NEWYORK ENGINEERS

October 6, 2023

DRAFT REPORT

# ASHRAE Level-II Energy Audit Study

NEWYORK ENGINEERS

**Grand Cayman Campus – Model 5**

- **Sam Basdeo Library**
- **School of Nursing Block**

**168 Olympic Way, PO Box 702 Grand Cayman, Cayman Islands KY1-1107**

# Disclaimer

The goal of this energy study is to identify potential energy efficiency and carbon reduction opportunities, help prioritize specific measures for implementation. Most energy conservation measures have received preliminary analysis of feasibility that identifies expected ranges of savings and costs. This level of analysis is usually considered sufficient to establish a basis for further discussion and to help prioritize energy measures. NYE reviewed the energy conservation measures and estimates of energy savings were reviewed for technical accuracy. Actual, achieved energy savings depend on behavioral factors and other uncontrollable variables and, therefore, estimates of final energy savings are not guaranteed. NYE shall in no event be liable should the actual energy savings vary. NYE bases estimated installation costs on our experience at similar facilities, pricing from US & Cayman Island local contractors and vendors, and/or cost estimates from RS Means. We encourage the owner of the facility to independently confirm these cost estimates and to obtain multiple estimates when considering measure installations. Actual installation costs can vary widely based on individual measures and conditions. NYE does not guarantee installed cost estimates and shall in no event be held liable should actual installed costs vary from estimates. The customer and their respective contractor(s) are responsible to implement energy conservation measures in complete conformance with all applicable Cayman Island Local Laws.

NEWYORK ENGINEERS

# Table of Contents

# Introduction

The Sam Basdeo Library Block and School of Nursing Block, 14,611-square-foot structures on Grand Cayman Campus, 168 Olympic Way, Cayman Islands. These buildings were built in the late 70s. New York Engineers performed an ASHRAE-II energy audit and made recommendations for energy efficiency solutions.

Dr. Robert Robertson, Principle In-charge of university college Cayman Islands (UCCI), contracted New York Engineers (NYE) to perform an ASHRAE Level 2 Energy Audit and solar feasibility study at Grand Cayman Campus. The purpose of the energy audit is to identify energy savings opportunities. NYE built a calibrated energy model based on utility data, building drawings, and site access provided by UCCI. The model was developed with eQuest software, and Energy Conservation Measures (ECM) were applied to acquire the findings of this report.

# Methodology

This audit is per ASHRAE Level II requirements. This audit includes a review of existing drawings, annual utility bills, and other data; one-week site visits to check equipment conditions and working performance; Mr. Vishwaraj Nimbalkar and Mr. Thomas Dugan conducted one-week site visits from July 10–15, 2023.

The energy analysis is performed using standard engineering calculation procedures and the building energy simulation program eQuest, an hour-by-hour energy usage modeling program evolved from DOE2, which was jointly developed by National Laboratories for the U.S. Department of Energy. While eQuest is generally accepted as one of the most accurate building energy simulation programs, the estimated energy usage should not be interpreted as an absolute prediction.

The actual energy usage may differ from the prediction due to variables beyond the energy analyst’s control. These may include changes in occupancy, schedules, final equipment selection, installation, and operation, weather variations from typical year data used, and other unforeseen circumstances.
A baseline building energy performance model was first developed based on the existing building conditions. Energy conservation measures (ECMs) were identified and analyzed by modifying the baseline building to reflect the impact of each ECM on the building’s energy performance. An interactive model was created to simulate the net effect of all ECMs.

The cost-effectiveness of each ECM was evaluated using a simple payback analysis, which yields the time required to recover the cost of implementing the ECM by its annual energy cost savings. The ECM cost estimates are either obtained from RSMeans or provided by the US & Cayman Island local equipment vendors.

# Energy Audit Team

The NYE team conveys their gratitude and thanks to the management of M/s Grand Cayman Campus, 168 Olympic Way, PO Box 702 Grand Cayman, Cayman Islands KY1-1107 for giving us an opportunity to study their campus for the Energy Audit, Which was conducted in July 10-15, 2023.

## Institutional Contact information

| Name | E-mail | Phone |
|---|---|---|
| Dr. Robert Robertson, president/CEO | - | +1 (345) 623-8224 |
| Cleveland Julien, Project Manager | CJulien@ucci.edu.ky | +1 (345) 623-0528 |
| Sherrilyn Harvey,<br>Facilities Administrator | sharvey@ucci.edu.ky | - |
| Fernando McLaughlin, Facilities management | FMcLaughlin@ucci.edu.ky | +1(345)-623-0505 |

## Auditor Contact Information

| Name | E-mail | Phone |
|---|---|---|
| Mr. Vishwaraj Nimbalkar PE, CEM, CEA, CBCP | VNimbalkar@nyc-engineers.com | 718-689-7322 |
| Mr. Thomas Dugan, Mechanical Energy Engineer | TDugan@nyc-engineers.com | 646-907-5095 |

# Executive Summary

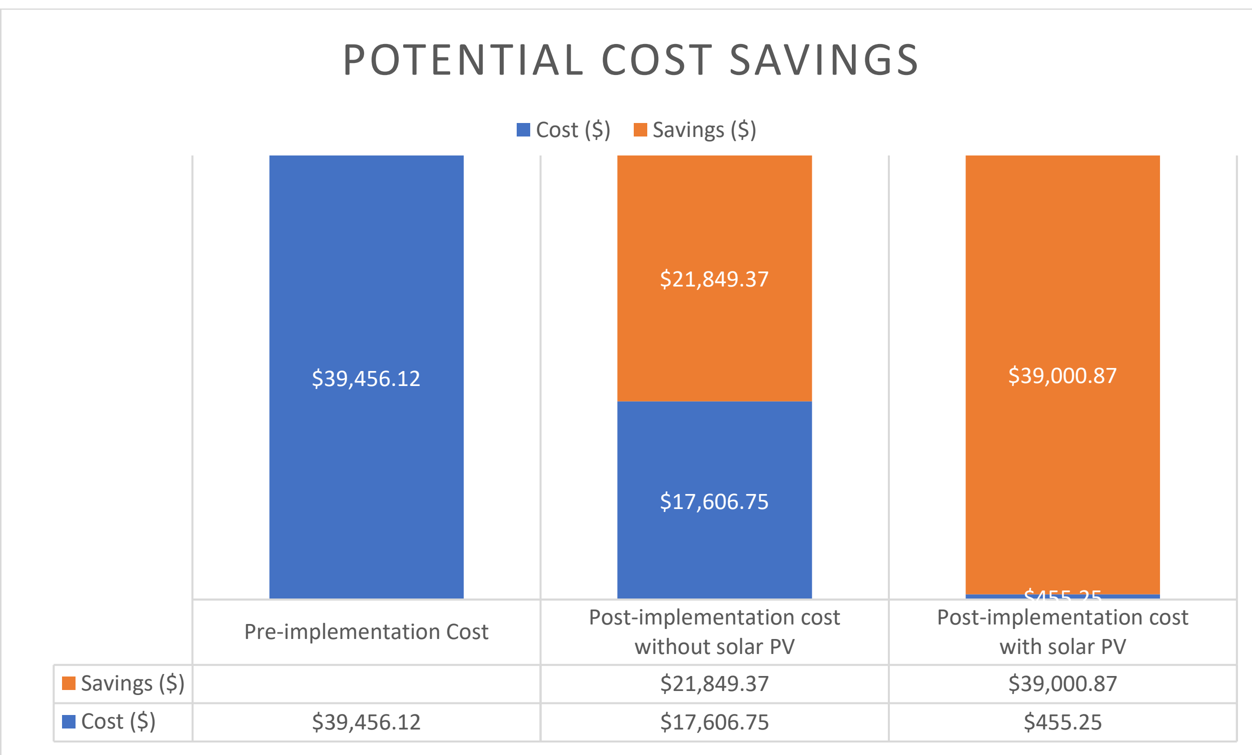
The NYE team surveyed all the building's major energy-consuming equipment, such as Split Units, Misq. Equipment, lighting. The Sam Basdeo Library Block and School of Nursing Block contains DX coil units for space cooling to the respective spaces, such as the library, reading area, conference room, Classrooms, nursing lab, office, store, restrooms etc.

# Cost Reduction Opportunities

Several energy conservation measures were studied, including those for the building's heating, ventilation, air-conditioning, Building management system, lighting. We found some potential options of the energy conservation measures (ECMs) to reduce the total energy consumption by 499 MMbtu and annual greenhouse gas emissions by about 124 tons of $CO_2e$.

Refer to table 1 for an ECM summary for energy values of each measure and table 2 for cost values and simple payback calculations.

The breakdown of existing utility costs and projected annual savings following implementation of all measures are shown in Figure 1. Together these measures represent an opportunity to reduce UCCI annual energy usage by about 99% overall.




**Graph 1: Potential implementation cost**

A detailed description of UCCI existing energy usage can be found in Section Building Energy Use and Costs. Estimates of total cost, energy savings, and financial incentives, which may be available for each ECM, are summarized below in Table 1 & 2. A brief description of each measure category can be found below. A detailed description of each ECM can be found in Section Energy Conservation Measures.

# ECM Summary Table

### Table 1 Energy Conservation Measure Summary

| Measure Number | Measure Description | Annual Energy Use (kWh) | Total Energy Use (MMBtu) | ton Co2 Emission | Saving ton Co2 Emission | Electricity Savings (kWh) | Total Energy Savings (MMBtu) | Energy Savings to Total Baseline use (%) |
|---|---|---|---|---|---|---|---|---|
| | | Annual Energy Savings | | | | | | |
| | Baseline Consumption | 169,617 | 579 | 144 | - | | | |
| ECM-1 | Lighting Control | 163,985 | 560 | 139 | 5 | 5,632 | 19 | 3% |
| ECM-2 | Window Upgradation | 166,344 | 568 | 141 | 3 | 3,273 | 11 | 2% |
| ECM-3A | BMS - Night Setback Control (NSB) | 150,446 | 513 | 128 | 16 | 19,171 | 65 | 11% |
| ECM-3B | BMS - Fan Control | 140,926 | 481 | 120 | 24 | 28,691 | 98 | 17% |
| ECM-3C | BMS - Optimal On- Off | 164,779 | 562 | 140 | 4 | 4,838 | 17 | 3% |
| ECM-3D | BMS - Demand Control Ventilation (DCV) | 167,539 | 572 | 142 | 2 | 2,078 | 7 | 1% |
| ECM-4 | VFD Installation on Indoor units | 155,639 | 531 | 132 | 12 | 13,978 | 48 | 8% |
| ECM-5 | Weatherization | 148,088 | 505 | 126 | 18 | 21,529 | 73 | 13% |
| ECM-6 | Solar PV (50 KW) | 101,011 | 345 | 86 | 58 | 68,606 | 234 | 40% |
| **Total** | | | | | **143** | **167,796** | **573** | **99%** |

### Table 2: Energy Conservation Measure Results with Payback

| Measure Number | Measure Description | Annual Energy Savings: Electricity Savings (kWh) | Total Energy Savings (MMBtu) | Electric Cost Savings ($) | Total Energy Cost Savings ($) | Payback Analysis: Measure Cost | Saving ton Co2 Emission | Simple Payback (years) |
|---|---|---|---|---|---|---|---|---|
| ECM-1 | Lighting Control | 5,632 | 19 | $1,408 | $1,408 | $1,893 | 5 | 1 |
| ECM-2 | Window Upgradation | 3,273 | 11 | $818 | $818 | $10,661 | 3 | 13 |
| ECM-3A | BMS - Night Setback Control (NSB) | 19,171 | 65 | $4,793 | $4,793 | $51,157 | 16 | 11 |
| ECM-3B | BMS - Fan Control | 28,691 | 98 | $7,173 | $7,173 | $41,035 | 24 | 6 |
| ECM-3C | BMS - Optimal On- Off | 4,838 | 17 | $1,210 | $1,210 | $9,041 | 4 | 7 |
| ECM-3D | BMS - Demand Control Ventilation (DCV) | 2,078 | 7 | $520 | $520 | $5,407 | 2 | 10 |
| ECM-4 | VFD Installation on Indoor units | 13,978 | 48 | $3,495 | $3,495 | $5,525 | 12 | 2 |
| ECM-5 | Weatherization | 21,529 | 73 | $5,382 | $5,382 | $25,104 | 18 | 5 |
| ECM-6 | Solar PV ( 50 KW) | 68,606 | 234 | $17,152 | $17,152 | $101,800 | 58 | 6 |
| **Total** | | **167,796** | **573** | **$41,949** | **$41,949** | **$251,623** | **143** | **6** |

## ENERGY EFFICIENT PRACTICES

A facility's energy performance can be significantly improved by employing certain behavioral or operational adjustments and by performing better routine maintenance on building systems. These practices can extend equipment lifetime, improve occupant comfort, provide better health and safety, as well as reduce annual energy and O&M costs.

