,	17.2	16	10.91	1	6.6	100.99
6 October,	17.4	16.1	10.91	1	6.6	100.99
7 October,	17.9	16.3	10.91	1	6.6	100.99
8 October,	18.8	16.6	10.91	1	6.6	100.99
9 October,	20.1	17.1	10.91	1	6.6	100.99
10 October,	21.6	17.6	10.91	1	6.6	100.99
11 October,	23.4	18.2	10.91	1	6.6	100.99
12 October,	25	18.7	10.91	1	6.6	100.99
13 October,	26.2	19.1	10.91	1	6.6	100.99
14 October,	27	19.3	10.91	1	6.6	100.99
15 October,	27.3	19.4	10.91	1	6.6	100.99
16 October,	27	19.3	10.91	1	6.6	100.99
17 October,	26.3	19.1	10.91	1	6.6	100.99
18 October,	25.2	18.8	10.91	1	6.6	100.99
19 October,	23.9	18.3	10.91	1	6.6	100.99
20 October,	22.6	17.9	10.91	1	6.6	100.99
21 October,	21.4	17.5	10.91	1	6.6	100.99
22 October,	20.4	17.2	10.91	1	6.6	100.99
23 October,	19.6	16.9	10.91	1	6.6	100.99
24 October,	19	16.7	10.91	1	6.6	100.99
1 November,	20.9	19.1	13.09	1	3.3	100.99
2 November,	20.4	18.9	13.09	1	3.3	100.99
3 November,	20.1	18.8	13.09	1	3.3	100.99
4 November,	19.8	18.7	13.09	1	3.3	100.99
5 November,	19.7	18.7	13.09	1	3.3	100.99
6 November,	19.9	18.7	13.09	1	3.3	100.99
7 November,	20.4	18.9	13.09	1	3.3	100.99
8 November,	21.2	19.1	13.09	1	3.3	100.99
9 November,	22.4	19.5	13.09	1	3.3	100.99
10 November,	23.8	20	13.09	1	3.3	100.99
11 November,	25.4	20.5	13.09	1	3.3	100.99
12 November,	26.9	20.9	13.09	1	3.3	100.99

13 November,	28	21.2	13.09	1	3.3	100.99
14 November,	28.7	21.5	13.09	1	3.3	100.99
15 November,	29	21.5	13.09	1	3.3	100.99
16 November,	28.7	21.5	13.09	1	3.3	100.99
17 November,	28.1	21.3	13.09	1	3.3	100.99
18 November,	27	21	13.09	1	3.3	100.99
19 November,	25.8	20.6	13.09	1	3.3	100.99
20 November,	24.6	20.2	13.09	1	3.3	100.99
21 November,	23.6	19.9	13.09	1	3.3	100.99
22 November,	22.7	19.6	13.09	1	3.3	100.99
23 November,	21.9	19.4	13.09	1	3.3	100.99
24 November,	21.4	19.2	13.09	1	3.3	100.99
1 December,	22.6	20.8	14.69	1	3.3	100.99
2 December,	22.1	20.6	14.69	1	3.3	100.99
3 December,	21.8	20.5	14.69	1	3.3	100.99
4 December,	21.5	20.4	14.69	1	3.3	100.99
5 December,	21.4	20.4	14.69	1	3.3	100.99
6 December,	21.6	20.5	14.69	1	3.3	100.99
7 December,	22	20.6	14.69	1	3.3	100.99
8 December,	22.8	20.8	14.69	1	3.3	100.99
9 December,	24	21.2	14.69	1	3.3	100.99
10 December,	25.3	21.6	14.69	1	3.3	100.99
11 December,	26.8	22	14.69	1	3.3	100.99
12 December,	28.3	22.4	14.69	1	3.3	100.99
13 December,	29.3	22.7	14.69	1	3.3	100.99
14 December,	30	22.9	14.69	1	3.3	100.99
15 December,	30.3	23	14.69	1	3.3	100.99
16 December,	30	22.9	14.69	1	3.3	100.99
17 December,	29.4	22.8	14.69	1	3.3	100.99
18 December,	28.4	22.5	14.69	1	3.3	100.99
19 December,	27.3	22.1	14.69	1	3.3	100.99
20 December,	26.1	21.8	14.69	1	3.3	100.99
21 December,	25.1	21.5	14.69	1	3.3	100.99
22 December,	24.2	21.3	14.69	1	3.3	100.99
23 December,	23.5	21	14.69	1	3.3	100.99
24 December,	23	20.9	14.69	1	3.3	100.99

APPENDIX E –295 ANN STREET TYPICAL FLOOR PLAN



APPENDIX F - BCA 2010 GLAZING CALCULATOR



BCA VOLUME ONE GLAZING CALCULATOR (first issued with BCA 2010)

HELP

Building name/description: 2

Application: other

Climate zone: 2

Storey: 15

Facade areas

	N	NE	E	SE	S	SW	W	NW	internal
Option A		91.25m²		216m²		91.25m²		216m²	
Option B									n/a
Glazing area (A)		41.2m²		95.7m²		41.4m²		95.7m²	

Number of rows preferred in table below 14 (as currently displayed)

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS									SHADING		CALCULATED OUTCOMES FAILURES (highlighted below)					
Glazing element		Facing sector		Size			Performance		P&H or device		Shading		Multipliers		Size	Outcomes
ID	Description (optional)	Option A facades	Option B facades	Height (m)	Width (m)	Area (m²)	Total U-Value (AFRC)	SHGC (AFRC)	P (m)	H (m)	P/H	G (m)	Heating (S_H)	Cooling (S_C)	Area used (m²)	Element share of % of allowance used
1	Zone 1	NW		1.76	11.20		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.77	19.71	21% of 163%
2	Zone 14	NW		1.76	10.40		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.77	18.30	19% of 163%
3	Zone 16	NW		1.76	16.90		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.77	29.74	31% of 163%
4	Zone 17	NW		1.76	15.90		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.77	27.98	29% of 163%
5	Zone 10	NE		1.76	3.00		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.77	5.28	13% of 201%
6	Zone 12	NE		1.76	16.40		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.77	28.86	70% of 201%
7	Zone 14	NE		1.76	4.00		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.77	7.04	17% of 201%
8	Zone 1	SW		1.76	4.00		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.82	7.04	17% of 115%
9	Zone 3	SW		1.76	15.00		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.82	26.40	64% of 115%
10	Zone 5	SW		1.76	4.50		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.82	7.92	19% of 115%
11	Zone 5	SE		1.76	11.20		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.79	19.71	21% of 131%
12	Zone 7	SE		1.76	14.40		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.79	25.34	26% of 131%
13	Zone 8	SE		1.76	16.90		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.79	29.74	31% of 131%
14	Zone 10	SE		1.76	11.90		5.9	0.80	0.500	1.800	0.28	0.04	1.00	0.79	20.94	22% of 131%

IMPORTANT NOTICE AND DISCLAIMER IN RESPECT OF THE GLAZING CALCULATOR

The Glazing Calculator has been developed by the ABCB to assist in developing a better understanding of glazing energy efficiency parameters.

