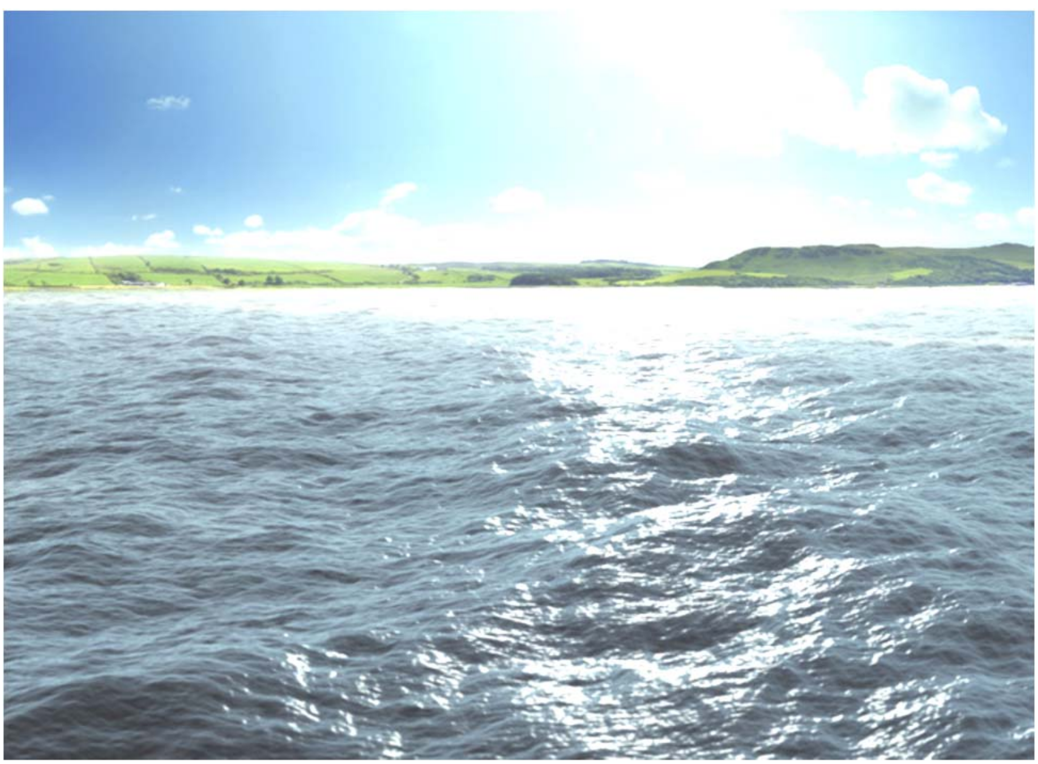
Investment Grade Audits of Schools and Hospitals in Jamaica

Jamaica Ministry of Science, Energy and Technology

Date: September 14, 2016



1 EXECUTIVE SUMMARY

An Investment Grade Audit (IGA) was performed by DNV GL Energy Engineers of six (6) government buildings in Jamaica. The two week-long visit was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation. The team included the facility managers, Ministry of Science, the Inter-American Development Bank (IDB) Energy and Technology (MSET), representatives from the utility Petroleum Corporation of Jamaica (PCJ), and the Ministry in charge of managing the building. Foreign mission attendees included:

- Kent Dahlquist, DNV GL
- Joseph St. John, DNV GL

The objective of the mission was to visit six (6) GoJ facilities which had been identified as ripe for deep energy retrofits and perform IGAs of each facility. From this information, the team garnered: opportunities for energy savings, facilities envelope conditions, mechanical systems conditions, lighting systems conditions, power factor, current maintenance issues, and potential for distributed renewable energy. A list of facilities visited is provided below:

Building
Ministry of Health: Victoria Jubilee Hospital Kingston C.S.O., Kingston
Min of Health: Mandeville Public Hospital Mandeville P..O., Manchester
Heart Trust NTA – Ebony Park Academy
Marcus Garvey High
Ministry of Health: Cornwall Regional Hospital Montego Bay #1 P.O., St. James
Ministry of Health Falmouth Hospital; Rodney Street Falmouth Trelawny

The project is commissioned by the IDB and the goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. The expected results of the project are:

- Reduced electricity consumption within government facilities
- Decreased oil imports through improved EE
- Reduced GHG emissions which can contribute to Jamaica's INDC commitment
- An increased capacity to promote and supervise electricity planning in Jamaica