Potential opportunities identified at UCCI include:

- Reduce Air Leakage
- Close Doors and Windows
- Ensure Lighting Controls Are Operating Properly
- Reduce Motor Short Cycling
- Perform Routine Motor Maintenance
- Practice Proper Use of Thermostat Schedules and Temperature Resets
- Ensure Economizers are Functioning Properly
- Check for and Seal Duct Leakage
- Perform Proper Water Heater Maintenance
- Install Plug Load Controls
- Replace Computer Monitors
- Water Conservation

For details on these energy efficient practices, please refer to Section Energy Efficient Best Practices.

## ON-SITE GENERATION MEASURES

NYE evaluated the potential for installing on-site generation for UCCI campus. Based on the configuration of the site and its loads there appears to be a low potential for cost-effective installation of any solar PV or combined heat and power self-generation measures. For details on our evaluation and on-site generation potential, please refer to Section On-Site Generation.

## ECM SUMMARY AND INCREASE IN BUILDING VALUE

As a result of our study utility cost saving packages were bundled together based on our findings. The measures include upgrades for the building envelope, lighting, lighting controls, HVAC. Implementation cost, potential incentives, and energy savings have all been calculated.

- Lighting controls, Window Upgrade, BMS system (Night Setback Control, Fan Control, Optimal ON/OFF, and Demand Control Ventilation (DCV), VFD installation on Indoor units and Solar PV installation.

Upon completion of installation, the building's value will immediately increase due to a higher net operating income. The net operating income increase has been calculated via energy savings and penalty avoidance. Annual energy savings with penalties avoided are the change in net operating income. Given a capitalization rate of 5% from Marcus & Millichap's Institutional Property Advisors (IPA), the following equation was used to calculate the net operating income increase per recommended package.

**Table 3: Increase in building value**

| | Construction Cost | Saving ton Co2 Emission | Annual Energy Savings | Net Property Value Increase |
|---|---|---|---|---|
| **Description** | $251,623 | 143 | $41,949 | $838,980 |

$$Capitalization\ Rate = \frac{\Delta\ Net\ Operating\ Income}{\Delta\ Value\ of\ Property}$$

## EMISSIONS OUTLOOK

Cayman Island sustainability development Goals report determined that some progress has been made towards the 2030 target. According to the Cayman Islands' 2021 Census Report, Cayman has achieved almost universal access to electricity, i.e. 97 per cent of Caymanian households have access to electricity. Energy policy aims to reduce greenhouse case emissions from 12.3tCO2e per person in 2014 to 4.8tCO2e by 2030

In February 2017, the Cabinet approved the Cayman Islands' NEP 2017–2037. The NEP, first drafted in 2013, and reviewed in 2016, set a target of generating 70 per cent of electricity from renewable sources by 2037. When the target was set in 2015, more than 99 per cent of energy in the Cayman Islands was generated from oil products. At that time, renewable energy accounted for 0.2 per cent of electricity generation. In the seven years since the target was set, little progress has been made. By February 2023, renewable energy contributed 3 per cent of Grand Cayman's total energy production. Significant effort will be needed to increase the use of renewable energy over the next 15 years and to achieve the target of 70 percent.

# Facility Information and Existing Conditions

## GENERAL SITE INFORMATION

**Table 4: General Site information**

| BUILDING DETAILS | |
|---|---|
| **Client Name** | Dr. Christopher Williams |
| **Property Superintendent** | Cleveland Julien |
| **Building Name** | 1. Sam Basdeo Library<br>2. School Of Nursing |
| **Total SF** | 14,611 SF |
| **Number of Buildings** | 2 |
| **# Stories** | Library Block 2 Floors & Nursing Block 1 Floor |

## ENVELOPE DESCRIPTION

The envelope or building exterior exchanges energy with the outside air and absorbs energy from the sun, affecting the energy required by the building's HVAC system for indoor comfort. The details of the envelope parameter for the existing building are as follows:

- Exterior Wall: The exterior wall of the project has a U-value, which is the inverse of the R-value and is calculated as 0.58 Btu/h-ft2-°F.
- Exterior Roof: The exterior roof of the project has minimal insulation to resist the heat flow from the sun's rays. The U-value, which is the inverse of the R-value, is calculated as 0.034 Btu/h-ft2-°F.
- Exterior Window Glass: The exterior window glass consists of double-pane clear glass. The U-value is calculated as 1.47 Btu/h-ft2-°F, the shading coefficient is calculated as 0.60 and visible light transmittance is 0.80.

## OCCUPANCY

The both block has 215 persons (students, faculty and non-teaching staff members). The Library building is open all seven days and Nursing building closed on the weekends. The typical schedule is presented in the table below. During a typical day.

**Table 5: Operational Schedule**

| BUILDING NAME | WEEKDAY/WEEKEND | OPERATING SCHEDULE |
|---|---|---|
| 1. Sam Basdeo Library | All week working | Monday-Thursday: 9AM-9PM<br>Friday: 9AM-4PM<br>Saturday-Sunday:9AM-5PM |

| | | |
|---|---|---|
| 2. School of Nursing | Weekday | 9:00 AM to 5:00 PM |
| | Weekend | Closed |

## EQUIPMENT SCHEDULES AND SETPOINT

We consider a cooling set point of 75 °F.

## SPACE COOLING SYSTEM

The buildings has DX coil units with dehumidifier which is used to provide space cooling and maintain humidity in to the space, For library building Rheem outdoor unit and Rheem (1 AHU in Library building) model no RHGL-180ZL with corresponding condensing unit RWAL-091CAZ & RWAL-091CAZ. Three condensing unit with central system model no RA1636AJ1NA, RA1636AJ1NA, 116BNA036-B. For nursing building Lennox mini split unit LI018CI-170P432-1 for classroom-1, Lennox mini split unit with models LI018CI-210P432, and Goodman GMX160122HWE for enclosed offices. Lennox mini split unit model no LI024CI-210P432 and Samsung mini split model no AR24JVSSAWKX for nursing classroom and lab. Borel with model EQX24HPJ1IB and Samsung with model AR24JVSSAWKN for open office area. DX coil units are there to provide space cooling to the library, reading area, classrooms, offices, nursing lab.



**Figure 1: DX coil Unit**

## LIGHTING POWER

The lighting system in the blocks are provided mostly by LED- Fixtures 12W & 18W lamps with magnetic ballasts, some 32-Watt linear LED T8 Linear tubes, plus some 13W Linear fluorescent lights. Most of the fixtures are 2-lamp or 3-lamp, 4-foot long troffers with diffusers. Lighting control in most spaces is provided by wall switches. Nearly all of the buildings exit signs have been upgraded to LED fixtures. The building's exterior lighting is minimal and consists primarily of LED surface mounted fixtures that are controlled by photocells. The lighting plan is used to calculate lighting power density (LPD) on a space-by-space basis. The Appendix D contains the lighting power density (LPD) for each space.

**Figure 2: Lighting Load**

## PLUG LOAD

The building has classrooms, offices, labs, kitchen and Maintenance room equipment like computers, projectors, printers, monitors, Microwave, Dehumidifier, freezers and fans. The equipment power density (EPD) load is calculated on space-by-space basis. The appendix D contains the Equipment power density (EPD) for each space.



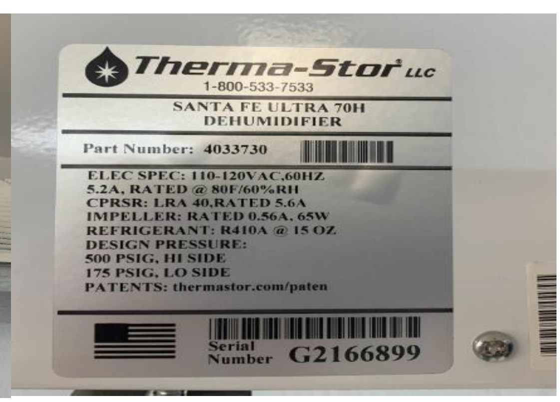




**Figure 3: Plug Loads**

## EQUIPMENT CONTROL

The building does not have a centralized BMS system.

## INDOOR AIR QUALITY (IAQ)

Indoor air quality (IAQ) is the quality of the air within and around buildings and structures, particularly as it relates to the health and comfort of building occupants. Understanding and controlling common indoor pollutants can help you reduce your risk of developing indoor health issues. However, indoor air pollution can have serious and negative health consequences.

EPA studies of human exposure to air pollutants indicate that indoor levels of pollutants may be two to five times and occasionally more than 100 times, higher than outdoor levels. Because most people spend 90 percent of their time indoors, these levels of indoor air pollutants are of particular concern. The following are examples of good indoor air quality (IAQ) management for this guide:

- Control of airborne pollutants.
- Introduction and distribution of adequate outdoor air.
- Maintaining a comfortable temperature and relative humidity.

Temperature and humidity cannot be overlooked because thermal comfort concerns underlie many complaints about "poor air quality." Inadequate ventilation can increase indoor pollutant levels by not bringing in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the area. High temperature and humidity levels can also increase concentrations of some pollutants.

The temperature and humidity of indoor air have been widely recognized as factors that influence directly the thermal sensation of the human body (Fanger 1972). However, they were mainly considered indirect factors that influence perceived air quality due to their influence on indoor air pollution sources.

Outdoor air enters Collage buildings through windows, doors, and ventilation systems, so it should be considered. As a result, transportation and grounds maintenance activities influence both indoor pollutant levels and outdoor air quality on Collage grounds.

# Building Energy Use and Costs

Home Gas Ltd Supplies on demand propane in UCCI. Caribbean Utilities Company, Ltd. (CUC) supplies utilities in UCCI. It has three electrical services, one (24505-302934) of which is classified as large commercial based on its consumption levels, and the other two (24505-317270 and 24505-342700) are classified as general commercial. At the outset of the review, the metered data for all three services was looked at to determine whether there could be immediate benefits through either the aggregation of the three services into a single metered service or the splitting of the large commercial electrical service into multiple services such that each new service was lowered to general commercial rates. In each case, there were no immediate savings due to the specific consumption characteristics of the electrical services and the charge component differences for the general commercial (consumption-only rates) and large commercial (demand and consumption rates) rate classes. CUC would therefore not recommend, all else being equal, investments made to aggregate or split electrical services for cost-optimization efforts.