While the ABCB believes that the Glazing Calculator, if used correctly, will produce accurate results, it is provided "as is" and without any representation or warranty of any kind, including that it is fit for any purpose or of merchantable quality, or functions as intended or at all.

Your use of the Glazing Calculator is entirely at your own risk and the ABCB accepts no liability of any kind.

APPENDIX G - BCA 2010 GLAZING CALCULATOR

BCA VOLUME ONE GLAZING CALCULATOR (first issued with BCA 2010) HELP

Building name/description: **295 Ann Street**

Application: **other**

Climate zone: **2**

Storey: **15**

Facade areas

	N	NE	E	SE	S	SW	W	NW	internal
Option A		91.25m²		216m²		91.25m²		216m²	
Option B									n/a
Glazing area (A)		41.2m²		95.7m²		41.4m²		95.7m²	

Number of rows preferred in table below **14** *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS									SHADING		CALCULATED OUTCOMES OK (if inputs are valid)					
Glazing element		Facing sector		Size			Performance		P&H or device		Shading		Multipliers		Size	Outcomes
ID	Description (optional)	Option A facades	Option B facades	Height (m)	Width (m)	Area (m²)	Total U-Value (AFRC)	SHGC (AFRC)	P (m)	H (m)	P/H	G (m)	Heating (S_H)	Cooling (S_C)	Area used (m²)	Element share of % of allowance used
1	Zone 1	NW		1.76	11.20		3.4	0.48	0.500	1.800	0.28	0.04	1.00	0.77	19.71	21% of 99%
2	Zone 14	NW		1.76	10.40		3.4	0.48	0.500	1.800	0.28	0.04	1.00	0.77	18.30	19% of 99%
3	Zone 16	NW		1.76	16.90		3.4	0.48	0.500	1.800	0.28	0.04	1.00	0.77	29.74	31% of 99%
4	Zone 17	NW		1.76	15.90		3.4	0.48	0.500	1.800	0.28	0.04	1.00	0.77	27.98	29% of 99%
5	Zone 10	NE		1.76	3.00		3.4	0.40	0.500	1.800	0.28	0.04	1.00	0.77	5.28	13% of 100%
6	Zone 12	NE		1.76	16.40		3.4	0.40	0.500	1.800	0.28	0.04	1.00	0.77	28.86	70% of 100%
7	Zone 14	NE		1.76	4.00		3.4	0.40	0.500	1.800	0.28	0.04	1.00	0.77	7.04	17% of 100%
8	Zone 1	SW		1.76	4.00		3.4	0.69	0.500	1.800	0.28	0.04	1.00	0.82	7.04	17% of 99%
9	Zone 3	SW		1.76	15.00		3.4	0.69	0.500	1.800	0.28	0.04	1.00	0.82	26.40	64% of 99%
10	Zone 5	SW		1.76	4.50		3.4	0.69	0.500	1.800	0.28	0.04	1.00	0.82	7.92	19% of 99%
11	Zone 5	SE		1.76	11.20		3.4	0.61	0.500	1.800	0.28	0.04	1.00	0.79	19.71	21% of 100%
12	Zone 7	SE		1.76	14.40		3.4	0.61	0.500	1.800	0.28	0.04	1.00	0.79	25.34	26% of 100%
13	Zone 8	SE		1.76	16.90		3.4	0.61	0.500	1.800	0.28	0.04	1.00	0.79	29.74	31% of 100%
14	Zone 10	SE		1.76	11.90		3.4	0.61	0.500	1.800	0.28	0.04	1.00	0.79	20.94	22% of 100%

if inputs are valid ✓

APPENDIX H - MODELLING OUTPUT FOR EXISTING BUILDING

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		------- Monthly Energy Consumption -------												
Alternative: 1		**295 Ann Street - Mixing Boxes**												
Electric														
	On-Pk Cons. (kWh)	856,968	775,706	816,186	722,789	688,902	625,513	631,470	639,129	641,097	718,980	748,552	825,212	8,690,506
	On-Pk Demand (kW)	1,483	1,527	1,470	1,361	1,116	1,020	985	1,001	1,062	1,188	1,370	1,431	1,527
Gas														
	On-Pk Cons. (kWh)	4,523	1,685	7,691	27,162	88,294	151,500	184,253	154,253	87,970	44,723	13,732	9,716	775,503
	On-Pk Demand (kW)	39	20	61	173	323	437	474	455	369	262	99	65	474
Water														
	Cons. (kL)	5,592	5,059	5,052	3,951	2,930	1,984	1,735	1,902	2,415	3,494	4,369	5,200	43,682

Energy Consumption		
Building	1,773	MJ/(m2-year)
Source	5,035	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 1 295 Ann Street - Mixing Boxes

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	666.3	599.7	582.6	401.7	224.1	87.4	46.0	49.3	129.3	347.2	464.7	607.3	4,205.5
Peak (kL/Hr)	1.0	1.0	0.9	0.6	0.4	0.2	0.1	0.1	0.2	0.6	0.7	0.9	1.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,778 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 405.8 kW] (Cooling Equipment)													
Electric (kWh)	192,192.6	172,572.9	174,169.4	140,853.4	92,248.5	57,116.9	49,226.7	54,086.9	72,480.9	117,885.5	156,808.9	182,653.9	1,462,296.5
Peak (kW)	376.2	360.3	358.4	343.9	238.9	167.5	143.2	158.8	207.2	302.0	355.7	357.2	376.2
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,515 kW / 47.22 kW]													
Electric (kWh)	35,135.2	31,735.0	35,135.2	34,001.8	35,135.2	33,247.8	31,752.3	32,480.4	34,001.8	35,135.2	34,001.8	35,135.2	406,896.7
Peak (kW)	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,806.0	4,328.2	4,538.5	3,950.5	2,929.9	1,983.9	1,734.6	1,902.2	2,415.4	3,493.6	4,251.5	4,693.3	41,027.5
Peak (kL/Hr)	8.6	8.4	8.3	8.4	6.8	5.3	4.7	5.2	6.2	7.9	8.5	8.4	8.6
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 346.2 kW] (Cooling Equipment)													
Electric (kWh)	32,101.8	29,719.8	20,281.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,446.6	20,292.9	106,842.6
Peak (kW)	206.0	210.2	192.1	153.8	0.0	0.0	0.0	0.0	0.0	0.0	164.9	190.6	210.2