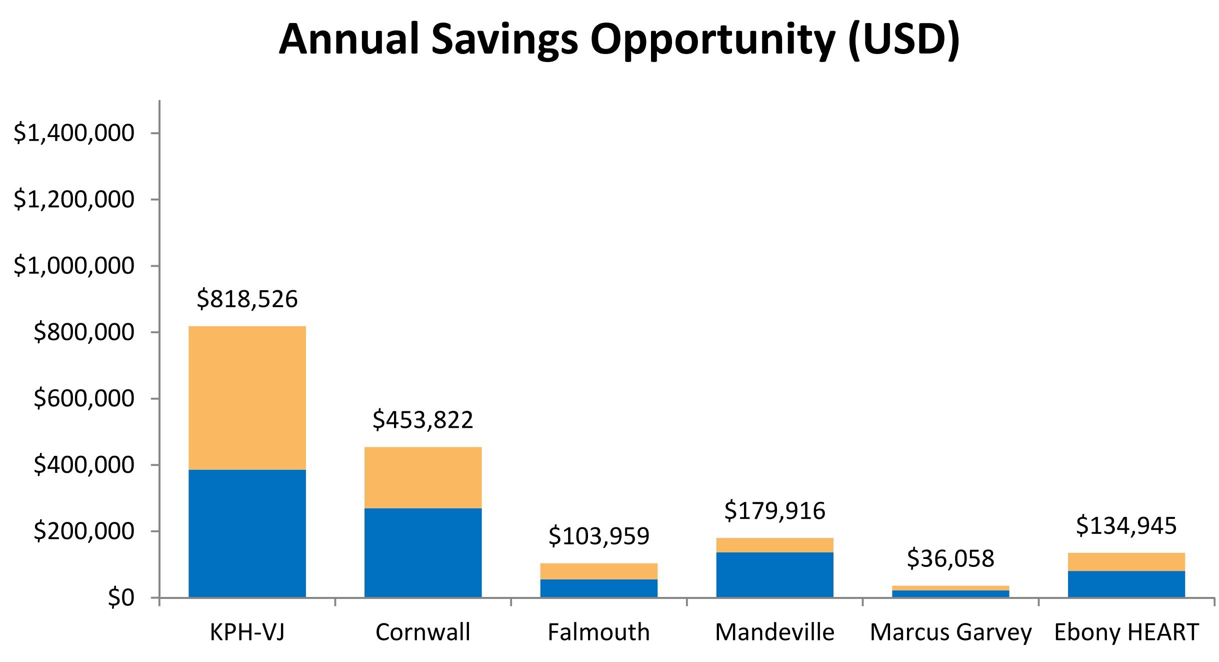
A Technical Assessment Report has been created for each building which describes in detail: existing conditions, system-by-system assessment, facilities conditions, recommended Energy Efficiency Measures (EEMs) and associated savings.

1.1 Overall Savings Opportunity

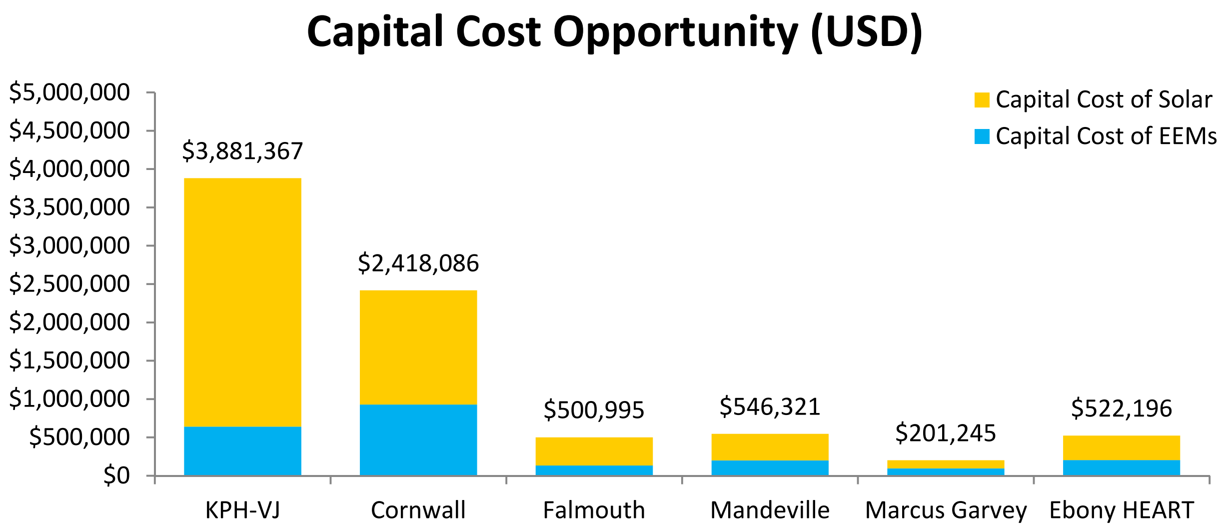
A thorough analysis of energy savings opportunity at each site has been provided in the form of a Investment Grade Audit for each school and hospital visited. For more information, please reference the Technical Assessment Reports that have been prepared by the DNV GL team. The following table and charts provide an outline of total cost and energy cost savings opportunity per building.

Spending and Savings Overview						
Facility	Capital Cost of EEMs	Capital Cost of Solar	Total Capital Cost	Annual Savings of EEMs	Annual Savings of Solar	Total Savings
KPH-VJ	$639,867	$3,241,500	$3,881,367	$385,943	$432,583	$818,526
Cornwall	$927,686	$1,490,400	$2,418,086	$269,525	$184,297	$453,822
Falmouth	$132,355	$368,640	$500,995	$55,547	$48,412	$103,959
Mandeville	$200,449	$345,871	$546,321	$136,839	$43,077	$179,916
Marcus Garvey	$94,391	$106,853	$201,245	$22,113	$13,945	$36,058
Ebony HEART	$203,290	$318,906	$522,196	$80,487	$54,458	$134,945
Totals	**$2,198,038**	**$5,872,171**	**$8,070,209**	**$950,455**	**$776,772**	**$1,727,226**

The following chart outlines savings opportunity by building.



