City of Mississauga | White Paper

Diving into Natatorium Environment

Key Elements for Maintaining Efficient and "Cool" Pools

2021

Prepared by

Energy Management

(Facilities & Property Management)

The purpose of this white paper is to analyze and present various aspects of the natatorium environment, which influence the City's indoor pools performance.

The study looks at design considerations, different dehumidification technologies, equipment installation and maintenance to provide guidance for future implementations.

The intent is to have a comfortable and energy efficient natatorium space.

KEY TAKEAWAYS

- Natatoriums require 24/7 conditioning for occupant comfort and building envelope protection
- Effective conditioning of the space is affected by many factors including the water temperature set point, level of activity in the pool, chemicals, building envelope, space design, etc.
- Several design challenges exist, with primary ones being dual environmental control, natatorium pressurization and condensation
- The two technology for pool dehumidification used at City of Mississauga: Dectron and Engineered Air have unique features that impact the operation and maintenance in various ways
- From an energy perspective, Dectron units consume lower natural gas and Engineered Air units consume lower electricity. Due to the energy mix and utility rates in Ontario, Engineered Air units provide utility cost savings, while Dectron units provide greenhouse gas (GHG) savings
- Indoor vs. outdoor installation of the dehumidification units has an impact on the energy efficiency, operation and maintenance cost

Introduction

City of Mississauga owns and operates a number of pools including nine natatoriums to provide for the aquatics demand of its residents. Each of these natatoriums are a single space with a combination of a lap pool and either a therapy pool or a hot tub. These natatoriums are a unique environment where humidity control is required 24 hours a day and year-round. Figure 1 shows a typical natatorium schematic.