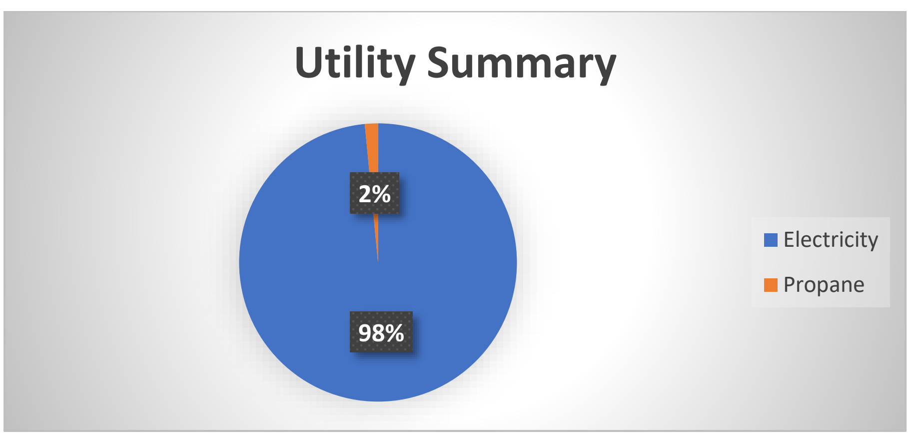
Combined utility data for electricity and Propane was evaluated to determine the annual energy performance metrics for the building in terms of energy cost per square foot and energy usage per square foot. These metrics are an estimate of the relative energy efficiency of this building. There are a number of factors that could cause the energy use of this building to vary from the "typical" energy usage profile for facilities with similar characteristics. Please refer to the benchmarking section for additional information.

## TOTAL COST OF ENERGY

Twelve months of utility billing data are used to develop annual energy consumption and cost data. This information creates a profile of the annual energy consumption and energy costs.

Table 6: Utility Summary

| Fuel | Usage | Cost |
|---|---|---|
| Electricity | 849,420 kWh | $212,355 |
| Propane | 574 Gallon | $3,329 |
| Total | | $215,684 |




Graph 2: Utility Summary

An energy balance identifies and quantifies energy use in your various building systems. This can highlight areas with the most potential for improvement. This energy balance was developed using calculated energy use for each of the end uses noted in the figure.

The energy auditor collects information regarding equipment operating hours, capacity, efficiency, drawings and other operational parameters from facility staff and on-site observations. This information is used as the inputs to calculate the existing conditions energy use for the site. The calculated energy use is then compared to the historical energy use, and the initial inputs are revised as necessary to balance the calculated energy use to the historical energy use.

## UTILITY USAGE

Utility usage for UCCI includes electricity measured in kilowatt-hours. The electric per unit cost was utilized is $ 0.25 per kWh

Electricity is used for the following applications in the base building:

- Base buildings
  - Interior Lighting
  - Plug Loads
  - HVAC system
  - Lab equipment's
  - Kitchen equipment's

## UTILITY BILLING

- Electricity
  - Supplied by: Caribbean Utilities Company, Ltd. (CUC)
  - Billed to UCCI
  - Number of Meters: 03 (24505-302934, 24505-317270 & 24505-342700)
  - The total average electric cost over the past 12 months was $0.25/kWh, which is the blended rate that includes energy supply, distribution, demand, and other charges. This report uses this blended rate to estimate energy cost savings.

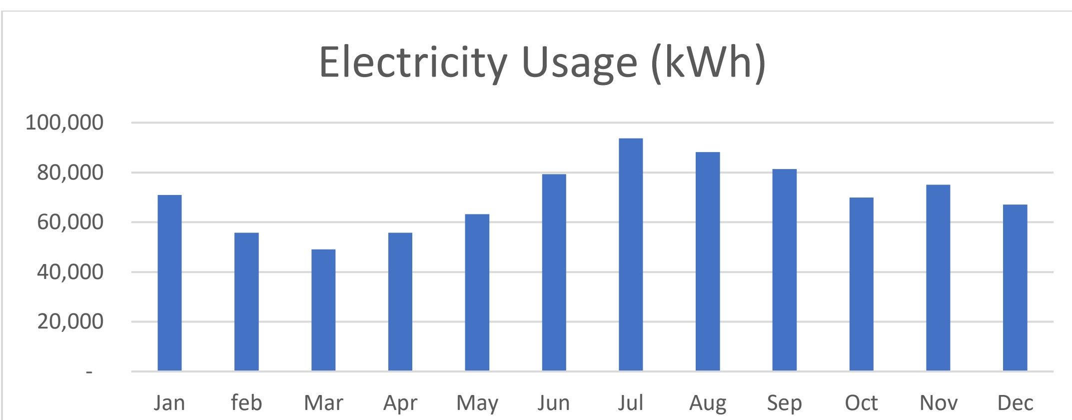


**Table 7: Annual Electric Usage (kWh)**

| Month | Electric Usage KWh | Total Electric Cost |
|---|---|---|
| January | 70,880 | $17,720 |
| February | 55,720 | $13,930 |
| March | 49,140 | $12,285 |
| April | 55,780 | $13,945 |
| May | 63,220 | $15,805 |
| June | 79,320 | $19,830 |
| July | 93,720 | $23,430 |
| August | 88,220 | $22,055 |
| September | 81,320 | $20,330 |
| October | 69,900 | $17,475 |
| November | 75,100 | $18,775 |
| December | 67,100 | $16,775 |
| **Total** | **849,420** | **$212,355** |

## BUILDING WISE UTILITY CONSUMPTION

The Library and Nursing School both use electricity as their main sole energy source. The monthly consumption of electricity at each building can be seen in Table 9 below.

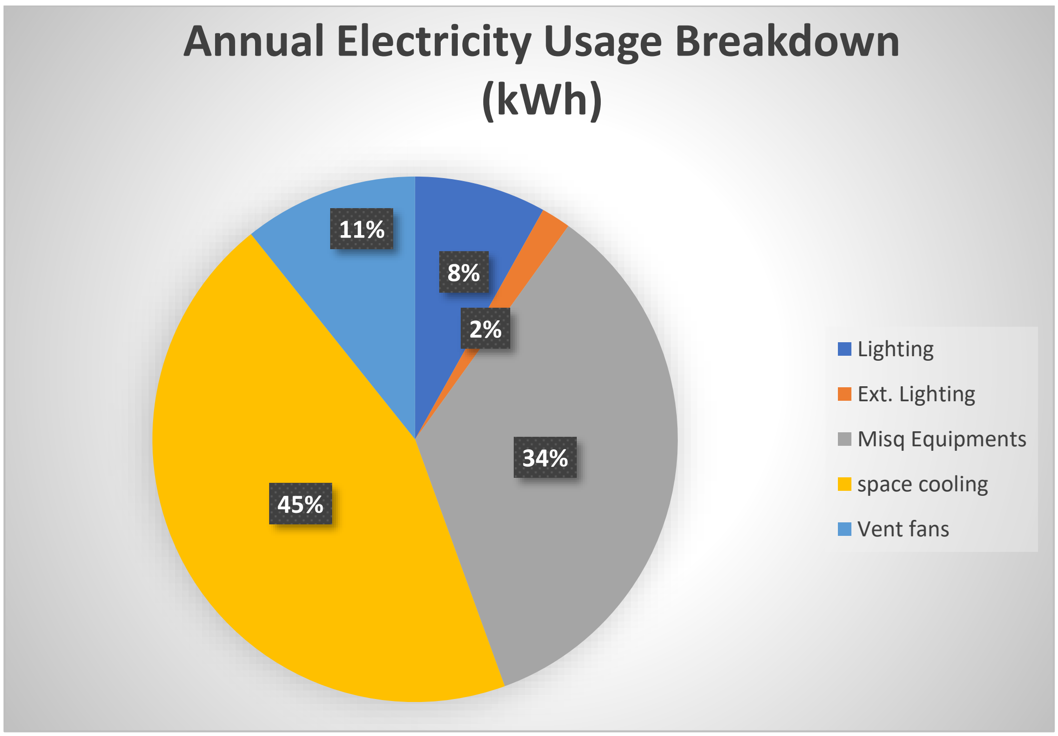
**Table 8: Annual Electricity Usage (KWH)**

| Month | Total (kWh) | Library Block (kWh) | Nursing Block (kWh) |
|---|---|---|---|
| January | 13,954 | 11,024 | 2,930 |
| February | 12,467 | 9,850 | 2,618 |
| March | 13,170 | 10,404 | 2,765 |
| April | 10,353 | 8,179 | 2,174 |
| May | 9,130 | 7,213 | 1,917 |
| June | 10,364 | 8,188 | 2,176 |
| July | 11,746 | 9,280 | 2,466 |
| August | 14,738 | 11,643 | 3,094 |
| September | 17,413 | 13,757 | 3,656 |
| October | 16,392 | 12,950 | 3,442 |
| November | 15,109 | 11,937 | 3,172 |
| December | 12,988 | 10,261 | 2,727 |
| **Total** | **157,824** | **124687** | **33138** |

# Energy End-Use Breakdown

In order to provide a complete overview of energy consumption across building systems, an energy balance was performed at this facility. An energy balance utilizes standard practice engineering methods to evaluate all components of the various electric systems found in a building to determine their proportional contribution to overall building energy usage. This chart of energy end uses highlights the relative contribution of each equipment category to total energy usage. This can help determine where the greatest benefits might be found from energy efficiency measures.

**Graph 3: Annual Electricity Usage Breakdown**



## MODEL CALIBRATION

The existing building is modeled with inputs based on the actual conditions of the project, and the existing annual consumption of the building is matched with the energy simulation results within a permissible variation range of ±10%.

## CALIBRATED MODEL AS PER EXISTING CONDITIONS

**Model Result:**

The annual electricity and annual Propane consumption of eQuest, when compared with the baseline building, were calibrated with a variation of -7.5% in the case of annual electricity consumption. The variation is within the permissible range of ±10%.

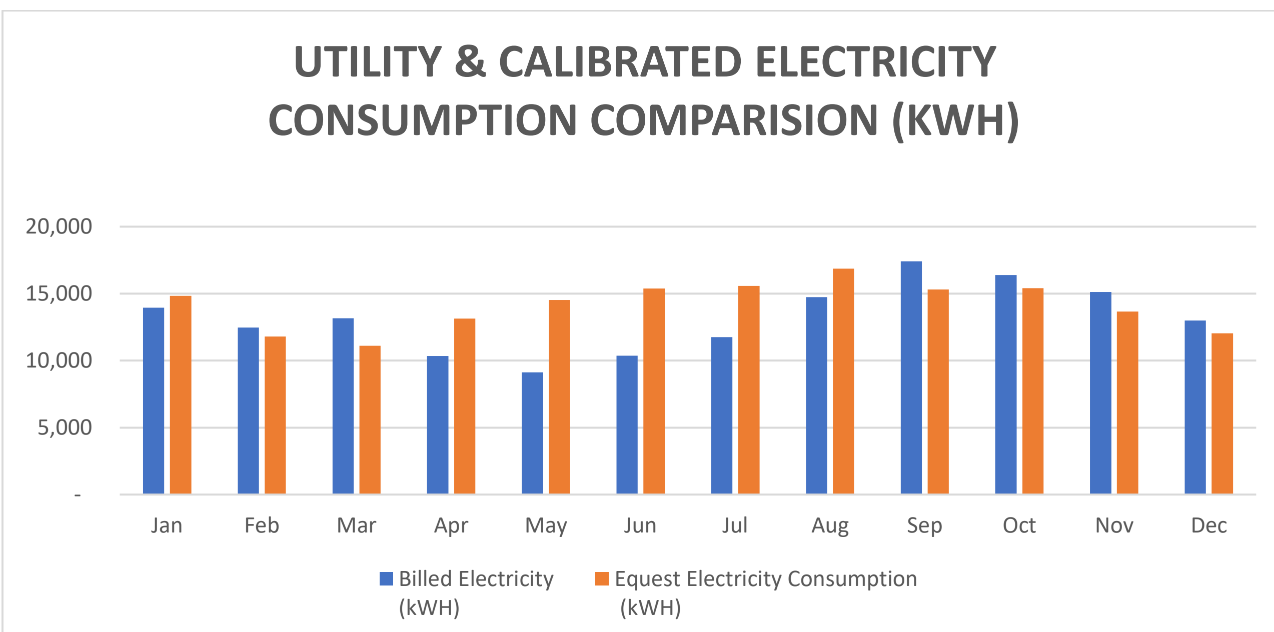
**Table 8: Annual calibrated results**

| Library & Nursing Block Building | |
|---|---|
| Annual Electricity Consumption Calculation | |
| Total Annual Electricity Consumption as per Utility Bills (kWh) | 157,824 |
| Annual Electricity Consumption as per Baseline Model (kWh) | 169,617 |
| Difference Units (kWh) | -11,793 |
| % Variation | -7.5% |

The baseline building's consumption as calculated by the eQuest energy modelling software Table 12 & 13 data and graph 1 & 2 compare the monthly electricity usage from the utility bills and the calibrated model.