In order to achieve the aforementioned savings, substantial energy efficiency investments will be required. The proposed project will provide loan financing from IDB and the Japan International Cooperation Agency (JICA) of US$30 million to the GoJ. The following chart outlines the capital cost opportunity at the six facilities assessed.

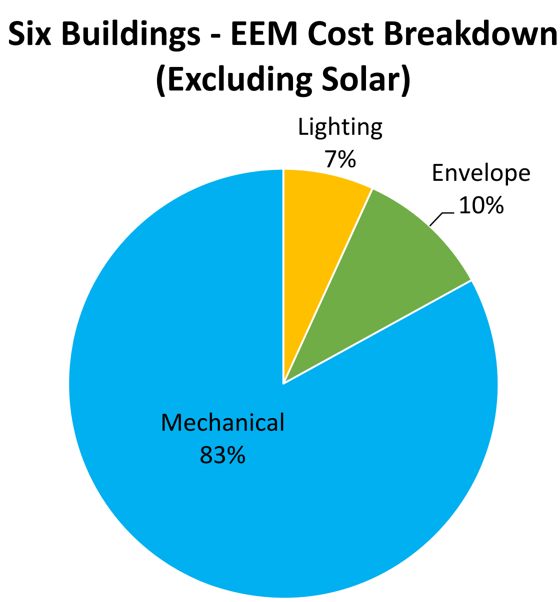


Capital Cost Opportunity (USD)
$5,000,000
$4,500,000
$4,000,000
$3,500,000
$3,000,000
$2,500,000
$2,000,000
$1,500,000
$1,000,000
$500,000
$0
Capital Cost of Solar
Capital Cost of EEMs
$3,881,367
$2,418,086
$500,995
$546,321
$201,245
$522,196
KPH-VJ
Cornwall
Falmouth
Mandeville
Marcus Garvey
Ebony HEART

1.2 System-specific breakdown

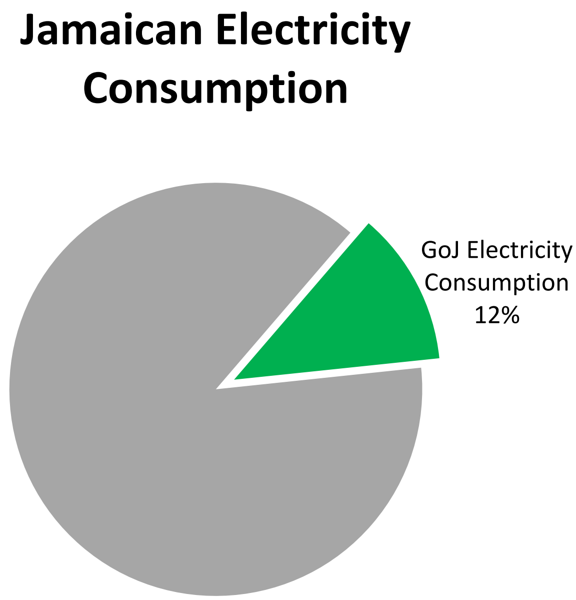
The following table breaks down capital costs and savings by building system (envelope, mechanical, lighting, solar, and water.) The GoJ has specified that this breakdown helps in understanding the benefits of the loan in terms of depth of retrofit. It must be noted that the audit and associated analysis assume savings based on a holistic Deep Energy Retrofit approach. Improving the a single building system such as envelope without implementing mechanical upgrades will not result in the additive savings that can be seen by considering whole building upgrades.

		Capital Costs USD$				
Facility	**Annual Consumption (kWhr)**	**Lighting**	**Envelope**	**Mechanical**	**Solar**	**Total Capital Costs**
Ministry of Health: Victoria Jubilee Hospital Kingston C.S.O., Kingston	6,627,747	$60,442	$69,063	$1,683,451	$2,291,328	$4,104,284
Ministry of Health: Cornwall Regional Hospital Montego Bay #1 P.O., St. James	4,537,430	$62,505	$103,649	$836,532	$1,490,400	$2,493,086
Min of Health: Mandeville Public Hospital Mandeville P.O., Manchester	1,508,712	$32,177	$10,115	$158,158	$345,871	$546,321
Ministry of Health Falmouth Hospital; Rodney Street Falmouth Trelawny	703,799	$19,295	$23,669	$89,318		$132,282
HEART TRUST Ebony Park	914,666	$47,269	$100,161	$55,860	$318,906	$522,196
Marcus Garvey High-St Ann	179,925	$13,342	$44,631	$39,989	$106,853	$204,815
TOTAL	**14,472,279**	**$235,030**	**$351,288**	**$2,863,308**	**$4,553,358**	**$8,002,984**