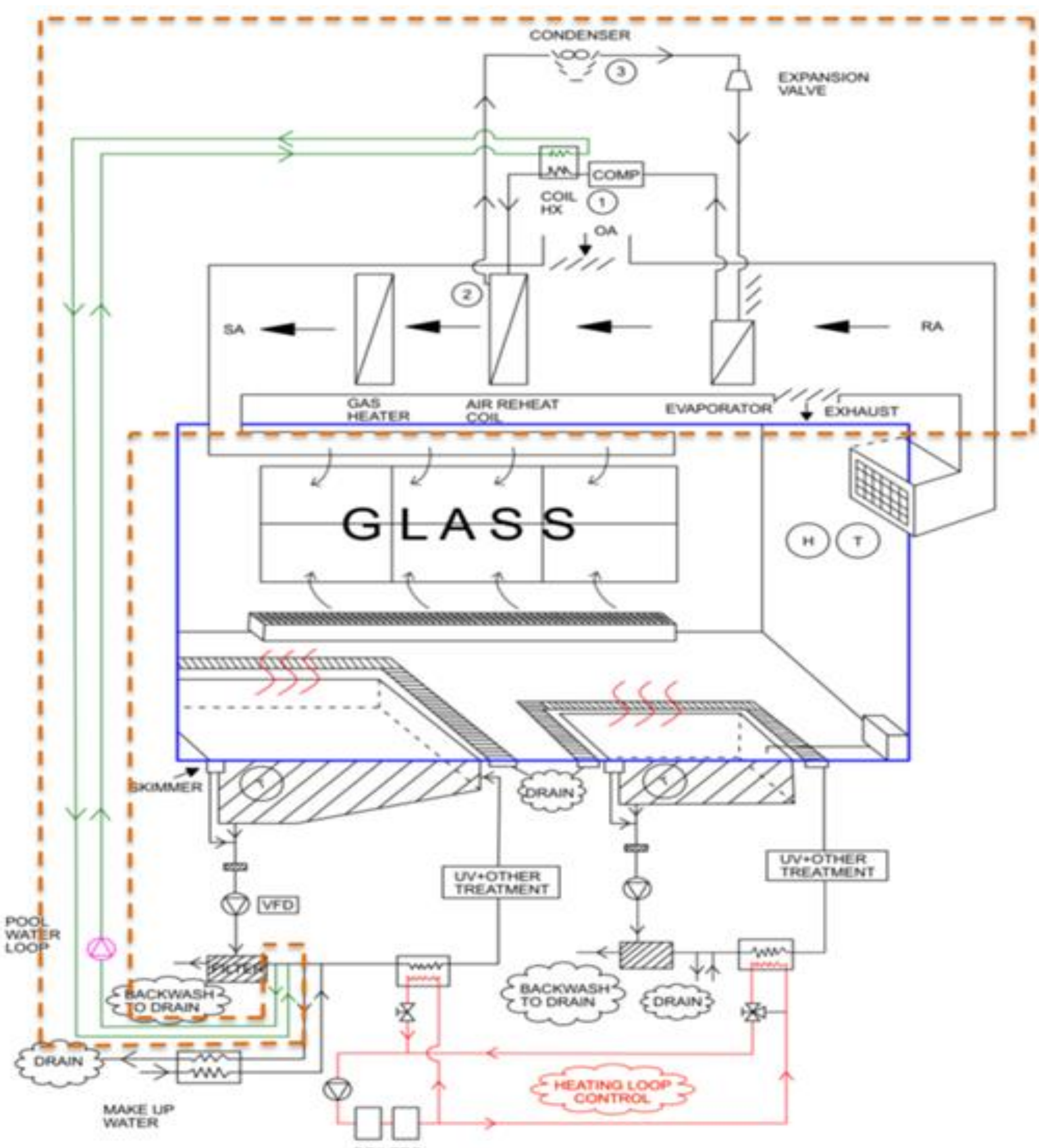

Figure 1: Natatorium schematic depicting main equipment and process flow

The pool dehumidification unit is the equipment tasked with achieving and maintaining comfortable space conditions in the natatorium. It accomplishes this by conditioning the indoor space (temperature and relative humidity), while ensuring adequate ventilation. Effective conditioning of the space, however, is affected by many factors including the water temperature set point, level of activity in the pool, chemicals, building envelope, space design, among other things. This creates multiple challenges such as the formation of condensation in the winter on cold surfaces, which can accelerate corrosion, rot and mold growth within the natatorium.

The relative humidity, space and water temperature should be set to achieve occupant comfort but also to optimize the energy requirement. Keeping the space temperature above the water temperature reduces evaporation, thereby reducing the quantity of water in the air thus impacting the dehumidification effort.

The recommended ASHRAE set points are in Table 1 below. Actual lap pool temperature set point recommendations are determined by the pool activities, such as competition swim, recreation swim, etc.

Table 1: ASHRAE recommended set points for different pool types

Parameter	**Lap Pool**	**Therapy Pool**	**Hot Tub**
Water Temperature Set point	26 – 29°C (80 - 85°F)	32-35°C (90-95°F)	36-40°C (97-104°F)
Space Temperature	Recommended to be 2 to 4°F greater than water temperature but <= 86°F (comfort threshold)		
Relative Humidity	Recommended to be between 50% to 60%		

Design Considerations

Dual Environmental Control

The ideal air temperature is recommended to be a fixed offset above the water temperature – having two pools with different set points in the same space presents a unique challenge. The air temperature set point is determined by the lap pool, however, this means that persons leaving the therapy pool typically at 35°C are immediately faced with 30°C air, making them feel cool which can present some discomfort. Due to the air/water temperature differential, there is a greater amount of evaporation from the hot tub and therapy pool compared to the lap pool (excluding consideration for surface area and activity level). The impact that this has on the pool dehumidification unit is dependent on the air distribution and circulation as well as the location of the sensors used to control the unit.