**Table 9: Annual utility billed & baseline consumption**

| Library & Nursing Block - Monthly Electricity Consumption Comparison | | | |
|---|---|---|---|
| **Sl. No.** | **Month** | **Electricity Consumption As Per Utility Bills (kWh)** | **Electricity Consumption As Per Calibrated Model (kWh)** |
| 1 | Jan | 13,954 | 14,830 |
| 2 | Feb | 12,467 | 11,791 |
| 3 | Mar | 13,170 | 11,101 |
| 4 | Apr | 10,353 | 13,128 |
| 5 | May | 9,130 | 14,521 |
| 6 | Jun | 10,364 | 15,372 |
| 7 | Jul | 11,746 | 15,582 |
| 8 | Aug | 14,738 | 16,860 |
| 9 | Sep | 17,413 | 15,308 |
| 10 | Oct | 16,392 | 15,410 |
| 11 | Nov | 15,109 | 13,672 |
| 12 | Dec | 12,988 | 12,042 |
| **Annual Electricity Consumption** | | **157,824** | **169,617** |




Graph 4 : Annual utility billed & baseline result comparison

# Energy Conservation Measures

The goal of this audit report is to identify potential energy efficiency opportunities, help prioritize specific measures for implementation, and provide information to the UCCI regarding financial incentives for which they may qualify to implement the recommended measures. For this audit report, most measures have received only a preliminary analysis of feasibility which identifies expected ranges of savings and costs.

This level of analysis is usually considered sufficient to demonstrate project cost-effectiveness and help prioritize energy measures. Savings are based on the RMS, USA and Cayman island Vendors. Further analysis or investigation may be required to calculate more precise savings based on specific circumstances. A higher level of investigation may be necessary to support any Pay for Performance. The following sections describe the evaluated measures.

The measures below have been evaluated by the auditor and are recommended for implementation at the facility.

| Annual Energy Savings | | | | | | Payback Analysis | | |
|---|---|---|---|---|---|---|---|---|
| **Measure Number** | **Measure Description** | **Electricity Savings (kWh)** | **Total Energy Savings (MMBtu)** | **Electric Cost Savings ($)** | **Total Energy Cost Savings ($)** | **Measure Cost** | **Saving ton Co2 Emission** | **Simple Payback (years)** |
| ECM-1 | Lighting Control | 5,632 | 19 | $1,408 | $1,408 | $1,893 | 5 | 1 |
| ECM-2 | Window Upgradation | 3,273 | 11 | $818 | $818 | $10,661 | 3 | 13 |
| ECM-3A | BMS - Night Setback Control (NSB) | 19,171 | 65 | $4,793 | $4,793 | $51,157 | 16 | 11 |
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| ECM-5 | Weatherization | 21,529 | 73 | $5,382 | $5,382 | $25,104 | 18 | 5 |
| ECM-5 | Solar PV ( 50 KW) | 68,606 | 234 | $17,152 | $17,152 | $101,800 | 58 | 6 |
| **Total** | | **167,796** | **573** | **$41,949** | **$41,949** | **$251,623** | **143** | **6** |

# Energy Conservation Measures

Sam Basdeo library and School of Nursing block Energy Conservation Measures (ECMs) Summary.

## ECM #1 LIGHTING CONTROLS

| | |
|---|---|
| **Measure Description** | This measure studies the addition of occupancy sensors to each room's lighting and daylight sensors to all rooms with exterior lighting.<br><br>This will partially cut back on lighting usage during the day. Occupancy sensors turn a section of lighting fixtures and release the lights off after time of no detection. Benefits include:<br>• Reduction the unnecessary lighting usage and building's total electricity consumption. |
| **Operation and Maintenance Impacts** | This ECM does not require any maintenance. |
| **Design Considerations** | Daylighting controls and occupancy sensors need to be implemented in sections where they are beneficial. Discussion with on-site personnel and observation of high daylight should be conducted to understand where new controls would be beneficial and not disrupt users. |
| **Estimated Project Costs** | $1,893 |
| **Annual Energy Savings** | • Electricity: 5,632 (kWh)<br>• Total Energy Savings : 19(MMBTU) |
| **Annual Energy Cost Savings** | $1,408 |
| **Saving ton Co2 Emission** | 5 |
| **Simple Payback, year** | 1 |

## ECM #2 WINDOW UPGRADE

| | |
|---|---|
| **Measure Description** | New efficient windows have a low solar heat gain coefficient and visual light transmittance value. Upgraded frames with a good seal between the window frame and the wall reduce air infiltration leaks and reduce the cooling load for a building.<br><br>Heat gain and heat loss through windows are responsible for 25%–30% of residential heating and cooling energy use [DOE] and upgrades will lower that number. Old Windows have many problems like: Messy or Incomplete caulking, properly opening and shutting, Condensation between the glass panes, Drafts and water damage, Glass stains and discoloration, Gaps between the windowsill and frame, Uneven windows, and Repair Expenses. |
| **Operation and Maintenance Impacts** | None |
| **Design Considerations** | Window selections tips.<br>• Look for the ENERGY STAR and NFRC labels.<br>• In warmer climates, select windows with coatings to reduce heat gain.<br>• Look for a low solar heat gain coefficient (SHGC). SHGC is a measure of solar radiation admitted through a window. Low SHGCs reduce heat gain in warm climates.<br>• Look for whole-unit SHGCs, rather than center-of-glass SHGCs. Whole-unit numbers more accurately reflect the energy performance of the entire product. |
| **Estimated Project Costs** | $10,661 |
| **Annual Energy Savings** | • Electricity: 3,273 (kWh)<br>• Total Energy Savings : 11 (MMBTU) |
| **Annual Cost Savings** | $818 |
| **Saving ton Co2 Emission** | 3 |
| **Simple Payback (years)** | 13 |

## ECM #3A BUILDING MANAGEMENT SYSTEM (BMS) – NIGHT SETBACK CONTROL (NSB)

| | |
|---|---|
| **Measure Description** | A Building Management System (BMS) or centralized control system can manage and monitor building systems and equipment. This will enhance efficiency, comfort, safety, and reduce energy consumption. The BMS feature implemented in this modelled study is night setback.<br>• A night setback controls HVAC equipment to run at a lower rate during unoccupied hours. The strategy optimizes energy usage while still providing full comfort during occupied hours. |
| **Operation and Maintenance Impacts** | • Set point temperatures of cooling systems during unoccupied hours should be monitored. Setback points should reduce the load of equipment while still providing sufficient nighttime cooling for unoccupied buildings. |
| **Design Considerations** | • Designing a Building Management System with a Night Setback feature requires careful planning and consideration to ensure that it effectively optimizes energy usage while maintaining occupant comfort.<br>The occupant profile, operational schedule, setpoint adjustments, integration of the HVAC system, monitoring, data logging analysis, and energy efficiency optimization should all be accounted for in design. |
| **Estimated Project Costs** | $51,157 |
| **Annual Energy Savings** | • Electricity: 19,171 (kWh)<br>• Total Energy Savings : 65 (MMBTU) |
| **Annual Cost Savings** | $4,793 |
| **Saving ton Co2 Emission** | 16 |
| **Simple Payback (years)** | 11 |

## ECM #3B BUILDING MANAGEMENT SYSTEM (BMS) – FAN CONTROL

| | |
|---|---|
| **Measure Description** | A Building Management System (BMS) implementation serves as a centralized control system managing and monitoring various building systems and equipment to enhance efficiency, comfort, safety, and sustainability.<br><br>This BMS implementation utilizes a fan schedule feature.<br>• The fan schedule feature optimizes the operation of fans and ventilation systems. |
| **Operation and Maintenance Impacts** | The fan schedule allows for precise control of fan operation based on occupancy and building needs. Fans can be set to operate only when necessary, reducing energy consumption.<br>• The feature will yield benefits of improved air quality (IAQ), comfort control, humidity control, and HVAC system integration.<br>Monitoring of fan schedule should be performed to ensure both energy reduction and satisfactory occupant comfort. |
| **Design Considerations** | Designing a building management system (BMS) with a fan schedule feature involves several considerations to ensure efficient operation, occupant comfort, and energy savings.<br>Design must consider:<br>• Zones<br>• Occupancy patterns<br>• Ventilation needs<br>• Scheduling<br>Temperature set points |
| **Estimated Project Costs** | $41,035 |
| **Annual Energy Savings** | • Electricity: 28,691 (kWh)<br>• Total Energy Savings : 98 (MMBTU |
| **Annual Cost Savings** | $7,173 |
| **Saving ton Co2 Emission** | 24 |
| **Simple Payback (years)** | 6 |

## ECM #3C BUILDING MANAGEMENT SYSTEM (BMS) – OPTIMAL ON-OFF

| | |
|---|---|
| **Measure Description** | Continuing the additional functions of a BMS, this measure implements an optimal ON-OFF feature.<br>• Optimal start-stop control optimizes operation of various building systems and equipment, ensuring energy efficiency, occupant comfort, and operational cost savings.<br>• Under optimal start, cooling equipment will begin cooling at just the right time before the occupancy starts, so that setpoint will be met right at the scheduled time. On less hot mornings, cooling will start closer to occupancy hours, and on hotter mornings, cooling will start even earlier.<br>• Optimal stop aims to shut the system down before the scheduled unoccupied time and let the building "coast" down. If the outdoor temperature is close to the set point it can shut it down or back off some time before the end of occupancy. |
| **Operation and Maintenance Impacts** | Successful implementation requires careful planning, ongoing monitoring, and proactive management to ensure the system operates as intended and delivers the expected benefits. Regular maintenance and data analysis are key components of optimizing the long-term performance of a BMS with optimal on-off control. |
| **Design Considerations** | Occupancy schedules and activities outside of normal occupant hours need to be considered. |
| **Estimated Project Costs** | $9,041 |
| **Annual Energy Savings** | • Electricity: 969 (kWh)<br>• Total Energy Savings : 3 (MMBTU) |
| **Annual Energy Cost Savings** | $1,210 |
| **Saving ton Co2 Emission** | 4 |
| **Simple Payback, year** | 7 |

## ECM #3D BUILDING MANAGEMENT SYSTEM (BMS) – DCV CONTROL

| | |
|---|---|
| **Measure Description** | Direct Control Ventilation (DCV) uses CO2 sensors to determine the required amount of make-up air provided by the mechanical system to meet the required ventilation levels.<br><br>Over-ventilation can be one of the largest indirect contributors to a building's energy use. Compared to a fixed ventilation approach, DCV saves energy by eliminating the need for additional cooling and dehumidification.<br><br>When integrated with the appropriate building control strategy, ventilation can be controlled zone by zone based on actual occupancy. This allows for the use of supply air from under-occupied zones to be redistributed to areas where more ventilation or cooling is needed. A CO2 control strategy can be issued to maintain any per-person ventilation. As a result, this approach is highly adaptable to changing building uses. |
| **Operation and Maintenance Impacts** | None |
| **Design Considerations** | • 400-1,000 ppm is CO2 permissible limit in school.<br>• A VFD is required to control the speed of motors controlling intake air.<br>• Installing VFDs usually requires a mechanical/controls contractor.<br>• Requires pressure-independent OA dampers for non-DCV zones. |
| **Estimated Project Costs** | $5,407 |
| **Annual Energy Savings** | • Electricity: 28,691 (kWh)<br>• Total Energy Savings : 98 (MMBTU |
| **Annual Energy Cost Savings** | $520 |
| **Saving ton Co2 Emission** | 2 |
| **Simple Payback, year** | 10 |