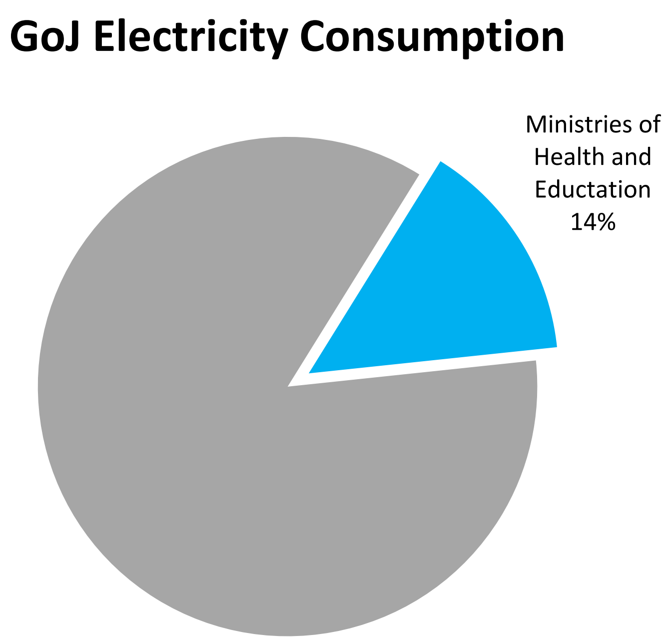
1.3 Context within Jamaican Electricity Use

Annual electricity consumption in Jamaica was roughly 3 TeraWatt-hours (TWh) in 2014 according to MSET's "An Overview of Jamaica's Electricity Sector." Of this annual energy consumption, 12% is used by GoJ facilities and equipment.

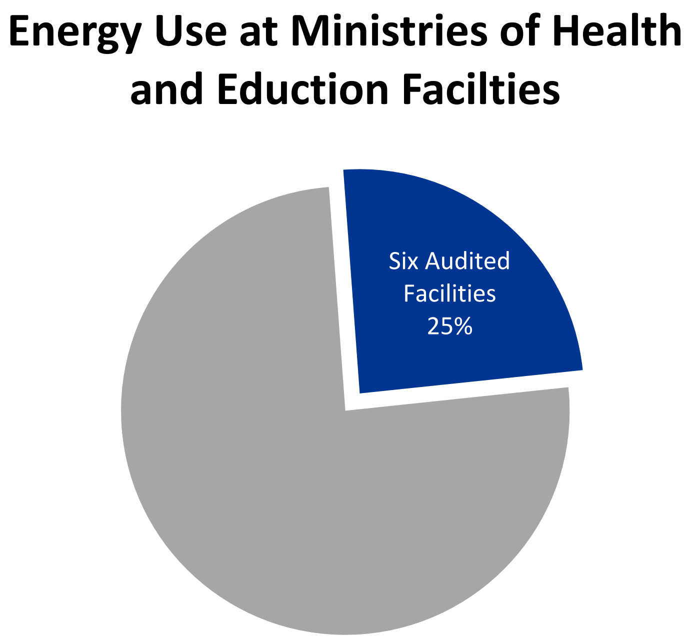


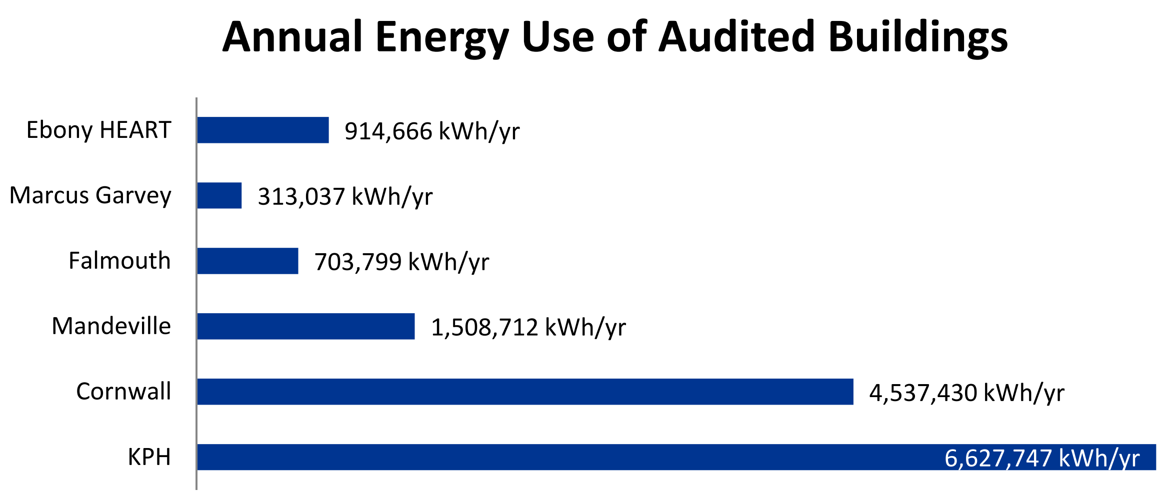
The dominant energy users in the GoJ are the National Water Commission (NWC) and street lighting. Of building stock, healthcare and educational facilities rank top among energy users, accounting for 14.5% of the GoJ's annual electricity usage.

	Consumption		Cost	
Public Agencies	**GWh/Y**	**%**	**Million US$/Y**	**%**
National Water Commission	188.2	45.7%	50.1	41.3%
Street Lighting	69.8	17.0%	25.3	20.9%
Public Agencies - Combined	43.7	10.6%	13.6	11.2%
Health	31.6	7.7%	8.7	7.1%
Education	28.1	6.8%	9.3	7.6%
Civil Aviation	16.9	4.1%	4.5	3.7%
Security and Justice	16.3	4.0%	5.0	4.1%
Irrigation	8.4	2.1%	2.6	2.2%
Defense	8.3	2.0%	2.2	1.8%
Total Jamaica Public Sector	**411.3**		**121.3**	



The six buildings audited in association with this report were chosen due to their exceptionally high energy use characteristics, regional importance, ripeness for retrofit, and other factors. Kingston Public Hospital & Victoria Jubilee Hospitals represent the highest energy use among GoJ buildings. The six buildings audited as part of this study represent a full quarter of annual Ministry of Health and Ministry of Education energy use.