Natatorium Air Quality

Water can have an impact on the quality of air above it, through the process of evaporation. While chemical treatment is required to maintain safe pool water conditions, it is important to limit the amount used for many reasons. The chemicals, specifically chlorine, is used to neutralize contaminants, however a by-product of that is chloramines. Chloramines are responsible for the strong odors in a pool space. Additionally, as a result of pool water evaporation, the chemical laden corrosive air gets deposited on surfaces throughout the space accelerating the deterioration over time.

When there are too much chemicals in the air, one way to restore air quality is to purge the contaminated air in the space and replace it with fresh air. This works well, however, it has an energy penalty. To mitigate this challenge, designers seek to ensure proper water filtration which reduces the level of contaminants, and amount of chemicals used in the first place.

Natatorium Pressurization

Negative pressure in the natatorium is required to prevent moist, chemical laden air from migrating into adjacent spaces. In the absence of the physical barrier between natatorium and adjacent space, maintaining a negative pressure in the natatorium is another challenge.

Condensation

Glass is aesthetically appealing, however as a result of the reduced insulation effect of glass relative to walls, more condensation occurs during the winter on glass surfaces. Strategies to address the condensation challenge should be considered at the design stage, as it requires air to be specifically directed to 'wash' the glass.

Other Factors

Other elements, which are important for a natatorium and its energy use, include building orientation and building envelope. For example, South facing walls will see more sun and will be warmer than their north facing counterparts. This will affect the energy requirements to condition the space in various seasons.

A vapor barrier that envelopes the entire building has to be present and installed without tears or broken seams which can allow moisture damage the building structure.

Technology

Overview

There are two different types of pool dehumidification systems installed to provide comfortable temperatures and to remove excess moisture content from the natatorium space. The manufacturers of these pool dehumidifiers are Dectron and Engineered Air. Their dehumidifiers are designed with proprietary and distinctive technology to provide and maintain a comfortable natatorium environment – the City of Mississauga has five Dectron and four Engineered Air units installed.

Configuration

Engineered Air units in the City are supplied with the following (as shown in Figure 2);

- One supply fan
- One return fan
- Six compressors
- Continuously modulating outdoor air damper (OAD)
- Return air damper (RAD)
- Exhaust air damper (EAD)
- Two heat exchangers (HX)
- Bypass damper

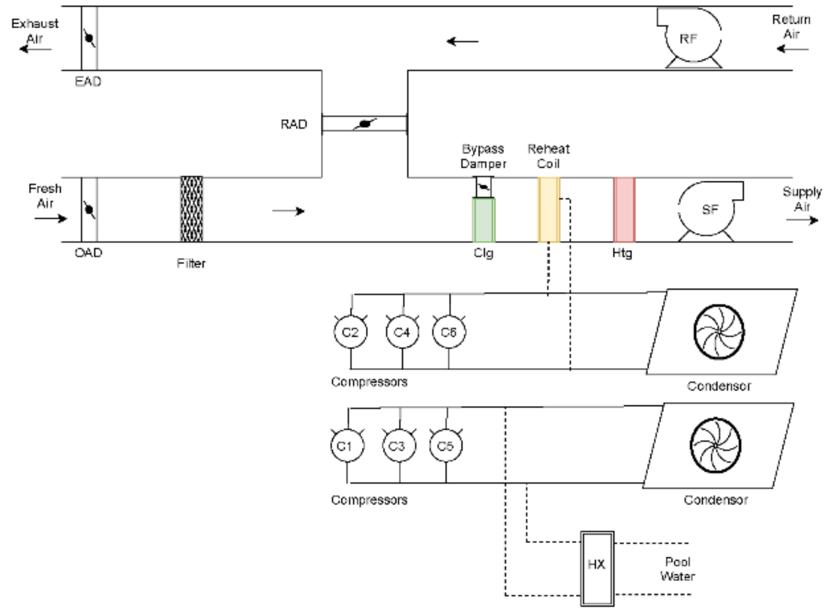

Figure 2: Engineered Air Pool Dehumidification Unit

Dectron units in the City are supplied with the following (as shown in Figure 3);