APPENDIX I - MODELLING OUTPUT FOR REFERENCE BUILDING WITH ZONE MIXING BOXES & CENTRAL AIR HANDLING

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 4	**reference building**													
Electric														
	On-Pk Cons. (kWh)	745,706	674,534	699,810	612,354	571,441	513,420	513,431	519,863	529,830	610,127	641,636	712,890	7,345,042
	On-Pk Demand (kW)	1,334	1,352	1,284	1,078	927	832	800	808	884	1,013	1,133	1,284	1,352
Gas														
	On-Pk Cons. (kWh)	1,339	503	3,261	12,335	44,221	81,379	108,961	83,625	41,218	22,160	5,376	3,834	408,212
	On-Pk Demand (kW)	19	6	27	74	183	256	331	271	211	164	44	36	331
Water														
	Cons. (kL)	5,079	4,572	4,487	3,354	2,287	1,401	1,080	1,241	1,835	2,829	3,830	4,672	36,666

(------- Monthly Energy Consumption -------)

Energy Consumption

Building	1,452	MJ/(m2-year)
Source	4,207	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis

CO2	No Data Available
SO2	No Data Available
NOX	No Data Available

Project Name: Final Year Project
Dataset Name: Final Year Project2.trc

TRACE® 700 v6.2.6.5 calculated at 10:51 AM on 07/22/2011
Alternative - 4 Monthly Energy Consumption report Page 3 of 3

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 4 reference building

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	128,758.0	116,297.7	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	1,516,023.1
Peak (kW)	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	723.3	652.5	630.8	438.9	253.4	110.8	62.8	68.5	159.1	361.3	509.9	657.8	4,629.1
Peak (kL/Hr)	1.1	1.1	1.0	0.7	0.4	0.2	0.1	0.1	0.3	0.7	0.8	1.0	1.1
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,396 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 502.4 kW] (Cooling Equipment)													
Electric (kWh)	237,883.4	207,305.0	206,892.2	141,758.4	87,662.0	52,903.9	41,888.3	47,782.8	68,585.1	115,001.6	167,657.8	218,044.6	1,593,365.0
Peak (kW)	459.2	461.9	469.5	355.6	232.0	152.6	127.7	140.8	203.4	293.7	406.6	440.0	469.5
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,612 kW / 49.04 kW]													
Electric (kWh)	36,484.5	32,953.7	36,484.4	35,307.6	36,484.5	33,295.2	31,416.8	32,168.0	35,296.2	36,484.5	35,307.5	36,484.5	418,167.3
Peak (kW)	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,951.3	4,339.3	4,487.0	3,353.8	2,286.5	1,400.9	1,080.2	1,241.1	1,834.8	2,828.9	3,829.7	4,672.1	36,305.7
Peak (kL/Hr)	8.7	8.7	8.8	7.6	5.6	4.0	3.5	3.8	5.1	6.8	8.3	8.6	8.8
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 428.6 kW] (Cooling Equipment)													
Electric (kWh)	6,301.5	11,365.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17,667.2
Peak (kW)	224.2	225.0	202.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	207.1	225.0

APPENDIX J - MODELLING OUTPUT FOR VARIABLE AIR VOLUME WITH CENTRAL AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

------- Monthly Energy Consumption -------

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 2	**295 Ann Street - VAV**													
Electric														
	On-Pk Cons. (kWh)	846,944	767,036	804,934	701,662	649,089	580,201	585,658	596,886	609,478	692,073	732,166	811,849	8,377,974
	On-Pk Demand (kW)	1,483	1,527	1,469	1,366	1,120	981	943	994	1,072	1,188	1,370	1,431	1,527
Gas														
	On-Pk Cons. (kWh)	0	0	0	0	0	2	1,140	593	0	0	0	0	1,735
	On-Pk Demand (kW)	0	0	0	0	0	0	8	5	0	0	0	0	8
Water														
	Cons. (kL)	5,505	5,004	4,932	3,705	2,416	1,324	1,038	1,258	1,935	3,113	4,218	5,074	39,522

Energy Consumption		
Building	1,569	MJ/(m2-year)
Source	4,707	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

Project Name: Final Year Project
Dataset Name: Final Year Project.trc

TRACE® 700 v6.2.6.5 calculated at 09:32 PM on 09/08/2011
Alternative - 2 Monthly Energy Consumption report Page 2 of 4

EQUIPMENT ENERGY CONSUMPTION
By University of Southern Queensland

Alternative: 2 295 Ann Street - VAV

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	661.7	596.5	575.2	388.1	200.3	61.8	26.7	31.0	109.5	316.7	456.5	600.5	4,024.3
Peak (kL/Hr)	1.0	1.0	0.9	0.6	0.4	0.2	0.1	0.1	0.2	0.6	0.7	0.9	1.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,778 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 405.8 kW] (Cooling Equipment)													
Electric (kWh)	182,923.6	170,647.6	164,413.0	132,929.5	78,408.9	43,218.2	33,837.7	40,340.9	62,289.9	107,146.2	151,885.8	172,441.3	1,340,482.6
Peak (kW)	375.9	375.9	348.3	347.5	241.7	155.4	131.0	155.7	212.3	301.9	355.7	370.3	375.9
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,515 kW / 47.22 kW]													
Electric (kWh)	35,135.2	31,735.0	35,135.2	34,001.8	35,135.2	31,406.6	29,993.3	30,741.5	33,616.8	35,135.2	34,001.8	35,135.2	401,172.6
Peak (kW)	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,594.0	4,270.9	4,297.4	3,705.0	2,416.1	1,324.2	1,037.9	1,258.1	1,934.7	3,112.8	4,100.5	4,444.4	36,496.0
Peak (kL/Hr)	8.5	8.5	8.3	8.4	6.9	4.9	4.3	5.1	6.4	7.9	8.5	8.5	8.5
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 346.2 kW] (Cooling Equipment)													
Electric (kWh)	37,204.3	29,835.8	25,110.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,446.0	25,213.7	121,810.0
Peak (kW)	206.0	210.2	191.9	154.6	0.0	0.0	0.0	0.0	0.0	0.0	164.9	190.6	210.2