2 Kingston Public Hospital

An Energy Technical Assessment was performed by DNV GL Energy Engineers of government buildings in Jamaica. The full day site visit of KPH and VJ Hospital was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation. The team included the facility managers, MSET, representatives from the utility PCJ, and the Ministry in charge of managing the building.

The goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. The project is commissioned by the IDB and the goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. The expected results of the project are:

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Utility analysis shows the campus energy consumption has been decreasing annually. Opportunities to further lower energy consumption, identified as Energy Efficiency Measures (EEMs), are summarized in Table 1. Additionally, the renewable energy analysis indicates potential electric generation that would provide large savings, implying that there is a large potential for the facility to achieve net zero.

2.1 Site Visit Summary

On April 4, 2016, an Energy Conservation and Efficiency Team Technical Visit was conducted at KPH and VJH beginning at 09:00AM. It was attended by representatives from MSET, PCJ, Inter-American Development Bank (IDB), and Academy Operations and Maintenance staff. The half-day site visit of the selected campus was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation.

A walk-through assessment was conducted with appropriate personnel familiar with the physical condition and day-to-day operation of the facility and equipment. Through the facility profile established during the kickoff meeting, the following systems were specifically targeted:

- Lighting Systems
- Mini-Split Air Conditioning Systems
- Air Handling Unit Fans
- Chilled Water Pumps
- Steam Plant
- Steam Distribution System
- Compressed Air Systems
- Kitchen Operations
- Refrigeration Systems
- Energy Management

- Rainwater collection and distribution
- Solar PV Potential
- Existing System Maintenance and Reliability
- Equipment Scheduling

2.2 Key Recommendations

The following table outlines key recommendations for the project. If all measures are selected from the recommendations below, the project will cannot attain net zero energy status due to roof area limitations.

Table 1. KPH Recommendations Summary

Measure Description	Annual Energy and Cost Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Window Replacements with Insulated Glazing	14,150	$3,581	$39,543	9.1%	11.04
Automatic Door Closers	10,586	$2,679	$2,693	99.5%	1.01
Air Seals on Doors	675	$171	$987	17.3%	5.78
Variable Refrigerant Flow (VRF) Systems	749,190	$189,597	$1,173,000	16.2%	6.19
Proper Spacing between Split Units	40,806	$10,327	$25,800	40.0%	2.50
Replace split systems with high efficiency, inverter-driven units	143,617	$36,345	$215,000	16.9%	5.92
VFD Installation on Kitchen Fans	39,091	$9,893	$8,000	123.7%	0.81
VFD Installation on Chiller Pumps	104,419	$26,425	$70,000	37.8%	2.65
Fluorescent to LED Fixture Retrofit	892,302	$225,814	$422,280	53.5%	1.87
Occupancy Sensor for Interior Lights	97,332	$24,632	$37,648	65.4%	1.53
Compressed Air Leakage	34,120	$8,635	$10,000	86.3%	1.16
Centralized Chiller Controls	67,353	$17,045	$40,000	42.6%	2.35
Solar PV	1,709,351	$432,583	$3,241,500	13.3%	7.49
				0.0%	
Total	3,902,992	$987,726	$5,286,451	18.7%	5.35
Total (Not Including Renewable Sources)	2,193,641	$555,142	$2,044,951	27.1%	3.68

Savings of non-renewable EEMs	33%
Annual GHG Savings (metric tons CO2)	2,486
15 year GHG Reduction (metric tons CO2)	37,293