## ECM #4 VFD ON AHU

| | |
|---|---|
| **Measure Description** | Install variable frequency drive (VFD) on the indoor units.<br><br>VFDs ramp up a motor for a smooth startup or to prevent a heavy load from straining the unit during startup. This is accomplished by varying the frequency of the unit's output. This results in longer lasting units longer, translating to less downtime and lower repair costs. |
| **Operation and Maintenance Impacts** | VFD maintenance ensures that the units stay safe from external factors such as water and debris, as well as faulty internal mechanics. Good maintenance practices include visual inspections, regular cleanings, connection checks, and replacing parts before they start to impede good performance. The maintenance in motors is of vital importance since it guarantees its correct operation, prevents some type of faults and even allows to increase its useful life. |
| **Design Considerations** | Consider the size of motors and VFDs. The system should be easily configured with the existing equipment. VFD drive will enable AHU capacity modulation and speed control.<br>Items to consider for the measure's implementation:<br>• Motor capacity<br>• VFD compatibility with motor |
| **Estimated Project Costs** | $5,525 |
| **Annual Energy Savings** | • Electricity: 13,978 (kWh)<br>• Total Energy Savings : 48 (MMBTU) |
| **Annual Cost Savings** | $3,495 |
| **Saving ton Co2 Emission** | 12 |
| **Simple Payback (years)** | 2 |

## ECM #5 WEATHERIZATION

| | |
|---|---|
| **Measure Description** | Weatherization means protecting a building and its interior from direct sunlight, heat, wind, and humidity by providing air sealing, insulation, moisture removal or ventilation.<br>• In air sealing, caulk is used to fill up cracks and openings between stationary envelope components like window frames, fixed windows, and door frames. This process is called caulking. Sealing of moving envelope components like doors and operable windows using flexible strip materials is called weather-stripping. Air sealing results in a decrease in cooling load due to lower air leakage rates.<br>• In the same measure, insulation is added to existing walls. This lowers the U value of wall reducing the heat gain coefficient for the building. |
| **Operation and Maintenance Impacts** | Annual inspection of sealant quality will monitor replacement needs. |
| **Design Considerations** | Consider the required rate of air change for academic buildings. Sealing material should be applied on clean surfaces and look coherent with framing for aesthetics. While selecting building insulation, method and ease of installation, material finishing, life cycle costs should be considered. |
| **Estimated Project Costs** | $25,104 |
| **Annual Energy Savings** | • Electricity: 21,529 (kWh)<br>• Total Energy Savings :73 (MMBTU) |
| **Annual Cost Savings** | $17,152 |
| **Saving ton CO2 Emissions** | 18 |
| **Simple Payback (years)** | 5 |

## ECM #6 SOLAR PV INSTALLATION

| | |
|---|---|
| **Measure Description** | Addition of a rooftop photovoltaic solar system.<br>• Solar PV installations generate an emissions free source of electricity. This reduces greenhouse gas emissions, promotes energy independence, and saves on energy costs.<br>• Rooftop solar plant with a capacity of 50 kW. |
| **Operation and Maintenance Impacts** | • Proper maintenance and monitoring are essential to ensure long-term performance, maximize energy generation, and extend the system's lifespan. Regular cleaning and inspection of equipment is highly recommended.<br>• Monitoring through a BMS system that records solar data can be beneficial to both optimizing energy generation and academic opportunities to understand the system.<br>• Regular safety inspections ensure that the PV installation meets safety standards and poses no hazards to personnel or the environment. |
| **Design Considerations** | Designing a solar photovoltaic (PV) installation requires careful planning to ensure that the system operates efficiently, generates maximum energy, and has a long lifespan.<br>• Mainly site assessment, system size and capacity, solar panel selection, inverter selection, mounting and racking, shading analysis, electrical design, monitoring and control, maintenance access, and environmental considerations.<br>A solar PV plant with a capacity of 50 kW has been modelled on the roof of the building. |
| **Estimated Project Costs** | $101,800 |
| **Annual Energy Savings** | • Electricity: 68,606 (kWh)<br>• Total Energy Savings : 234 (MMBTU) |
| **Annual Cost Savings** | $17,152 |
| **Saving ton Co2 Emission** | 58 |
| **Simple Payback (years)** | 6 |

# On-Site Generation Measures

On-site generation measure options include renewable (e.g., solar, wind) on-site technologies that generate power to meet all or a portion of the electric energy needs of a facility. Also referred to as distributed generation, these systems contribute to Greenhouse Gas (GHG) emission reductions, demand reductions and reduced customer electricity purchases, resulting in the electric system reliability through improved transmission and distribution system utilization.

Preliminary screenings were performed to determine the potential that a generation project could provide a cost-effective solution for your facility. Before making a decision to implement, a feasibility study should be conducted that would take a detailed look at existing energy profiles, siting, interconnection, and the costs associated with the generation project including interconnection costs, departing load charges, and any additional special facilities charges.

## Photovoltaic

Sunlight can be converted into electricity using photovoltaics (PV) modules. Modules are racked together into an array that produces direct current (DC) electricity. The DC current is converted to alternating current (AC) through an inverter. The inverter is interconnected to the facility's electrical distribution system. The amount of unobstructed area available determines how large of a solar array can be installed. The size of the array combined with the orientation, tilt, and shading elements determines the energy produced. A preliminary screening, based on the facility's electric demand, size, location, and unshaded free area, shows that the facility has a high potential for installing a PV array.

The amount of free area, ease of installation (location), and the lack of shading elements contribute to the potential for PV at the site. In order to be cost-effective, a solar PV array needs certain minimum criteria, such as flat or south-facing rooftop or other unshaded space on which to place the PV panels. In our opinion, the facility might not meet these minimum criteria for cost-effective PV installation.

**Figure 4: Solar Panels Placement**

Figure 4 above portrays the area and locations of the modelled solar panels. The modelled areas for lines of solar panels can be seen in blue. The area has a constant Total Solar Resource Fraction or the amount of sunlight each panel would receive over the year.

The modelling analysis was conducted through Helioscope, a solar simulation tool from the Folsom Labs. Based on our simulation, a relatively small rooftop PV array might be feasible. We estimate that the available space might support up to a 50-kW solar array. Such an array might produce up 68,606 kWh per year, which could save the college up to $17,152 per year in electric purchases. Based on average costs for commercial solar installation and current CUC prices, such an installation might pay for itself in energy savings in 6 years. The available roof space needs to be properly accessed by a qualified solar installer to determine feasibility. A structural analysis of the roof may be necessary as well. Roof conditions might make available roof space smaller than we assumed, or too costly to develop, which might make a solar array not economically viable for the site.

# Intelligent Building Management System Measures

Energy efficiency is one of the many benefits of incorporating IoT into buildings. IoT ecosystem includes sensors, actuators, cloud-based software and communication protocols, layered and controlled by a central building management system (BMS) that helps optimize systems, allowing them to communicate with each other and work together.

IoT ecosystem is comprised of these components:

- Devices for monitoring and controlling energy use, which ideally identify areas of high consumption, actively control energy usage and indirectly control consumption based on factors such as occupancy, time of day, or other factors
- Location-based automatic controls that optimize controls in specific rooms or sections of a building, often in relation to time-based patterns, occupancy, weather or a variety of other factors
- Cloud-computing platforms that store data and run software, such as data analytics software that evaluates data
- Software applications that implement programmed energy efficiency strategies, such as integration software that interprets and communicates data between systems

Using IoT, energy efficiency is driven by automation. With data gathered by smart sensors, a BMS can turn off lights in unoccupied rooms, reduce airflow in office buildings on weekends, or automatically close blinds when windows are exposed to direct sunlight.

**Energy-Saving IoT Devices**

As physical hardware, IoT devices can be used to create greater energy efficiency throughout a building's systems.

These IoT devices include:

**Lighting Controls**

Lighting controls are comprised of both sensors and actuators that control lighting through the use of IoT. Energy efficiency results from lowering lighting output based on certain conditions. In a recent literature review focusing on lighting and controls in office environments that use IoT, energy efficiency estimates ranged widely. Results depended upon occupant behavior, control system type, patterns of activity, and other conditions. They showed between 17-94% savings from smart controls over manually controlled systems.

***Daylight Sensors***

These use photocells to turn off or dim lighting based on the amount of available natural light. These photo sensors can also be used to raise or lower blinds to optimize lighting. They typically achieve savings of more than 40%.

***Occupancy Sensors***

Sensors that automatically turn on or off lights based on whether a room is occupied use infrared or ultrasonic technology, and can also be used for managing heating and cooling as well. Occupancy sensors generated from 3-

60% in savings when used in lighting systems. Another study saw a 20% reduction in energy use from such sensors in HVAC systems.

***HVAC Controllers***

HVAC controllers using IoT technology could reduce energy use by 24%, according to a 2011 study by Pacific Northwest National Laboratory (PNNL). Sensors measure various conditions within a building, using this data to regulate output within climate control systems. Smart controllers typically use predefined set points to determine actions and can be deployed at certain key points or throughout a building. Some more advanced sensors and controls implement machine learning (ML) algorithms to enact real-time changes.

***HVAC Economizer Controls***

Pulling in cool outside air to reduce the need for electrical cooling, economizers use sensors to measure either air temperature or heat and humidity to determine actions based on energy efficiency and occupant comfort. Economizers generate 57% energy savings on average, but savings can range from 22-90% depending on a variety of conditions.

***Smart Thermostats***

These enable remote monitoring and control of temperature within built environments. More advanced models can automatically provide analytics on energy usage that include reports showing amounts saved on a monthly basis. Two independent studies that looked at a top manufacturer of smart thermostats reported that customers saved 15% on cooling and 10-12% on heating on average.

***Variable Speed Drives***

These are also known as adjustable speed drives, AC drives, inverter adjustable frequency drives, or variable frequency drives. In older buildings, fans in HVAC systems normally operate on a single speed, using dampers, throttles, and valves to control airflow. As these fans only operate at full speed, this results in significant energy wastage. Variable speed drives allow fans to operate at higher or lower speeds, according to the energy needed. Typically, variable speed drives reduce energy usage for heating and cooling in buildings between 24-35%. However, a 2017 study by the American Council for an Energy-Efficient Economy (ACEEE) estimated energy use savings between 15–50% from such controls.

**Sensors for Predictive Building Maintenance**

Networks of IoT sensors that are connected to building systems, equipment, and other infrastructure help optimize building performance and save on energy costs. However, lowering energy expenses is just one way they promote efficiency. By proactively identifying issues before they become problems, facility managers are also able to get ahead of maintenance and avoid catastrophic system failures.

IoT sensors used to deal with maintenance issues include:

- Early fault detection sensors that alert when unseen issues show a fault is imminent
- Failure detection sensors that detect faults and disable machinery to prevent wider failures, which helps prevent injuries and downtime

While predictive maintenance offers energy efficiency indirectly, it creates savings in other areas.

According to the US Department of Energy (DOE), predictive maintenance:

- Cuts downtime by 35-40%
- Decreases breakdowns by 70-75%
- Increases productivity by 20-25%
- Offers ten times the return on investment
- Reduces maintenance costs by 25-30%

Some IoT technology can detect structural damage by measuring strain and cracks at key points. More directly, sensors used in predictive maintenance detect maintenance issues in energy-sucking systems like HVAC and lighting, reducing costs by keeping these systems working optimally.