- One (or multiple small) supply fan
- Two exhaust fans
- Two compressors
- Open/Close outdoor damper
- Return air damper
- Two exhaust air dampers
- Three heat exchangers
- Bypass damper

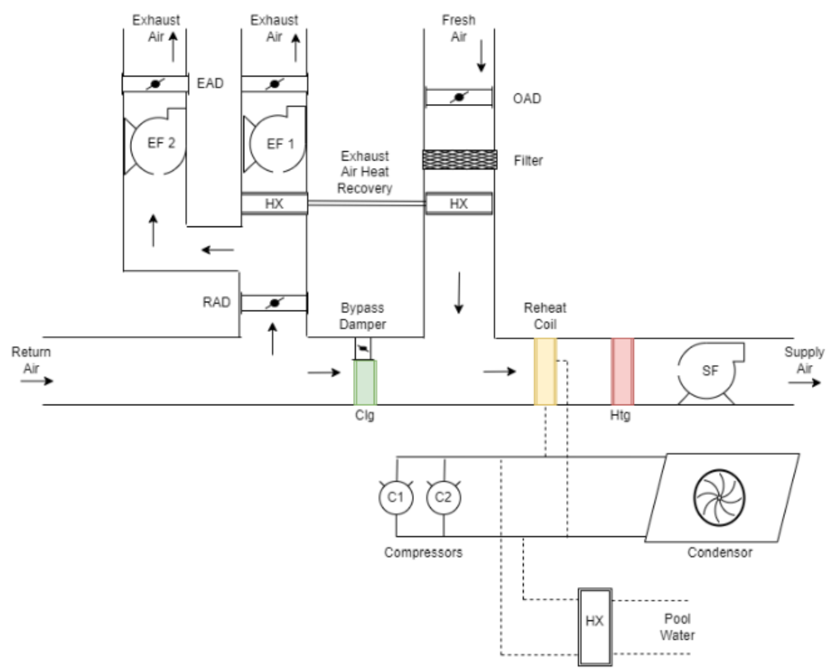

Figure 3: Dectron Pool Dehumidification Unit

Comparison of Technologies

Based on the unit specifications, the comparison of the technologies modes of operation are summarized in Table 2 below:

Table 2: Modes of Operation Comparison

Modes	**Engineered Air**	**Dectron**
1.0 Unit ON	• Outdoor damper open to minimum position • Fans run continuously	• Outdoor damper open to minimum position • Fans run continuously
1.1 Dehumidification Mode	• OAT[1]> 50°F: Mechanical dehumidification available, Recovered Heat and Gas heating • OAT <50°F: Free Dehumidification available and gas heating	• OAT >50°F: Mechanical dehumidification available, Recovered Heat and Gas heating • OAT <50°F: Same as above
1.2 Cooling Mode[2]	• OAT > 50°F: Mechanical cooling available • OAT <50°F: Mechanical cooling lockout	• OAT > 50°F: Mechanical cooling available • OAT <50°F: Same as above
1.3 Heating Mode	• Upon demand and after heat recovery	• Upon demand and after heat recovery
1.4 Heat Recovery[3]	• OAT > 50°F: Heat recovery available • OAT <50°F: Heat Recovery not available • Odd numbered compressors supply recovered heat to pool • Even numbered compressors supply recovered heat to air	• OAT > 50°F: Heat recovery available • OAT <50°F: same as above • Both compressors supply recovered heat to pool and air simultaneously
1.5 Exhaust Air Heat Recovery to Fresh Air	• No heat recovery available in installed units	• Heat recovery available in installed units

[1] OAT: Outdoor Air Temperature.

[2] Free cooling economizer function is an optional feature available for Dectron units but not installed/enabled for City of Mississauga installations. The mode operates between an outdoor dew point range (default is 55°F to 65°F).

[3] Available whenever compressors are ON.