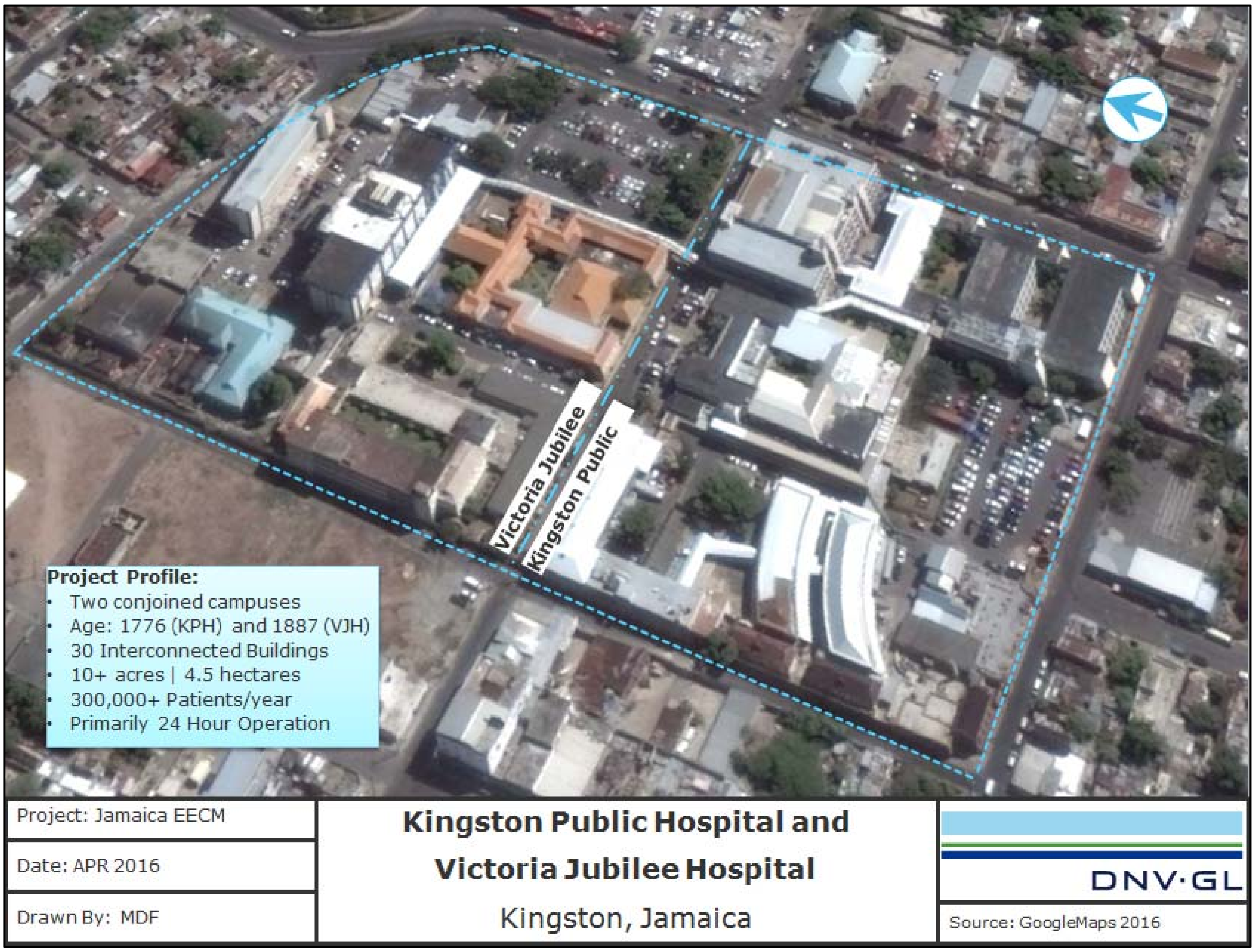
2.3 FACILITY OVERVIEW

Kingston Public Hospital (KPH) and Victoria Jubilee Hospital (VJH) are located at North Street, Kingston, Jamaica. The facilities are centuries old, with KPH opening in 1776 and VJH in 1887. This institution is one of Jamaica's highest-volume hospitals, seeing more than 300,000 patients annually and over 50,000 patients are seen in the Accident and Emergency Department each year. This campus is the largest hospital in the Government Health Service as well as the largest trauma center in the public hospital system.

KPH is a 500-bed General Hospital offering a full suite of medical services, and is one of the few Type A hospitals in the country. VJH is a 300-bed facility originally opened to train midwives, and has expanded to offer maternity and gynecology services as the largest referral maternity hospital in the Caribbean. Both facilities are primarily in a 24/7 operational status, with specialty clinics open during business hours.

Maintenance is typically performed by the in-house team, comprised of foremen and a 24-man technical staff. Contractors are used for all non-routine maintenance on typical 1-year service contracts.

Water is supplied through the National Water Commission (NWC) by pipeline an on-site storage tank, and there a limited rainwater collection system in place on the roof of KPH.



Campus Aerial View

2.3.1 UTILITY ANALYSIS

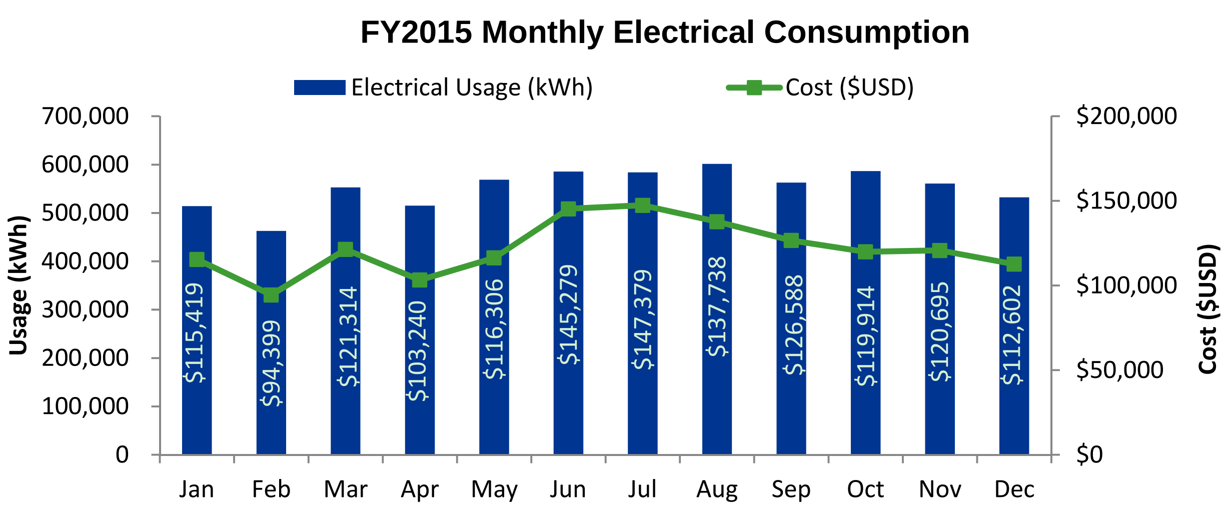
Utility data were evaluated for 2012 through 2015. Based on the provided information, electricity is the primary fuel used with diesel fuel only utilized for the emergency generator. Water utility and other fuel types were requested but were not made available for data analysis. The table below summarizes the annual utility profile. The combined campus has 3 electricity meters, and all power systems are tied into a ring structure that supports the entire installation. Intermediate fuel is used for the steam plant, and LPG for the kitchen operations.