***Smart Meters***

When it comes to IoT, energy efficiency in buildings is built upon metering and monitoring. Smart meters are an essential tool in tracking energy use, generally offering immediate savings of about 10%. Over time, smart meters can deliver as much as 30 percent savings when utilized properly. Smart electric sub meters can also track energy consumption according to tenants, systems, or even individual plugs. Sub meters additionally help identify anomalies that indicate possible maintenance issues affecting energy consumption.

# Energy Efficient Best Practices

A facility energy performance can also be improved through application of many low cost or no-cost energy efficiency strategies. By employing certain behavioral and operational changes and performing routine maintenance on building systems, equipment lifetime can be extended; occupant comfort, health and safety can be improved; and energy and O&M costs can be reduced. The recommendations below are provided as a framework for developing a whole building maintenance plan that is customized to your facility. Consult with qualified equipment specialists for details on proper maintenance and system operation.

**Energy Tracking with ENERGY STAR® Portfolio Manager®**

You've heard it before - you can't manage what you don't measure. ENERGY STAR® Portfolio Manager® is an online tool that you can use to measure and track energy and water consumption, as well as greenhouse gas emissions. Your account has already been established. Now you can continue to keep tabs on your energy performance every month.

**Reduce Air Leakage**

Air leakage, or infiltration, occurs when outside air enters a building uncontrollably through cracks and openings. Properly sealing such cracks and openings can significantly reduce heating and cooling costs, improve building durability, and create a healthier indoor environment. This includes caulking or installing weather stripping around leaky doors and windows allowing for better control of indoor air quality through controlled ventilation.

**Close Doors and Windows**

Ensure doors and windows are closed in conditioned spaces. Leaving doors and windows open leads to a significant increase in heat transfer between conditioned spaces and the outside air. Reducing a facility's air changes per hour (ACH) can lead to increased occupant comfort as well as significant heating and cooling savings, especially when combined with proper HVAC controls and adequate ventilation.

**Ensure Lighting Controls Are Operating Properly**

Lighting controls are very cost effective energy efficient devices, when installed and operating correctly. As part of a lighting maintenance schedule, lighting controls should be tested annually to ensure proper functioning. For occupancy sensors, this requires triggering the sensor and verifying that the sensor's timer settings are correct. For daylight sensors, maintenance involves cleaning of sensor lenses and confirming set points and sensitivity are appropriately configured.

**Reduce Motor Short Cycling**

Frequent stopping and starting of motors subjects rotors and other parts to substantial stress. This can result in component wear, reducing efficiency, and increasing maintenance costs. Adjust the load on the motor to limit the amount of unnecessary stopping and starting to improve motor performance.

**Perform Routine Motor Maintenance**

Motors consist of many moving parts whose collective degradation can contribute to a significant loss of motor efficiency. In order to prevent damage to motor components, routine maintenance should be performed. This maintenance consists of cleaning surfaces and ventilation openings on motors to prevent overheating, lubricating moving parts to reduce friction, inspecting belts and pulleys for wear and to ensure they are at proper alignment and tension, and cleaning and lubricating bearings. Consult a licensed technician to assess these and other motor maintenance strategies.

**Practice Proper Use of Thermostat Schedules and Temperature Resets**

Ensure thermostats are correctly set back. By employing proper set back temperatures and schedules, facility heating and cooling costs can be reduced dramatically during periods of low or no occupancy. As such, thermostats should be programmed for a setback of 5-10°F during low occupancy hours (reduce heating set points and increase cooling set points). Cooling load can be reduced further by increasing the facility's occupied set point temperature. In general, during the cooling season, thermostats should be set as high as possible without sacrificing occupant comfort.

**Ensure Economizers are Functioning Properly**

Economizers, when properly configured, can be used to significantly reduce mechanical cooling. However, if the outdoor thermostat or enthalpy control is malfunctioning or the damper is stuck or improperly adjusted, benefits from the economizer may not be fully realized. As such, periodic inspection and maintenance is required to ensure proper operation. This maintenance should be scheduled with maintenance of the facility's air conditioning system and should include proper setting of the outdoor thermostat/enthalpy control, inspection of control and damper operation, lubrication of damper connections, and adjustment of minimum damper position. A malfunctioning economizer can significantly increase the amount of heating and mechanical cooling required by introducing excess amounts of cold or hot outside air.

**Check for and Seal Duct Leakage**

Duct leakage in commercial buildings typically accounts for 5% to 25% of the supply airflow. In the case of rooftop air handlers, duct leakage can occur to the outside of the building, significantly increasing cooling and heating costs. By sealing sources of leakage, cooling, heating, and ventilation energy use can be reduced significantly, depending on the severity of air leakage

**Perform Proper Water Heater Maintenance**

At least once a year, drain a few gallons out of the water heater using the drain valve. If there is a lot of sediment or debris, then a full flush is recommended. Turn the temperature down and then completely drain the tank. Once a year check for any leaks or heavy corrosion on the pipes and valves. For gas water heaters, check the draft hood and make sure it is placed properly, with a few inches of air space between the tank and where it connects to the vent. Look for any corrosion or wear on the gas line and on the piping. If you noticed any black residue, soot or charred metal, this is a sign you may be having combustion issues and you should have the unit serviced by a professional. For electric water heaters, look for any signs of leaking such as rust streaks or residue around the upper and lower panels covering the electrical components on the tank. For water heaters over three to four years old have a technician inspect the sacrificial anode annually.

**Plug Load Controls**

There are a variety of ways to limit the energy use of plug loads including increasing occupant awareness, removing under-utilized equipment, installing hardware controls, and using software controls. Some control steps to take are to enable the most aggressive power settings on existing devices or install load sensing or occupancy sensing (advanced) power strips. For additional information refer to "Plug Load Best Practices Guide" http://www.advancedbuildings.net/plug-load-best-practices-guide-offices.

**Replace Computer Monitors**

Replacing old computer monitors or displays with efficient monitors will reduce energy use. ENERGY STAR® rated monitors have specific requirements for on mode power consumption as well as idle and sleep mode power. According to the ENERGY STAR® website monitors that have earned the ENERGY STAR® label are 25% more efficient than standard monitors.

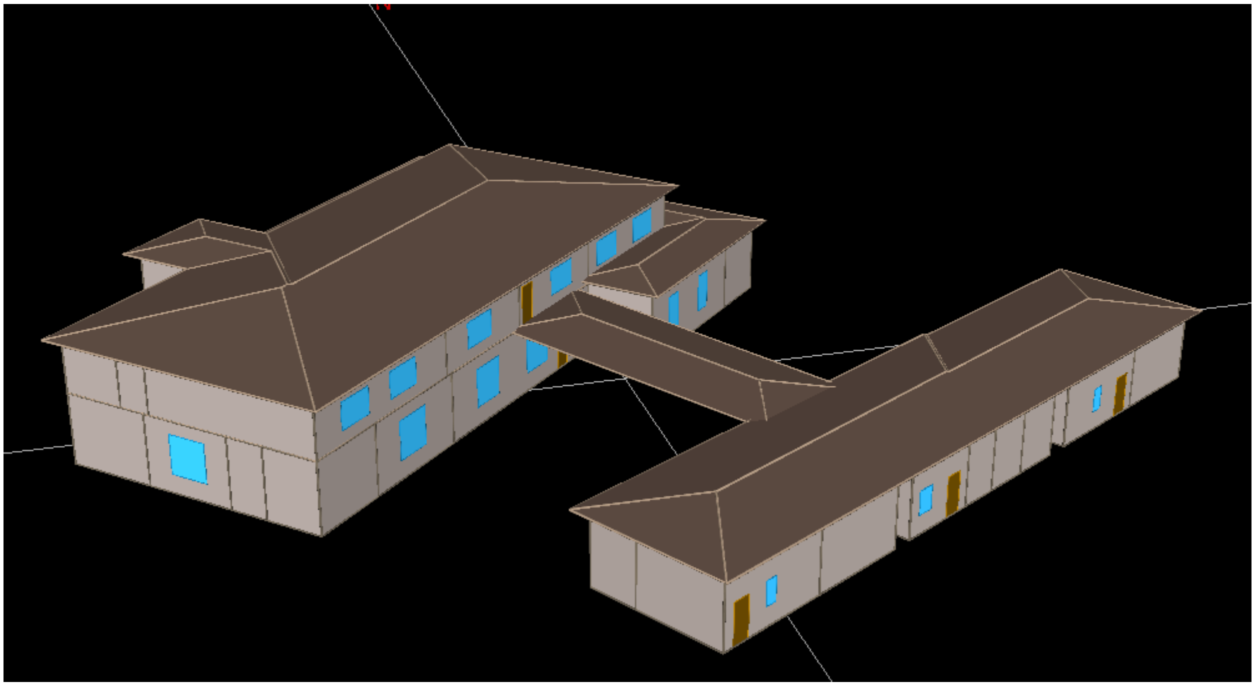
**Water Conservation**

Installing low-flow faucets or faucet aerators, low-flow showerheads, and kitchen sink pre-rinse spray valves saves both energy and water. These devices save energy by reducing the overall amount of hot water used hence reducing the energy used to heat the water. The flow ratings for EPA Water Sense™ (http://www3.epa.gov/watersense/products) labeled devices are 1.5 gallons per minute (gpm) for bathroom faucets, 2.0 gpm for showerheads, and 1.28 gpm for pre-rinse spray valves. Installing dual flush or low-flow toilets and low-flow or waterless urinals are additional ways to reduce the sites water use, however, these devices do not provide energy savings at the site level. Any reduction in water use does however ultimately reduce grid level electricity use since a significant amount of electricity is used to deliver water from reservoirs to end users. The EPA Water Sense™ ratings for urinals is 0.5 gallons per flush (gpf) and toilets that use as little as 1.28 gpf (this is lower than the current 1.6 gpf federal standard).