APPENDIX K - MODELLING OUTPUT FOR REFERENCE BUILDING WITH VARIABLE AIR VOLUME AND CENTRAL AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Energy Consumption -------								
Alternative: 4	**reference build vav**												
Electric													
On-Pk Cons. (kWh)	737,103	668,481	690,488	597,316	545,228	476,833	478,768	489,829	509,829	592,649	629,978	702,265	7,118,766
On-Pk Demand (kW)	1,334	1,351	1,286	1,080	927	821	784	819	894	1,017	1,132	1,284	1,351
Gas													
On-Pk Cons. (kWh)	0	0	0	0	0	0	1,338	468	0	0	0	0	1,806
On-Pk Demand (kW)	0	0	0	0	0	0	11	5	0	0	0	0	11
Water													
Cons. (kL)	5,036	4,545	4,426	3,207	1,980	968	706	907	1,565	2,577	3,738	4,606	34,261

Energy Consumption

Building	1,333	MJ/(m2-year)
Source	4,000	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis

CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION
By University of Southern Queensland

Alternative: 4 reference build vav

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	128,758.0	116,297.7	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	1,516,023.1
Peak (kW)	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	719.8	650.3	625.6	424.3	223.8	74.1	37.4	45.9	133.6	321.5	499.1	652.5	4,407.8
Peak (kL/Hr)	1.1	1.1	1.0	0.7	0.5	0.2	0.1	0.1	0.3	0.7	0.8	1.0	1.1
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,391 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 502.4 kW] (Cooling Equipment)													
Electric (kWh)	236,500.5	206,497.5	204,633.5	136,214.8	80,222.1	39,183.3	28,497.9	35,785.5	62,789.4	109,068.1	164,067.6	215,630.7	1,519,090.6
Peak (kW)	466.5	462.6	432.6	358.3	237.0	158.9	130.5	151.0	209.9	294.9	406.3	449.5	466.5
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,612 kW / 49.04 kW]													
Electric (kWh)	36,484.5	32,953.7	36,484.4	35,307.6	36,484.5	32,346.6	30,760.1	31,571.6	34,624.1	36,484.5	35,307.5	36,484.5	415,293.5
Peak (kW)	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,908.2	4,312.3	4,425.9	3,206.6	1,979.6	967.6	706.2	907.2	1,565.4	2,576.5	3,738.4	4,606.3	33,900.3
Peak (kL/Hr)	8.8	8.7	8.4	7.7	5.7	4.2	3.6	4.1	5.3	6.8	8.3	8.6	8.8
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 428.6 kW] (Cooling Equipment)													
Electric (kWh)	6,309.3	11,367.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17,677.1
Peak (kW)	224.4	225.0	203.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	207.2	225.0

APPENDIX L - MODELLING OUTPUT FOR VARIABLE AIR VOLUME SYSTEM WITH FLOOR AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

------- Monthly Energy Consumption -------

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 2	**295 Ann Street - VAV (floor AHU)**													
Electric														
	On-Pk Cons. (kWh)	830,842	753,974	789,045	688,491	637,509	573,968	577,418	587,896	600,316	681,207	720,324	796,645	8,237,635
	On-Pk Demand (kW)	1,452	1,490	1,427	1,316	1,074	944	910	956	1,039	1,157	1,340	1,401	1,490
Gas														
	On-Pk Cons. (kWh)	0	0	0	0	0	139	844	362	0	0	0	0	1,344
	On-Pk Demand (kW)	0	0	0	0	0	1	6	3	0	0	0	0	6
Water														
	Cons. (kL)	5,492	4,991	4,925	3,694	2,416	1,321	1,006	1,237	1,933	3,113	4,203	5,063	39,393

Energy Consumption		
Building	1,543	MJ/(m2-year)
Source	4,628	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO2	No Data Available
SO2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 2   295 Ann Street - VAV (floor AHU)

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	-------	Monthly Consumption	-------										
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	672.6	608.0	588.2	399.2	212.5	72.6	33.6	39.5	119.2	329.1	465.7	610.9	4,151.1
Peak (kL/Hr)	1.0	1.0	0.9	0.7	0.4	0.2	0.1	0.1	0.2	0.6	0.7	0.9	1.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,719 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 405.8 kW] (Cooling Equipment)													
Electric (kWh)	188,385.0	170,117.7	169,904.9	132,381.3	78,342.5	43,091.5	32,502.9	39,514.4	62,155.6	107,029.9	151,208.9	177,855.2	1,352,489.8
Peak (kW)	382.2	373.1	370.0	343.4	239.6	155.0	130.3	154.7	210.5	298.8	352.0	375.6	382.2
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,515 kW / 47.22 kW]													
Electric (kWh)	35,135.2	31,735.0	35,135.2	34,001.8	35,135.2	31,401.8	29,979.9	30,728.8	33,631.9	35,135.2	34,001.8	35,135.2	401,156.8
Peak (kW)	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,706.0	4,261.2	4,413.1	3,693.9	2,415.6	1,320.7	1,006.0	1,237.1	1,932.8	3,112.8	4,086.3	4,556.8	36,742.3
Peak (kL/Hr)	8.6	8.5	8.5	8.4	6.8	4.9	4.3	5.1	6.3	7.8	8.4	8.5	8.6
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 346.2 kW] (Cooling Equipment)													
Electric (kWh)	32,101.9	29,677.9	20,213.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4,420.8	20,257.6	106,671.7
Peak (kW)	204.9	208.9	190.7	153.6	0.0	0.0	0.0	0.0	0.0	0.0	163.9	189.6	208.9

APPENDIX M - MODELLING OUTPUT FOR REFERENCE BUILDING WITH VARIABLE AIR VOLUME AND FLOOR AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		------- Monthly Energy Consumption -------												
Alternative: 4	**reference building - VAV floor AHU**													
Electric														
	On-Pk Cons. (kWh)	727,550	659,401	680,926	589,338	538,559	473,175	474,799	484,588	504,589	585,240	622,165	693,227	7,033,557
	On-Pk Demand (kW)	1,306	1,320	1,254	1,053	901	802	767	798	874	994	1,112	1,259	1,320
Gas														
	On-Pk Cons. (kWh)	0	0	0	0	0	0	42	16	0	0	0	0	58
	On-Pk Demand (kW)	0	0	0	0	0	0	0	0	0	0	0	0	0
Water														
	Cons. (kL)	5,059	4,562	4,444	3,232	2,009	1,010	743	944	1,596	2,618	3,760	4,626	34,603

Energy Consumption

Building	1,317	MJ/(m2-year)
Source	3,952	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis

CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION
By University of Southern Queensland