Annual Utility Profile Summary							
Utility	Usage*	Unit	Cost*	Avg Unit Cost ($/kWh)	Energy (MMBTU)	Cost %	Energy %
Electricity	6,627,747	kWh	$1,460,874	$0.25	22,614	100%	100%
Natural Gas	#N/A	Therm	#N/A	$0.00	#N/A	#N/A	#N/A
Water	#N/A	Gallons	#N/A	$0.00	#N/A	#N/A	#N/A
Annual Sum			$1,460,874		22,614		
Per Floor Area			$9.25		0.14		
Floor Area=		158,000	square feet		1 MMBTU =	1,000,000	Btu
Correction Power Factor =		0.72			1 kWh =	3412	Btu
*From 2015 Utility Bills					1 Natural Gas Therm =	100,000	Btu

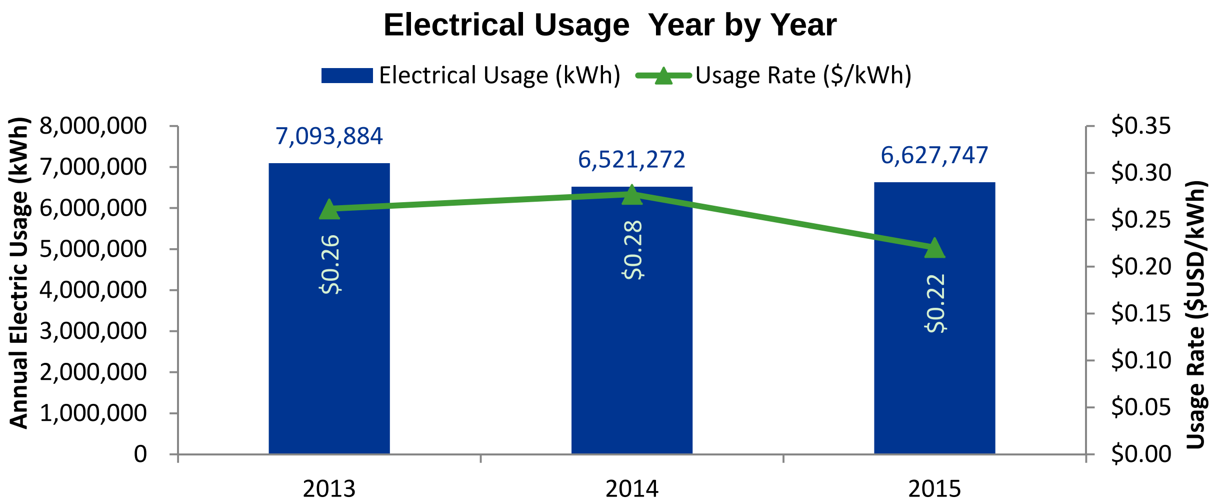
2.3.2 Electricity

Electrical Usage

Electricity is supplied by Jamaica Public Service Company. The facility is served by three (3) electrical meters. The facility annual assumption for year 2015 is approximately 6,627,747 kWh where the annual peak demand is 1,538 kVA. As shown in the figure below, monthly electrical energy consumption stays relatively consistent with slight seasonable variation to reflect the typical weather pattern in Jamaica where the hottest months are from July to September. The small variance in electrical consumption is expected for a hospital with high internal load. There is currently no renewable energy used on site at this time.