# Appendix – A

## 3D MODEL IMAGES

### Figure 4 : 2 Blocks Model



### Figure 5: Library Block

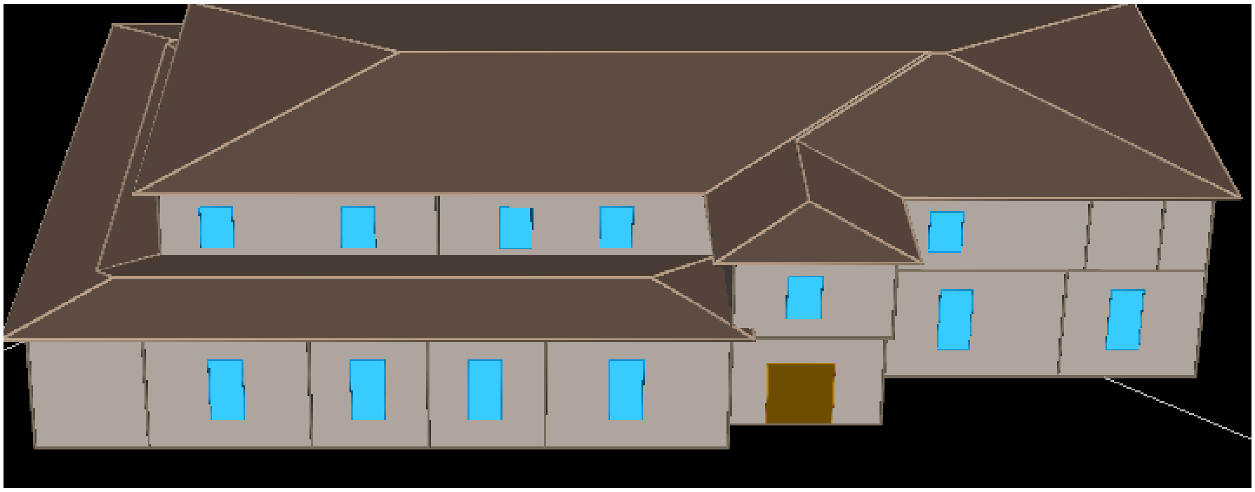
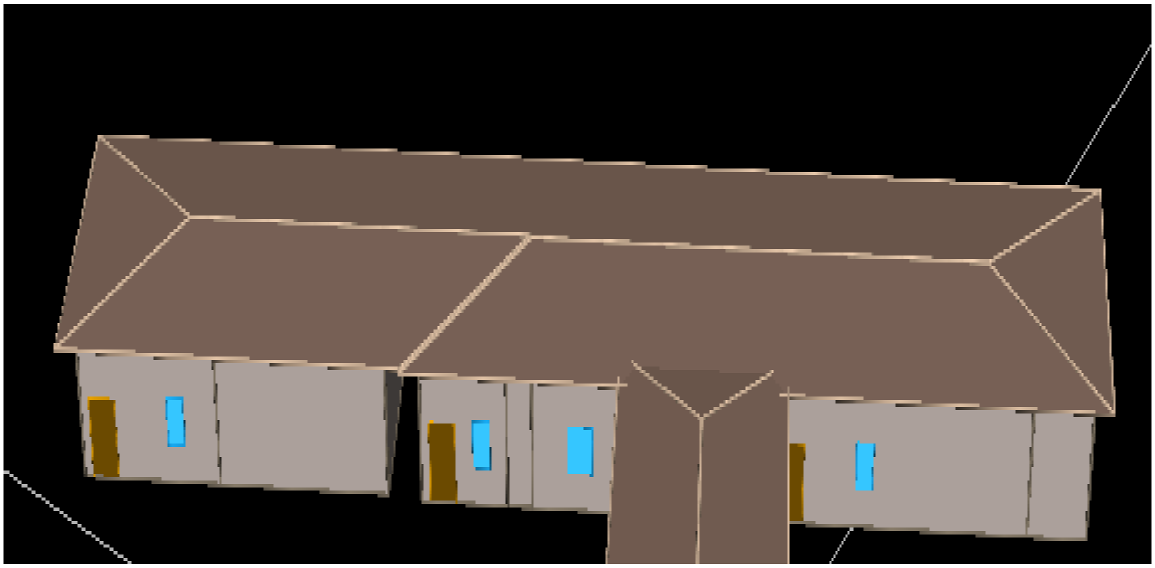


**Figure 6: Nursing Block**



# Appendix - B

## ENERGY MODEL INPUTS AND REFERENCE

**Table 10: Input parameters**

| | |
|---|---|
| **Building Information** | |
| Project Name | Sam Basdeo Library + School of Nursing |
| Client Name | Dr. Robert Robertson |
| Site Address | 168 Olympic Way, PO Box 702 Grand Cayman,KY1-1107, Cayman Islands |
| Construction year | 2004 |
| Building typology | University |
| No. stories | Library 2 Floor and Nursing 1 Floor |
| Built-up area (sq. ft) | 14,611 |
| **Utility Data** | |
| Billed Electricity Consumption (kWh) | 157,824 |
| **Reference** | |
| Weather file | CYM_SI_Grand.Cayman-East.End.783830_TMYx.2007-2021.BIN |
| Schedule (Refer "to schedule" sheet) | Default schedule of University/School by NREL |
| Exterior wall U-Value (Btu/h-ft2-F) | 0.58 (ASHRAE 2004) |
| Roof U-Value (Btu/h-ft2-F) | 0.034 (ASHRAE 2004) |
| Glass U-value (Btu/h-ft2-F) | 1.47 |
| SC & VLT of glass | SC:0.60 & VLT: 0.8 |
| Window/Glass | With Blinder |
| Occupancy | 215 persons in total |
| **Lighting Load** | |
| LPD (W/sq. ft./kW) | As per Appendix D |
| **Equipment Load** | |
| EPD (W/sq. ft./kW) | As per Appendix D |
| **Cooling System** | |
| Type of cooling system | AHU, Mini-Split-Unit |
| EER /COP | AS per HVAC Sheet |

## ASHRAE EPIDEMIC TASK FORCE

# ASHRAE EPIDEMIC TASK FORCE

### Core Recommendations for Reducing Airborne Infectious Aerosol Exposure

The following recommendations are the basis for the detailed guidance issued by ASHRAE Epidemic Task Force. They are based on the concept that within limits ventilation, filtration, and air cleaners can be deployed flexibly to achieve exposure reduction goals subject to constraints that may include comfort, energy use, and costs. This is done by setting targets for equivalent clean air supply rate and expressing the performance of filters, air cleaners, and other removal mechanisms in these terms.

1. *Public Health Guidance* – Follow all current regulatory and statutory requirements and recommendations, including vaccination, wearing of masks and other personal protective equipment, social distancing, administrative measures, circulation of occupants, hygiene, and sanitation.

2. *Ventilation, Filtration, Air Cleaning*
   - 2.1 Provide and maintain at least required minimum outdoor airflow rates for ventilation as specified by applicable codes and standards.
   - 2.2 Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems.
   - 2.3 Only use air cleaners for which evidence of effectiveness and safety is clear.
   - 2.4 Select control options, including standalone filters and air cleaners, that provide desired exposure reduction while minimizing associated energy penalties.

3. *Air Distribution* - Where directional airflow is not specifically required, or not recommended as the result of a risk assessment, promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person.

4. *HVAC System Operation*
   - 4.1 Maintain temperature and humidity design set points.
   - 4.2 Maintain equivalent clean air supply required for design occupancy whenever anyone is present in the space served by a system.
   - 4.3 When necessary to flush spaces between occupied periods, operate systems for a time required to achieve three air changes of equivalent clean air supply.
   - 4.4 Limit re-entry of contaminated air that may re-enter the building from energy recovery devices, outdoor air, and other sources to acceptable levels.

5. *System Commissioning – Verify that HVAC systems are functioning as designed.*

**Figure 7: ASHRAE epidemic task force**

# Appendix - C

## MONTHLY ECMS SAVING DETAILS

## CALIBRATION RESULTS

### Table 11: Calibrated Electricity Utility Details

| Month | Billed Electricity (KWh) | eQuest Calibrated Electricity consumption (kWh) | ECM 1 Lighting Control (KWh) | ECM 2 Window Upgradation (KWh) | ECM 3A BMS - Night Setback (NSB) (KWH) | ECM 3B BMS - Fan Control (KWH) | ECM 3C BMS - Optimal On-Off (KWH) | ECM 3D BMS - Demand Control Ventilation (DCV) (KWH) | ECM 4 VFD Installation (KWH) | ECM 5 Weatherization (KWH) | ECM 6 Solar PV(KWH) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | 13,954 | 14,830 | 13,635 | 14,576 | 12,892 | 12,571 | 14,442 | 14,749 | 13,997 | 13,179 | 9,262 |
| Feb | 12,467 | 11,791 | 10,953 | 11,537 | 10,387 | 9,658 | 11,507 | 11,682 | 10,951 | 10,219 | 6,821 |
| Mar | 13,170 | 11,101 | 10,348 | 10,902 | 9,912 | 9,194 | 10,828 | 10,991 | 10,290 | 9,831 | 6,158 |
| Apr | 10,353 | 13,128 | 12,225 | 12,841 | 11,504 | 10,657 | 12,809 | 13,000 | 12,201 | 11,402 | 7,499 |
| May | 9,130 | 14,521 | 13,794 | 14,261 | 12,741 | 12,011 | 14,142 | 14,361 | 13,484 | 12,739 | 8,556 |
| Jun | 10,364 | 15,372 | 15,184 | 15,111 | 13,522 | 13,039 | 14,842 | 15,158 | 14,076 | 13,401 | 9,499 |
| Jul | 11,746 | 15,582 | 15,432 | 15,252 | 13,812 | 12,775 | 15,124 | 15,322 | 14,106 | 13,411 | 9,291 |
| Aug | 14,738 | 16,860 | 16,683 | 16,564 | 14,941 | 13,980 | 16,303 | 16,583 | 15,239 | 14,516 | 10,190 |
| Sep | 17,413 | 15,308 | 15,164 | 15,006 | 13,697 | 12,508 | 14,842 | 15,036 | 13,760 | 13,118 | 9,022 |
| Oct | 16,392 | 15,410 | 15,242 | 15,145 | 13,746 | 12,829 | 14,949 | 15,193 | 13,965 | 13,456 | 9,442 |
| Nov | 15,109 | 13,672 | 13,519 | 13,423 | 12,276 | 11,693 | 13,245 | 13,549 | 12,518 | 12,191 | 8,336 |
| Dec | 12,988 | 12,042 | 11,806 | 11,726 | 11,016 | 10,011 | 11,746 | 11,915 | 11,052 | 10,625 | 6,935 |
| **Total** | **157,824** | **169,617** | **163,985** | **166,344** | **150,446** | **140,926** | **164,779** | **167,539** | **155,639** | **148,088** | **101,011** |
| **Saving on Baseline (KWh)** | | **(11,793)** | **5,632** | **3,273** | **19,171** | **28,691** | **4,838** | **2,078** | **13,978** | **21,529** | **68,606** |
| **Saving on Baseline (%)** | | | **3%** | **2%** | **11%** | **17%** | **3%** | **1%** | **8%** | **13%** | **8%** |

# Appendix - D

## LIGHTING POWER DENSITY (LPD) CALCULATION SHEET

### Table 12: Lighting Power Density Calculation Sheet

| LPD Sheet: The Sam Basdeo Library | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Location** | **Floor** | **Qty** | **Lighting Control** | **Lamp Type** | **Watts/Lamp** | **Total Watt** | **Area (Sqft)** | **LPD(W/Ft2)** |
| Library and library rooms & Book Store | 1 | 5 | Emergency Control 1 | Exit Sign | 48 | 240 | 2597 | 0.28 |
| | 1 | 10 | Wall Switch 1 | LED - Lamps | 48 | 480 | | |
| Computer lab | 1 | 4 | Wall Switch 1 | LED - Lamps | 88 | 352 | 362 | 0.97 |
| Director learning resource centre | 1 | 1 | Wall Switch 1 | LED - Lamps | 48 | 48 | 153 | 0.31 |
| Electrical room | 1 | 1 | Wall Switch 1 | LED - Lamps | 22 | 22 | 72 | 0.31 |
| Female bathroom | 1 | 2 | Wall Switch 1 | LED - Lamps | 22 | 44 | 40 | 1.10 |
| Male bathroom | 1 | 2 | Wall Switch 1 | LED - Lamps | 22 | 44 | 53 | 0.83 |
| Math lab | 1 | 2 | Wall Switch 1 | LED - Lamps | 22 | 44 | 191 | 0.23 |
| Study 1 | 1 | 2 | Wall Switch 1 | LED - Lamps | 88 | 176 | 138 | 1.28 |
| Study 2 | 1 | 2 | Wall Switch 1 | LED - Lamps | 88 | 176 | 136 | 1.29 |
| Testing center | 1 | 5 | Wall Switch 1 | LED - Lamps | 22 | 110 | 52 | 2.12 |
| Stairs | 1 | 2 | Wall Switch 1 | LED - Lamps | 22 | 44 | 174 | 0.25 |
| Conference Room 1 | 2 | 7 | Wall Switch 1 | LED - Linear Tubes | 88 | 616 | 1013 | 0.61 |
| Conference Room 2 | 2 | 6 | Wall Switch 1 | LED - Linear Tubes | 88 | 528 | 662 | 0.80 |
| Conference Room 3 | 2 | 6 | Wall Switch 1 | LED - Linear Tubes | 88 | 528 | 525 | 1.01 |
| Conference Room 4 | 2 | 6 | Wall Switch 1 | LED - Linear Tubes | 88 | 528 | 811 | 0.65 |
| Lobby/hallway | 2 | 6 | Wall Switch 1 | LED - Linear Tubes | 80 | 480 | 670 | 0.72 |
| Restroom female | 2 | 1 | Wall Switch 1 | LED - Linear Tubes | 20 | 20 | 20 | 1.00 |
| Restroom male | 2 | 1 | Wall Switch 1 | LED - Linear Tubes | 30 | 30 | 37 | 0.81 |
| Manager Room | 2 | 1 | Wall Switch 2 | LED - Linear Tubes | 48 | 48 | 79 | 0.61 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Ext. Light** | 8 | Wall Switch 2 | CFL | 30 | 240 | 480 |
| | 8 | Wall Switch 2 | LED - LED Fixture | 30 | 240 | |