Alternative: 4 reference building - VAV floor AHU

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	128,758.0	116,297.7	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	1,516,023.1
Peak (kW)	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	739.8	667.9	643.7	442.9	246.7	92.0	52.0	61.8	152.2	343.2	516.9	671.0	4,629.9
Peak (kL/Hr)	1.1	1.2	1.0	0.8	0.5	0.3	0.2	0.2	0.3	0.7	0.9	1.0	1.2
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,353 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 502.4 kW] (Cooling Equipment)													
Electric (kWh)	237,561.8	207,332.3	205,346.9	137,293.2	81,349.0	41,217.4	30,372.9	37,655.7	64,089.8	110,544.9	165,104.1	216,475.0	1,534,343.0
Peak (kW)	464.7	461.5	473.2	362.3	239.1	160.8	132.2	152.3	211.3	297.4	411.1	474.3	474.3
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,612 kW / 49.04 kW]													
Electric (kWh)	36,484.5	32,953.7	36,484.4	35,307.6	36,484.5	32,342.6	30,754.5	31,567.3	34,621.9	36,484.5	35,307.5	36,484.5	415,277.5
Peak (kW)	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,930.9	4,330.7	4,443.9	3,231.6	2,009.3	1,009.8	743.0	944.4	1,596.2	2,617.6	3,760.1	4,626.4	34,243.6
Peak (kL/Hr)	8.8	8.7	8.9	7.7	5.8	4.3	3.7	4.2	5.3	6.9	8.3	8.9	8.9
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 428.6 kW] (Cooling Equipment)													
Electric (kWh)	6,291.9	11,333.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17,625.6
Peak (kW)	223.6	224.3	202.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	206.6	224.3

APPENDIX N - MODELLING OUTPUT FOR ACTIVE CHILLED BEAMS WITH CENTRAL AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

------- Monthly Energy Consumption -------

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 3	**295 Ann Street - Active Chilled Beams**													
Electric														
	On-Pk Cons. (kWh)	829,368	750,740	796,045	716,660	678,089	622,909	633,873	638,472	638,803	708,422	736,225	804,161	8,553,768
	On-Pk Demand (kW)	1,320	1,326	1,292	1,220	1,031	957	928	953	1,004	1,088	1,241	1,291	1,326
Gas														
	On-Pk Cons. (kWh)	696	156	2,410	15,832	19,082	24,629	46,696	29,934	2,426	22,987	5,178	3,126	173,152
	On-Pk Demand (kW)	10	1	29	105	190	149	223	164	55	159	53	31	223
Water														
	Cons. (kL)	5,449	4,940	4,947	3,866	2,631	1,560	1,274	1,493	2,144	3,273	4,300	5,080	40,957

Energy Consumption		
Building	1,634	MJ/(m2-year)
Source	4,840	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 3 295 Ann Street - Active Chilled Beams

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
	-------				Monthly Consumption			-------					
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	689.3	622.3	621.2	460.9	280.1	136.6	92.0	101.3	194.2	371.1	517.3	642.2	4,728.4
Peak (kL/Hr)	1.0	1.0	0.9	0.7	0.5	0.3	0.2	0.2	0.4	0.6	0.8	0.9	1.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,980 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 405.8 kW] (Cooling Equipment)													
Electric (kWh)	192,748.0	168,661.9	176,264.6	137,955.1	84,135.2	49,001.7	41,138.1	47,340.0	66,848.8	111,018.6	159,686.8	184,017.3	1,418,816.0
Peak (kW)	367.3	380.8	370.3	352.2	239.7	166.4	137.3	161.5	213.2	294.1	352.3	362.5	380.8
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,515 kW / 47.22 kW]													
Electric (kWh)	35,135.2	31,735.0	35,135.2	34,001.8	35,135.2	31,865.6	30,276.8	31,030.6	33,951.1	35,135.2	34,001.8	35,135.2	402,538.6
Peak (kW)	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,806.2	4,236.6	4,566.4	3,865.5	2,630.8	1,560.0	1,274.0	1,492.9	2,144.0	3,273.0	4,300.3	4,705.1	38,854.8
Peak (kL/Hr)	8.4	8.5	8.5	8.4	6.8	5.3	4.5	5.3	6.4	7.8	8.4	8.4	8.5
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 346.2 kW] (Cooling Equipment)													
Electric (kWh)	26,341.0	28,639.4	15,066.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15,072.7	85,120.0
Peak (kW)	195.7	198.7	183.2	149.7	0.0	0.0	0.0	0.0	0.0	0.0	159.4	182.4	198.7

APPENDIX O - MODELLING OUTPUT FOR REFERENCE BUILDING WITH ACTIVE CHILLED BEAMS AND CENTRAL AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		------- Monthly Energy Consumption -------												
Alternative: 4		**reference build acb**												
Electric														
	On-Pk Cons. (kWh)	735,366	662,617	700,129	621,046	572,499	515,937	522,258	528,544	537,806	604,814	646,418	710,942	7,358,374
	On-Pk Demand (kW)	1,223	1,224	1,119	1,007	897	819	790	813	872	952	1,046	1,132	1,224
Gas														
	On-Pk Cons. (kWh)	1,060	184	1,898	11,782	3,083	4,790	18,340	9,082	0	12,746	3,329	2,654	68,946
	On-Pk Demand (kW)	13	3	19	81	98	49	113	80	0	102	44	24	113
Water														
	Cons. (kL)	4,982	4,492	4,438	3,283	1,943	944	691	885	1,546	2,501	3,791	4,605	34,101

Energy Consumption		
Building	1,391	MJ/(m2-year)
Source	4,148	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO2	No Data Available
SO2	No Data Available
NOX	No Data Available

Project Name: Final Year Project
Dataset Name: Final year project5.trc

TRACE® 700 v6.2.6.5 calculated at 10:10 PM on 08/14/2011
Alternative - 4 Monthly Energy Consumption report Page 1 of 1