Modes	Engineered Air	Dectron
2.0 Unit OFF	• Outdoor damper are closed • Fans shut off	• Outdoor damper are closed • Fans shut off

Further analysis was completed to quantify Dectron's annual energy, cost and GHG savings compared to Engineered Air for various modes of operation. In summary, Dectron units consume 256,000 kWh of additional electricity but 89,725 m^3 less natural gas compared to Engineered Air units. As a result, Dectron units are associated with GHG savings of 156 tonnes but utility cost increase of $3,490. The savings are summarized in Table 3 below.

Table 3: Annual Dectron Saving's comparison over Engineered Air[4]

Modes	Electricity Savings	Gas Savings	Cost Savings	GHG Savings
1.1 Dehumidification Mode	-186,000 kWh	57,950 m^3	-$5,400	100 tonne
1.4 Heat recovery	N/A	13,900 m^3	*$5,490*	26 tonne
1.5 Exhaust Air Heat Recovery to Fresh air	-70,000 kWh	17,875 m^3	-$3,580	30 tonne
Totals	**-256,000 kWh**	**89,725 m^3**	**-$3,490**	**156 tonne**

Installation

Location of Unit

The decision of selecting the unit location (indoor vs outdoor) is determined by various factors. It is important to select the location in such a way that reduces the overall length of the pool water heat recovery piping. Another factor is reducing the overall length of ductwork, which may help to

[4] Supporting assumptions and calculations can be found in Appendix A.

decrease the overall capacity of the unit and the insulation of the supply air ducts. The advantages and disadvantages of the different locations of the unit are shown in Table 4.

The dehumidification units at the City are mainly installed outdoor, except for Meadowvale Community Centre which is installed indoor.

Table 4: Advantages and disadvantages of indoor vs outdoor installations

Location of Unit	Advantages	Disadvantages
Indoor	• No requirements for weather proofing of unit enclosure, pool water piping and ducts. • More convenient for performing maintenance/repairs during severe weather conditions.	• Less convenient for Installation/Replacement of unit. • Requirement for constructed space, adds additional cost. • Higher preventative maintenance cost due to external condenser units.
Outdoor	• More convenient for Installation/Replacement of unit. • No requirement for constructed space, saves expensive prime real estate.	• Requirement for weather proofing of unit enclosure, pool water piping and ducts, increase overall cost. • Less convenient for performing maintenance/repairs during severe weather conditions.

Location of Sensors

The location of the space temperature and relative humidity (Rh) sensors on a pool deck, can impact the overall unit operation and energy performance.
It is important to select a location least affected by the people movement. Ideally, sensors should be mounted about 5 feet high on interior wall (for easy maintenance) with good air circulation, away from the supply air duct(s), with no hot or cold equipment nearby.

Maintenance

Preventative Maintenance

Based on the City's maintenance contracts, all pool dehumidification units are serviced and inspected four times a year. This has been increased recently to monthly services during summer peak months to reduce the number of service calls and address issues as early as possible.

The cost of preventive maintenance is identical for different Pool Dehumidification units regardless of the make of the units. However, the units at Meadowvale Community Center (Engineered Air) and South Common Community Center (Dectron) have additional 30-40% PM costs related to external condenser units.

Demand Maintenance

To analyze Demand Maintenance (DM), several factors have to be taken into consideration. The age of the unit is one of main contributing factors to DM and it varies significantly between the units. Additionally, the units operate under various conditions, different set points and different requirement in the conditioned space. There is also the human factor, the units are not operated or maintained by the same teams which could create different working conditions for the units and may impact DM calls. Due to lack of data that could help isolate the impact of external variables, DM analysis cannot be performed as it will not produce reliable insights that can be helpful for decision makers.

Redundancy

Engineered Air unit's configuration provides better redundancy. The failure of a single compressor, has less of an impact on an Engineered Air unit's operation compared to a Dectron units operation. The failure of a compressor in an Engineered Air unit results in the loss of approximately 17% of the dehumidification capacity compared to the loss of 50% in a Dectron unit. Additionally, Engineered Air compressors do not run in winter therefore the compressors run for less hours annually compared to Dectron compressors which are operational year around.