| **LPD Sheet: UCCI School of Nursing** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Location** | **Floor** | **Qty** | **Lighting Control** | **Lamp Type** | **Watts/Lamp** | **Total Watt** | **Area (Sqft)** | **LPD(W/Ft2)** |
| Classroom 1 | 1 | 6 | Wall Switch 1 | Linear Flourescent | 32 | 192 | 374.4 | 0.51 |
| Classroom 2 | 1 | 8 | Wall Switch 1 | Linear Flourescent | 32 | 256 | 464.5 | 0.55 |
| Enclosed offices | 1 | 4 | Wall Switch 1 | Linear Flourescent | 32 | 128 | 241 | 0.53 |
| Nursing classroom/lab | 1 | 12 | Wall Switch 1 | LED - Linear Tubes | 32 | 384 | 653.3 | 0.59 |
| Open offices | 1 | 14 | Wall Switch 1 | LED - Linear Tubes | 32 | 448 | 543 | 0.83 |
| Storage | 1 | 2 | Wall Switch 1 | LED - Linear Tubes | 32 | 64 | 175 | 0.37 |
| Exterior Lighting | 1 | 3 | Timer 1 | CFL | 100 | 300 | | |
| Restroom - Unisex 1 | 1 | 1 | Wall Switch 1 | LED - Fixtures | 20 | 20 | 57.9 | 0.35 |

## EQUIPMENT LIST

### Table 13: EPD list

| Equipment Details: The Sam Basdeo Library | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Floor | Location | Equipment Type | Model number | Make | Qty | Power Consumption (W) | Total Power Consumption (W) | Area (ft2) | EPD(W/ft2) |
| 1 | President Room | Dehumidifier | AP-T20 | HoMEDiCS | 1 | 37 | 37 | 308 | 1.09 |
| 1 | | PC | | DELL | 2 | 150 | 300 | | |
| 1 | Reception/Office | Dehumidifier | AP-T20 | HoMEDiCS | 1 | 37 | 37 | 670 | 0.39 |
| 1 | | Television | | TOSHIBA | 1 | 225 | 225 | | |
| 1 | Library- Hall | PC | | IBM | 18 | 150 | 2700 | 2597.7 | 1.04 |
| 1 | Computer Room-1 | PC | | DELL | 5 | 150 | 750 | 362 | 2.07 |
| 1 | Computer Room-2 | PC | | HP/DELL | 10 | 150 | 1500 | 146 | 10.27 |
| 2 | Waiting Area/Entrance Lobby | Dehumidifier | AP-T20 | HoMEDiCS | 1 | 37 | 37 | 130 | 0.28 |
| 2 | Printer Room | Printer | X94A016683 | EPSON | 1 | 25 | 25 | 78.9 | 0.32 |
| 2 | Conference Room- 1 | Television | UN70TU7000B | SAMSUNG | 1 | 225 | 225 | 1013.1 | 0.51 |
| 2 | | Television-Projector | 1510X | DELL | 1 | 287 | 287 | | |
| 2 | Conference Room- 2 | Television- Projector | 1510X | DELL | 1 | 287 | 287 | 662 | 1.57 |
| 2 | | Television | 65S434 | TCL | 3 | 250 | 750 | | |
| 2 | Conference Room- 3 | Television- Projector | 1609WX | DELL | 1 | 256 | 256 | 525 | 0.94 |
| 2 | | Television | 75UP7070PUP | LG | 1 | 240 | 240 | | |
| 2 | Conference Room- 4 | Television-Projector | 1510X | DELL | 1 | 287 | 287 | 811 | 0.63 |
| 2 | | Television | 70UP7070PUE | LG | 1 | 225 | 225 | | |

| Equipment Details: UCCI School of Nursing | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Floor | Location | Equipment Type | Model number | Make | Qty | Power Consumption (W) | Total Power Consumption (W) | Area (ft2) | EPD(W/ft2) |
| 1 | Enclosed offices | Computer Monitor | | HP | 2 | 150 | 300 | 241 | 3.11 |
| 1 | Enclosed offices | Desktop Computer | | VICTUS | 1 | 150 | 150 | | |
| 1 | Enclosed offices | Printer | LBWA1ZZ1CA | TUV Rheinland | 1 | 250 | 250 | | |
| 1 | Enclosed offices | Exhaust Fan | | | 1 | 50 | 50 | | |
| 1 | Classroom 1 | Dehumidifier | Part No-4033730<br>SR No- G2166899 | SANTA-FE | 1 | 580 | 580 | 374 | 2.19 |
| 1 | Classroom 1 | Television | 75UP7070PUD | LG | 1 | 240 | 240 | | |
| 1 | Classroom 2 | Television | UN70TU7000B | SAMSUNG | 1 | 225 | 225 | 464 | 1.73 |
| 1 | Classroom 2 | Dehumidifier | | SANTA-FE | 1 | 580 | 580 | | |
| 1 | Open offices | Dehumidifier | | SANTA-FE | 1 | 580 | 580 | 543 | 3.15 |
| 1 | Open offices | Microwave Oven | OGYW0701 | Oster | 1 | 1050 | 1050 | | |
| 1 | Open offices | Refrigerator | MCBR360W<br>MCBR360B<br>MCBR360S | Magic Chef | 1 | 80 | 80 | | |
| 1 | Storage | Dehumidifier | | U-AIRE | 1 | 580 | 580 | 175 | 3.31 |
| 1 | Nursing classroom/lab | Television | UN55TU8000F | SAMSUNG | 1 | 135 | 135 | 653.3 | 0.21 |

## HVAC SYSTEM LIST

**Table 14: HVAC Sheet**

| HVAC Sheet: The Sam Basdeo Library | | | | | | |
|---|---|---|---|---|---|---|
| **Zone** | **System type** | **Model Number** | **COP** | **Cooling Capacity** | **Make** | **Year of Manufactured** |
| Centralized | AHU | RHGL-180ZL | 15 TR | 180,000 | RHEEM | 2018 |
| | Condensing Unit | RWAL-091CAZ | 3.27 | | | |
| | Condensing Unit | RWAL-091CAZ | 3.27 | | | |
| Library | Condensing Unit | RA1636AJ1NA | 3.75 | 36000 | RHEEM | 2018 |
| Library | Condensing Unit | RA1636AJ1NA | 3.75 | 36000 | RHEEM | 2022 |
| Library | Condensing Unit | 116BNA036-B | 3.75 | 36000 | RHEEM | 2022 |

| HVAC Sheet: UCCI School of Nursing | | | | | | |
|---|---|---|---|---|---|---|
| **Zone** | **System type** | **Quantity** | **Model Number** | **Cooling Capacity(Btu/h)** | **Make** | **Year of Manufactured** |
| Classroom 1 | Mini-Split Unit | 1 | LI018CI-170P432-1 | 17400 | LENNOX | 2021 |
| Classroom 2 | Mini-Split Unit | 1 | LI018CI-210P432 | 17400 | LENNOX | 2021 |
| Enclosed offices | Mini-Split Unit | 1 | GMX160122HWE | 12000 | GOODMAN | 2018 |
| Nursing classroom/lab | Mini-Split Unit | 1 | LI024CO-210P432 | | LENNOX | 2021 |
| | Mini-Split Unit | 1 | LI024CI-210P432 | 22000 | LENNOX | 2021 |
| | Mini-Split Unit | 1 | AR24JVSSAWKN | 24000 | SAMSUNG | |
| | Mini-Split Unit | 1 | AR24JVSSAWKX | | SAMSUNG | |
| Open offices | Mini-Split Unit | 1 | EQX24HPJ1IB | 22000 | boreal | 2018 |
| | Mini-Split Unit | 1 | AR24JVSSAWKN | 24000 | SAMSUNG | |

# Appendix – E

## ESTIMATED COSTING PER ECMS

### Table 15: Estimation Project Cost Details

| S N | ECM | | Unit | Quantity | Total |
|---|---|---|---|---|---|
| **1** | **Lighting Control** | | | | **$1,893** |
| | Daylighting Sensor | | EACH | 7 | $469 |
| | Occupancy Sensor | | EACH | 12 | $1,424 |
| | | | | | |
| **2** | **Window Upgrade** | | | | **$10,661** |
| | Area of windows | | Area (ft2) | 990 | $10,661 |
| | | | | | |
| **3A** | **BMS - Night Setback Control (NSB)** | | | | **$51,157.18** |
| | Control Software | | Points | 29 | $300 |
| | Start-up Labor / hr | | EA | 4 | $600 |
| | Controller , 128 Point | | EA | 2 | $133 |
| | Panel | | EA | 1 | $1,301 |
| | Communications Cable/ LF | $/PANEL | LF | 290 | $1,299 |
| | Space Temperature | | EA | 29 | $9,600 |
| | Space Humidity | | EA | 29 | $16,602 |
| | | | | | |
| **3B** | **BMS - Fan Control** | | | | **$41,035.48** |
| | Control Software | | Points | 29 | $300 |
| | Start-up Labor / hr | | EA | 6 | $900 |
| | Controller , 128 Point | | EA | 2 | $133 |
| | Panel | | EA | 1 | $1,301 |
| | Communications Cable/ LF | $/PANEL | LF | 290 | $1,299 |
| | Space Temperature | | EA | 29 | $9,600 |
| | | | | | |
| **3C** | **BMS - Optimal On- Off** | | | | **$9,041.02** |
| | Control Software | | Points | 29 | $300 |
| | Start-up Labor / hr | | EA | 4 | $600 |
| | Controller , 128 Point | | EA | 2 | $133 |
| | Panel | | EA | 1 | $1,301 |
| | Communications Cable/ LF | $/PANEL | LF | 290 | $1,299 |
| | | | | | |
| **3D** | **BMS - Demand Control Ventilation (DCV)** | | | | **$5,407** |
| | CO2 Sensor | | EACH | 10 | $2,581 |
| | Motorised Damper , 12" x 12" | | EACH | 10 | $2,584 |
| | Control Software | | Points | 10 | $242 |
| | | | | | |
| **4** | **VFD Installation** | | | | **$5,525** |
| | Motors , 1.15 service factor | | KW | 3 | $2,559 |
| | VFD | | KW | 1 | $730 |
| | Panel for VFD | | EA | 1 | $2,236 |
| **5** | **Weatherization** | | | | **$25,104** |
| | Air Sealing | | $ft^2$ | 990 | $859 |
| | Wall Insulation (R-5.7) | | $ft^2$ | 990 | $24,245 |
| **6** | **Solar PV Installation** | | | | **$101,800** |
| | Solar Panels - Hanwha Q Cell Q.Peak DUO XL - G10.3/BFG (485W) | $/WATT | PER WATT | 50,000 | $101,800 |

NEWYORK ENGINEERS

**Grand Cayman Campus –**

**Sam Basdeo Library &**

**School of Nursing**

**168 Olympic Way, PO Box 702 Grand Cayman,**

**Cayman Islands KY1-1107**