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 4 reference build acb

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Lights													
Electric (kWh)	128,758.0	116,297.7	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	1,516,023.1
Peak (kW)	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	726.7	655.4	650.5	463.3	229.8	81.6	46.2	56.3	146.0	306.5	533.6	672.8	4,568.7
Peak (kL/Hr)	1.0	1.0	0.9	0.7	0.5	0.3	0.2	0.2	0.4	0.6	0.8	1.0	1.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,781 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 502.4 kW] (Cooling Equipment)													
Electric (kWh)	239,340.2	215,747.1	204,103.1	139,166.5	79,665.7	39,037.3	28,801.3	35,549.4	62,796.1	106,785.6	166,043.0	214,277.6	1,531,312.6
Peak (kW)	467.4	472.1	458.3	346.6	236.2	158.3	129.6	151.9	211.2	291.0	384.7	471.3	472.1
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,612 kW / 49.04 kW]													
Electric (kWh)	36,484.5	32,953.7	36,484.4	35,307.6	36,484.5	32,305.5	30,722.9	31,537.0	34,617.6	36,484.5	35,307.5	36,484.5	415,174.1
Peak (kW)	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,981.7	4,492.5	4,437.9	3,283.0	1,942.7	943.9	691.4	885.2	1,546.4	2,501.1	3,791.2	4,604.5	34,101.4
Peak (kL/Hr)	8.7	8.8	8.7	7.5	5.7	4.2	3.6	4.1	5.3	6.7	7.9	8.8	8.8
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 428.6 kW] (Cooling Equipment)													
Peak (kW)	212.2	212.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	212.4
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,228 kW / 41.83 kW]													
Peak (kW)	41.8	41.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.8

APPENDIX P - MODELLING OUTPUT FOR ACTIVE CHILLED BEAMS WITH FLOOR AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
		------- Monthly Energy Consumption -------												
Alternative: 3		**295 Ann Street - Chilled beam floor ahu**												
Electric														
	On-Pk Cons. (kWh)	820,470	742,467	786,893	707,319	668,826	614,098	624,823	629,371	629,917	699,490	727,697	796,002	8,447,375
	On-Pk Demand (kW)	1,305	1,314	1,279	1,207	1,018	945	916	940	992	1,075	1,228	1,278	1,314
Gas														
	On-Pk Cons. (kWh)	994	202	2,692	16,107	19,202	25,496	48,346	30,930	2,595	23,525	5,650	3,475	179,215
	On-Pk Demand (kW)	13	2	32	107	196	153	229	166	57	162	56	32	229
Water														
	Cons. (kL)	5,431	4,925	4,930	3,851	2,614	1,546	1,263	1,480	2,129	3,257	4,285	5,064	40,773

Energy Consumption		
Building	1,615	MJ/(m2-year)
Source	4,781	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION
By University of Southern Queensland

Alternative: 3 295 Ann Street - Chilled beam floor ahu

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	688.9	622.4	621.2	461.1	279.7	136.1	91.7	101.0	193.9	371.1	517.2	642.4	4,726.6
Peak (kL/Hr)	1.0	1.0	0.9	0.7	0.5	0.3	0.2	0.2	0.4	0.6	0.8	0.9	1.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,977 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 405.8 kW] (Cooling Equipment)													
Electric (kWh)	191,950.0	168,035.8	175,540.5	137,364.5	83,632.9	48,695.1	40,866.1	47,014.7	66,443.2	110,483.8	159,004.8	183,340.0	1,412,371.4
Peak (kW)	365.6	378.9	368.5	350.5	238.6	165.6	136.3	160.8	212.3	292.7	352.3	374.7	378.9
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,515 kW / 47.22 kW]													
Electric (kWh)	35,135.2	31,735.0	35,135.2	34,001.8	35,135.2	31,839.1	30,260.7	31,015.1	33,947.7	35,135.2	34,001.8	35,135.2	402,477.1
Peak (kW)	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2	47.2
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,789.4	4,222.7	4,550.4	3,850.7	2,613.8	1,546.1	1,262.7	1,480.3	2,128.7	3,257.1	4,284.6	4,690.2	38,676.6
Peak (kL/Hr)	8.4	8.5	8.5	8.4	6.8	5.2	4.5	5.2	6.4	7.7	8.4	8.6	8.6
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 346.2 kW] (Cooling Equipment)													
Electric (kWh)	26,273.2	28,569.9	15,029.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15,034.8	84,907.1
Peak (kW)	194.8	198.9	182.8	149.3	0.0	0.0	0.0	0.0	0.0	0.0	158.9	182.0	198.9

APPENDIX Q - MODELLING OUTPUT FOR REFERENCE BUILDING WITH ACTIVE CHILLED BEAMS AND FLOOR AIR HANDLING PLANT

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

------- Monthly Energy Consumption -------

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 4	**reference building - ACB floor AHU**													
Electric														
	On-Pk Cons. (kWh)	727,844	656,334	693,233	613,828	565,245	509,000	515,118	521,371	530,770	597,501	640,099	704,535	7,274,878
	On-Pk Demand (kW)	1,213	1,214	1,108	997	887	809	780	803	862	942	1,035	1,118	1,214
Gas														
	On-Pk Cons. (kWh)	1,211	138	1,935	11,633	3,080	4,916	18,740	9,262	0	13,033	3,809	2,743	70,502
	On-Pk Demand (kW)	14	1	20	81	98	50	114	80	0	106	45	25	114
Water														
	Cons. (kL)	4,971	4,482	4,426	3,271	1,932	936	684	877	1,537	2,491	3,780	4,593	33,980

Energy Consumption		
Building	1,375	MJ/(m2-year)
Source	4,101	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 4 reference building - ACB floor AHU

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	128,758.0	116,297.7	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	128,758.1	124,604.7	128,758.2	124,604.7	128,758.0	1,516,023.1
Peak (kW)	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1	173.1
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	726.8	655.3	650.1	462.4	228.7	81.1	45.9	55.9	145.2	305.6	533.4	672.7	4,563.3
Peak (kL/Hr)	1.0	1.0	0.9	0.7	0.5	0.3	0.2	0.2	0.4	0.6	0.8	1.0	1.0
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,780 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=2,110 kW / 502.4 kW] (Cooling Equipment)													
Electric (kWh)	238,749.1	215,147.1	203,498.6	138,655.8	79,342.3	38,812.4	28,598.6	35,315.5	62,466.8	106,414.3	165,544.6	213,689.2	1,526,234.4
Peak (kW)	467.9	471.3	456.8	345.6	235.6	157.6	129.0	151.2	210.5	290.2	383.5	466.6	471.3
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,612 kW / 49.04 kW]													
Electric (kWh)	36,484.5	32,953.7	36,484.4	35,307.6	36,484.5	32,300.9	30,715.6	31,528.6	34,617.6	36,484.5	35,307.5	36,484.5	415,153.9
Peak (kW)	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0	49.0
Cooling tower for Cent. Chillers													
Make Up Water (kL)	4,970.7	4,481.6	4,425.7	3,270.9	1,932.2	936.1	683.7	877.3	1,537.2	2,491.0	3,780.2	4,593.0	33,979.6
Peak (kL/Hr)	8.7	8.8	8.7	7.4	5.7	4.2	3.6	4.1	5.3	6.7	7.9	8.8	8.8
Cnst vol chill water pump (Misc Accessory Equipment)													
Electric (kWh)	29,760.0	26,880.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	29,760.0	28,800.0	29,760.0	28,800.0	29,760.0	350,400.0
Peak (kW)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Cnst vol cnd water pump - Low Eff (Misc Accessory Equipment)													
Electric (kWh)	14,880.0	13,440.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	14,880.0	14,400.0	14,880.0	14,400.0	14,880.0	175,200.0
Peak (kW)	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Water-cooled chiller - 002 [Clg Nominal Capacity/F.L.Rate=1,800 kW / 428.6 kW] (Cooling Equipment)													
Peak (kW)	211.4	212.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	212.0
Cooling tower for Cent. Chillers [Design Heat Rejection/F.L.Rate=2,228 kW / 41.83 kW]													
Peak (kW)	41.8	41.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.8