On the other hand, having more mechanical components will likely result in more service requests to keep the unit operational.

Conclusion

Achieving a successful natatorium environment while minimizing cost and providing good indoor air quality is not an easy task as the design, operation and maintenance requirements are unique compared to a typical building environment. A good indoor pool design can be achieved only by specialized professionals with years of experience. This white paper is not meant to provide a comprehensive analysis of natatorium conditions, requirements, and needs. It focuses only on those aspects observed by the EM team while researching ways to improve energy consumption and occupant comfort.

Design Aspects

Various design considerations need to be considered to reduce operation and maintenance costs. The following points were observed during EM analysis;

- An excessive use of glass presents a challenge in the ventilation design to prevent condensation
- A proper natatorium orientation can substantially reduce the energy use
- Building vapor barrier without tears or broken seams is essential in preventing early deterioration of the building structure
- When dual environment conditions coexist in a natatorium, special attention shall be given to the air distribution, air circulation and placement of the sensors (T & Rh) controlling the dehumidification unit
- A physical barrier between natatorium and adjacent space must be present in order to achieve constant negative pressure in the natatorium
- Consider effective filtration systems which minimize the need of excessive ventilation

Technology and Maintenance

The dehumidification equipment serving City pools are supplied by Dectron and Engineered Air. Our analysis revealed that Dectron units' consumer lower natural gas and Engineered Air units consume lower electricity. However, due to the energy mix and utility rates in Ontario, Engineered Air units provide cost savings, while Dectron provide GHG savings.

The features/characteristics of the units have also different impacts on operation and maintenance.

- Free dehumidification/cooling vs mechanical cooling:

  - Lowers electricity consumption, however increases the gas usage and therefore the GHG emissions
  - Lowers compressor runtime and translates to prolonged equipment life time and lower maintenance cost
- Ability to use the recovered heat from compressors based on demand (pool water or air) vs. predetermined allocation (pool water and air)
  - In the last scenario, if there is no demand in any of the two media, the allocated recovered heat is rejected/wasted therefore the efficiency of the heat recovery drops
- Larger number vs. smaller number of compressors
  - Provides better and more accurate control of the load, creates resilience in the system in case of failures however increases the maintenance requirements (multiple points of failure)

Installation

The location of the dehumidification unit as well sensors, have an impact on maintenance and operation.

- Ideally, the location of the unit is preferred to be in close proximity of a heat sink to minimize the pipe run and heat loss.
- Sensors (T & Rh) should be mounted 5ft high on the interior wall away from hot and cold equipment.

Appendix A

Assumptions and Supporting Calculations: Energy, Cost and GHG

Free Dehumidification Savings (1.1 Dehumidification Mode)

- Assume the case of River Grove Community Centre, where the daily dehumidification load is 8,250,000 Btu.
- Typically, this translates to 925 kWh of daily electrical usage due to mechanical dehumidification.
- Engineered Air units enable electrical savings by utilizing outside air for dehumidification whenever outside air is less than 10C and dew point is less than 20C. For our climate zone, these conditions typically occur 55% of the year.
- Using the typical full-load efficiency of mechanical dehumidification at 8.9 EER, an avoided electrical usage of 186,000 kWh (8,250,000 Btu/8.9 EER x 365 days x 1kWh/1000 Wh) annually can be estimated.
- However, the use of outside air for dehumidification requires gas heating to raise the temperature of outside air to natatorium air temperature. Using the burner efficiency of 80% and 8,250,000 Btu of daily dehumidification load results in 57,950 m^3 (8,250,000 Btu/80% eff x 365 days x 55% x 0.001055 MJ/1 Btu x 1 m^3/37.69 MJ) of annual natural gas usage to heat the colder outside air.
- Using an average natural gas rate of \$0.3/m^3, carbon rate of \$50/tonne, and average electrical rate of \$0.15/kWh, there is an annual cost increase of \$5,400 with Dectron units due to this feature.

Heat Recovery Savings (1.4 Heat Recovery Mode)

- Assume the case of River Grove Community Centre, where the daily dehumidification load is 8,250,000 Btu.
- This feature in Dectron units recovers heat from the mechanical dehumidification even during periods of "free dehumidification" and supplies it to the pool water and air-side of the unit. Therefore, savings are calculated during those periods only.
- Conservatively, the amount of heat rejected to heat recovery from the compressors to the pool water and air-side is 30% of the total load. Both units are

able to recover this heat whenever mechanical dehumidification is enabled. However, Engineered Air units do not utilize this option during the "free dehumidification" mode. As a result (and considering assumptions above), Dectron units allow 13,900 m^3 (8,250,000 Btu x 365 days x 55% x 0.001055 MJ/1 Btu x 1 m^3/37.69 MJ x 30% eff) of annual savings due to reduced gas usage for heating pool water and air-side of dehumidification units.

- Using an average natural gas rate of $0.3/$m^3$, and carbon rate of $50/tonne, there is an annual cost saving of $5,490 with Dectron units due to this feature.

Exhaust Air Heat Recovery Savings (1.5 Exhaust Air Heat Recovery to Fresh Air)

- Assume the case of River Grove Community Centre, where the ventilation air requirement is 5,000 cfm.
- Dectron units are supplied with exhaust air heat recovery, which allows sensible heat to be recovered from the air exhausted onto the ventilation air.
- Similar to the above assumption, the amount of heat rejected to heat recovery from the exhaust air heat recovery compressors to ventilation air is estimated at 30% of the total load.
- Applying the 30% heat recovery on the 5,000 cfm assumption results in 638,604,000 Btu (30% of 1.08 x 5000 x (41F - -4F) x 8760 hrs) recovered annually. This translates to 17,875 m^3 of annual natural gas savings.
- However, the use of refrigeration components should also be taken into account, which translates to 239,178,000 Btu (8.9 EER) electrical energy consumed. This translates to 70,000 kWh of annual electrical usage.
- Using an average natural gas rate of $0.3/$m^3$, carbon rate of $50/tonne, and average electrical rate of $0.15/kWh, there is an annual cost increase of $3,580 due to this feature.

Appendix B

Major Differences: Two Dehumidification Technologies

Table 5: Comparison between Engineered Air and Dectron

Item	Engineered Air	Dectron
Free cooling /dehumidification	***Available:*** Yes ***Advantage:*** Lowers the electricity consumption by utilizing free cooling/dehumidification vs mechanical cooling ***Disadvantage:*** Free cooling lowers the runtime of the compressors therefore the available heat recovered is lower. As a result the gas consumption is increased so the GHG emissions.	***Available:*** Optional ***Advantage:*** Use less natural gas by utilising reclaim heat from mechanical cooling. ***Disadvantage:*** Use more electrical energy.
Number of Compressors	***Total number of compressors***: Six (6) ***Advantage:*** Provides additional redundancy and more accurate temperature and relative humidity control. ***Disadvantage:*** More compressors require more maintenance, and introduce more points of failure.	***Total number of compressors:*** Two (2) ***Advantage:*** Less compressors require less maintenance. ***Disadvantage:*** Provides less redundancy.
BAS Integration	Old Engineered Air units supplied with in-built proprietary control system. This system is not compatible with the existing building automation system (BAS), and mostly, works as a stand alone system. New Engineered Air units provide control systems with BacNet communication protocol for easy integration with BAS. The number of control parameters available for measuring unit performance are limited. Therefore, additional cost required to add more information.	Dectron units provide control systems with BacNet communication protocol for easy integration with BAS. The units provide sufficient information to measure the unit performance.