APPENDIX R - MODELLING OUTPUT FOR TRIGENERATION WITH ZONE MIXING BOXES AND CENTRAL AIR HANDLING

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

------- Monthly Energy Consumption -------

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 4	**295 Ann Street - Trigeneration**													
Electric														
	On-Pk Cons. (kWh)	446,447	406,057	415,105	351,769	318,999	271,731	242,258	256,942	289,249	342,496	371,524	422,452	4,135,028
	On-Pk Demand (kW)	954	998	873	744	597	512	480	494	549	649	754	825	998
Gas														
	On-Pk Cons. (kWh)	1,279,765	1,153,517	1,282,933	1,261,267	1,363,536	1,385,605	1,459,495	1,429,495	1,322,075	1,319,965	1,247,837	1,284,958	15,790,446
	On-Pk Demand (kW)	1,753	1,734	1,775	1,887	2,037	2,151	2,188	2,169	2,083	1,976	1,813	1,779	2,188
Water														
	Cons. (kL)	7,094	6,413	6,537	5,366	4,380	3,354	3,076	3,283	3,827	4,963	5,795	6,689	60,778

Energy Consumption		
Building	3,731	MJ/(m2-year)
Source	5,436	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 4   295 Ann Street - Trigeneration

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
					------- Monthly Consumption -------								
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	666.3	599.7	582.6	401.7	224.1	87.4	46.0	49.3	129.3	347.2	464.7	607.3	4,205.5
Peak (kL/Hr)	1.0	1.0	0.9	0.6	0.4	0.2	0.1	0.1	0.2	0.6	0.7	0.9	1.0
Cgn 1: Cogeneration Plant													
Cgn 1: Caterpillar gas 500 kW (Cogen Equipment)													
Gas (kWh)	1,275,241.8	1,151,831.3	1,275,241.8	1,234,104.9	1,275,241.8	1,234,104.9	1,275,241.8	1,275,241.8	1,234,104.9	1,275,241.8	1,234,104.9	1,275,241.8	15,014,943.0
Peak (kW)	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0
Cgn 1: Caterpillar gas 500 kW (Misc Accessory Equipment)													
Electric (kWh)	744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0	8,760.0
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cgn 1: Caterpillar gas 500 kW (Misc Accessory Equipment)													
Make Up Water (kL)	685.1	613.6	669.3	632.3	626.8	589.4	602.0	615.5	617.6	651.8	643.4	674.9	7,621.8
Peak (kL/Hr)	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,778 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=500.0 kW / 406.5 kW] (Cooling Equipment)													
Steam (kWh)	298,198.9	269,112.5	294,724.0	278,407.1	278,120.9	260,350.1	248,067.7	256,757.3	264,767.4	283,051.8	281,242.7	295,761.0	3,308,561.5
Peak (kW)	409.2	408.8	405.4	396.8	385.3	375.1	370.4	372.1	380.6	391.3	400.3	406.7	409.2
Cooling Tower for 2-stage Abs. [Design Heat Rejection/F.L.Rate=906.5 kW / 14.44 kW]													
Electric (kWh)	10,742.0	9,702.5	10,742.0	10,395.5	10,742.0	10,395.5	10,593.1	10,723.0	10,395.5	10,742.0	10,395.5	10,742.0	126,310.7
Peak (kW)	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
Cooling Tower for 2-stage Abs.													
Make Up Water (kL)	2,308.7	2,084.5	2,296.8	2,199.2	2,239.6	2,136.2	2,067.1	2,127.4	2,152.2	2,256.6	2,209.0	2,300.3	26,377.6
Peak (kL/Hr)	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.1	3.1	3.1	3.1

APPENDIX S - MODELLING OUTPUT FOR TRIGENERATION COMBINED WITH VARIABLE AIR VOLUME AND FLOOR AIR HANDLING

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

------- Monthly Energy Consumption -------

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 2	**295 Ann Street - Trigeneration VAV Floor**													
Electric														
	On-Pk Cons. (kWh)	420,323	384,141	387,841	319,771	249,617	182,112	169,654	179,139	210,148	298,055	343,925	393,762	3,538,487
	On-Pk Demand (kW)	923	962	827	699	554	436	406	449	526	620	723	794	962
Gas														
	On-Pk Cons. (kWh)	1,275,242	1,151,831	1,275,242	1,234,105	1,275,242	1,234,244	1,276,086	1,275,603	1,234,105	1,275,242	1,234,105	1,275,242	15,016,288
	On-Pk Demand (kW)	1,714	1,714	1,714	1,714	1,714	1,715	1,720	1,717	1,714	1,714	1,714	1,714	1,720
Water														
	Cons. (kL)	6,994	6,345	6,409	5,118	3,812	2,460	2,162	2,410	3,197	4,563	5,632	6,551	55,653

Energy Consumption		
Building	3,474	MJ/(m2-year)
Source	4,948	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION

By University of Southern Queensland

Alternative: 2   295 Ant Street - Trigeneration VAV Floor

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	672.6	608.0	588.2	399.2	212.5	72.6	33.6	39.5	119.2	329.1	465.7	610.9	4,151.1
Peak (kL/Hr)	1.0	1.0	0.9	0.7	0.4	0.2	0.1	0.1	0.2	0.6	0.7	0.9	1.0
Cgn 1: Cogeneration Plant													
Cgn 1: Caterpillar gas 500 kW (Cogen Equipment)													
Gas (kWh)	1,275,241.8	1,151,831.3	1,275,241.8	1,234,104.9	1,275,241.8	1,234,104.9	1,275,241.8	1,275,241.8	1,234,104.9	1,275,241.8	1,234,104.9	1,275,241.8	15,014,943.0
Peak (kW)	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0
Cgn 1: Caterpillar gas 500 kW (Misc Accessory Equipment)													
Electric (kWh)	744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0	8,760.0
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cgn 1: Caterpillar gas 500 kW (Misc Accessory Equipment)													
Make Up Water (kL)	685.1	613.6	669.3	632.3	626.8	637.0	754.7	713.6	626.5	651.8	643.4	674.9	7,928.9
Peak (kL/Hr)	1.2	1.2	1.2	1.2	1.2	1.4	1.5	1.4	1.3	1.2	1.2	1.2	1.5
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,719 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=500.0 kW / 406.5 kW] (Cooling Equipment)													
Steam (kWh)	298,198.9	269,112.5	294,724.0	278,407.1	264,387.2	176,436.0	140,599.4	160,789.8	222,080.3	277,958.1	281,242.7	295,761.0	2,959,697.0
Peak (kW)	409.2	408.8	405.4	396.8	385.3	375.1	370.4	372.1	380.6	391.3	400.3	406.7	409.2
Cooling Tower for 2-stage Abs. [Design Heat Rejection/F.L.Rate=906.5 kW / 14.44 kW]													
Electric (kWh)	10,742.0	9,702.5	10,742.0	10,395.5	10,742.0	8,951.1	7,958.5	8,500.9	10,109.0	10,742.0	10,395.5	10,742.0	119,723.2
Peak (kW)	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
Cooling Tower for 2-stage Abs.													
Make Up Water (kL)	2,308.7	2,084.5	2,296.8	2,199.2	2,138.9	1,477.1	1,188.2	1,351.2	1,829.6	2,219.5	2,209.0	2,300.3	23,603.1
Peak (kL/Hr)	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.1	3.1	3.1	3.1

APPENDIX T - MODELLING OUTPUT FOR TRIGENERATION COMBINED WITH ACTIVE CHILLED BEAMS AND FLOOR AIR HANDLING

MONTHLY ENERGY CONSUMPTION

By University of Southern Queensland

------- Monthly Energy Consumption -------

Utility		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Alternative: 3	**295 Ann Street - Tri Chilled Beams Floor**													
Electric														
	On-Pk Cons. (kWh)	412,033	372,210	387,866	337,196	291,578	222,335	214,540	223,971	250,308	327,473	353,124	395,488	3,788,124
	On-Pk Demand (kW)	697	717	667	587	499	436	411	433	478	540	607	660	717
Gas														
	On-Pk Cons. (kWh)	1,276,236	1,152,034	1,277,933	1,250,214	1,294,444	1,259,601	1,323,587	1,306,172	1,236,700	1,298,766	1,239,755	1,278,717	15,194,159
	On-Pk Demand (kW)	1,727	1,716	1,746	1,821	1,910	1,867	1,943	1,880	1,771	1,876	1,770	1,746	1,943
Water														
	Cons. (kL)	6,929	6,277	6,411	5,270	4,053	2,740	2,405	2,672	3,456	4,733	5,709	6,550	57,205

Energy Consumption		
Building	3,555	MJ/(m2-year)
Source	5,123	MJ/(m2-year)
Floor Area	19,229	m2

Environmental Impact Analysis	
CO_2	No Data Available
SO_2	No Data Available
NOX	No Data Available

EQUIPMENT ENERGY CONSUMPTION
By University of Southern Queensland

Alternative: 3 295 Ann Street - Tri Chilled Beams Floor

------- Monthly Consumption -------

Equipment - Utility	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Total
Lights													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Misc. Ld													
Electric (kWh)	214,596.9	193,829.4	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	214,596.9	207,674.4	214,596.9	207,674.4	214,596.9	2,526,705.3
Peak (kW)	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4	288.4
Cooling Coil Condensate													
Recoverable Water (kL)	688.9	622.4	621.2	461.1	279.7	136.1	91.7	101.0	193.9	371.1	517.2	642.4	4,726.6
Peak (kL/Hr)	1.0	1.0	0.9	0.7	0.5	0.3	0.2	0.2	0.4	0.6	0.8	0.9	1.0
Cgn 1: Cogeneration Plant													
Cgn 1: Caterpillar gas 500 kW (Cogen Equipment)													
Gas (kWh)	1,275,241.8	1,151,831.3	1,275,241.8	1,234,104.9	1,275,241.8	1,234,104.9	1,275,241.8	1,275,241.8	1,234,104.9	1,275,241.8	1,234,104.9	1,275,241.8	15,014,943.0
Peak (kW)	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0	1,714.0
Cgn 1: Caterpillar gas 500 kW (Misc Accessory Equipment)													
Electric (kWh)	744.0	672.0	744.0	720.0	744.0	720.0	744.0	744.0	720.0	744.0	720.0	744.0	8,760.0
Peak (kW)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Cgn 1: Caterpillar gas 500 kW (Misc Accessory Equipment)													
Make Up Water (kL)	685.1	613.6	669.3	632.3	626.8	606.6	645.4	647.0	617.6	651.8	643.4	674.9	7,713.8
Peak (kL/Hr)	1.2	1.2	1.2	1.2	1.2	1.3	1.4	1.4	1.2	1.2	1.2	1.2	1.4
Cpl 1: Cooling plant - 001 [Sum of dsn coil capacities=2,977 kW]													
Water-cooled chiller - 001 [Clg Nominal Capacity/F.L.Rate=500.0 kW / 406.5 kW] (Cooling Equipment)													
Steam (kWh)	298,198.9	269,112.5	294,724.0	278,407.1	277,056.3	204,159.3	174,825.8	190,714.1	243,576.1	283,051.8	281,242.7	295,761.0	3,090,829.8
Peak (kW)	409.2	408.8	405.4	396.8	385.3	375.1	370.4	372.1	380.6	391.3	400.3	406.7	409.2
Cooling Tower for 2-stage Abs. [Design Heat Rejection/F.L.Rate=906.5 kW / 14.44 kW]													
Electric (kWh)	10,742.0	9,702.5	10,742.0	10,395.5	10,742.0	9,667.3	8,971.8	9,349.4	10,395.5	10,742.0	10,395.5	10,742.0	122,587.6
Peak (kW)	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
Cooling Tower for 2-stage Abs.													
Make Up Water (kL)	2,308.7	2,084.5	2,296.8	2,199.2	2,231.8	1,704.2	1,480.2	1,604.1	1,995.5	2,256.6	2,209.0	2,300.3	24,670.9
Peak (kL/Hr)	3.1	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0	3.1	3.1	3.1	3.1