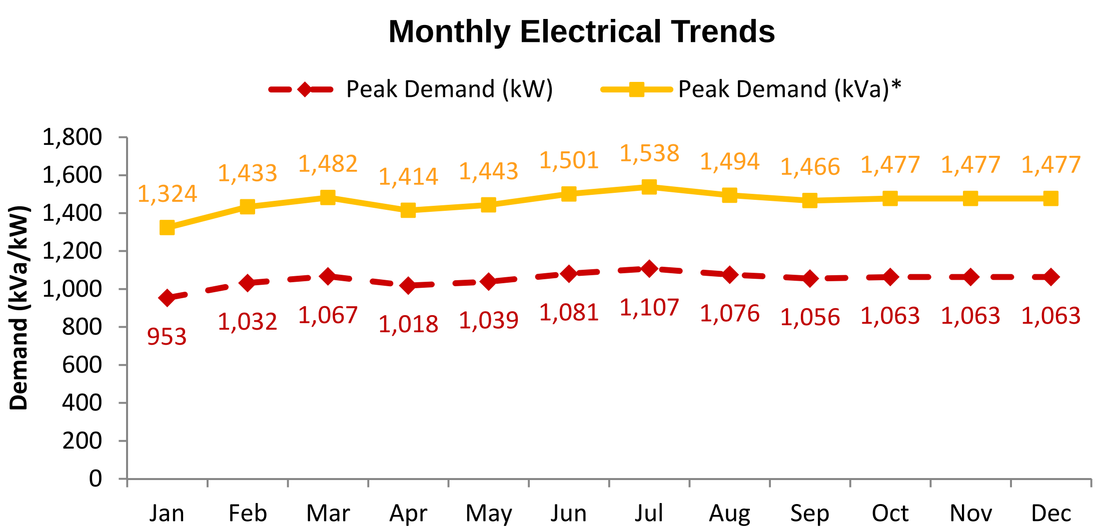


Year by year consumption trend shows that there was a decrease between 2013 and 2014 that may be a result of previous efforts to implement energy efficiency measures and space changes. The average utility rate from 2013 to 2015 is $0.25 USD per kWh. To account for the potential rate fluctuation in the future, this average utility rate is used to project energy saving costs.



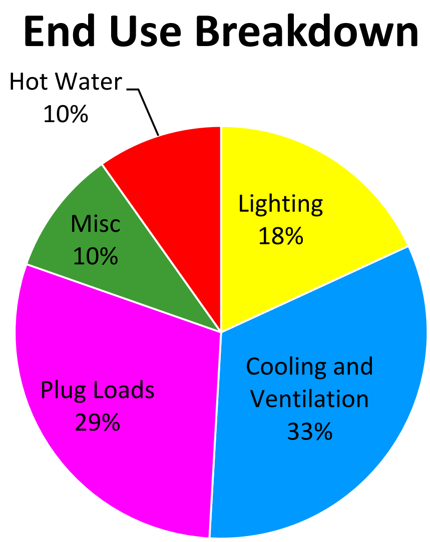
Electrical Demand

The figure below shows the Peak Demand in kVA (the demand charged by the utilities) and the Peak Demand in kW (actual demand of site). The Peak Demand in kW is estimated based on the power factor of 0.72, measured on site for year 2016, which is lower than U.S. standards of 0.9 or higher. Typical causes of low power factor include lowly loaded induction motors and lack of capacitors in transformer.



Load Profile Evaluation

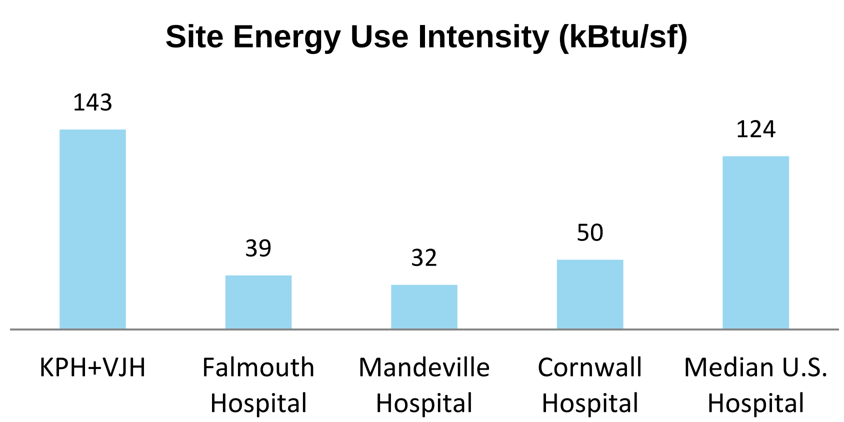
The building electrical use profile is divided into different end-use categories shown on the pie chart below. The annual end use breakdown will vary based on occupancy, operational changes, equipment maintenance, and occupant behavior. More accuracy can be garnered by adding sub-metering systems throughout the facility, which is recommended should a major electrical systems overhaul be undertaken.



2.3.3 Benchmarking

Energy use benchmarking is defined as the process that compares the energy use of a building with other similar structures. It is a critical evaluation for organizations with a large building portfolio to identify building performance and the factors that drive their energy use. The U.S. Department of Energy EnergySTAR program has developed an energy performance rating for commercial and institutional facilities.

The median hospital energy usage intensity (EUI) from EnergySTAR is 124 kBtu/sf annually. The campus EUI is 143 kBtu/sf annually, which is approximately 15% more than the median value for hospital. The high EUI is mostly due to the facility's high cooling and interior equipment load.



2.4 SAVINGS OPPORTUNITIES AND RECOMMENDATIONS

2.4.1 Building Envelope

Existing conditions

Site Context and Orientation

The campus is a combination of 30 interconnected buildings over a space of 30 acres (4.5 Hectares) in the Southern portion of Kingston, located .75 miles from the coastline. The campus is approximately 80 feet above sea level with a N-S 2% slope. The largest facilities have a South-facing orientation, but the intermediate buildings fluctuate in orientation.

General Building Description

The campus has progressively expanded over its 200+ year history, and thus construction methods and architecture varies drastically. The buildings range from 1 story up to 6 stories. The buildings are predominantly concrete, have structural shading devices, and were designed for natural ventilation. The facilities are clearly aging, and extensive maintenance and repairs have been completed throughout. Significant capital investments are required to modernize this large hospital to meet international medical standards.

Victoria Jubilee North Entrance

Wall and Roof Elements

The typical exterior walls throughout the campus are concrete, which is preferable for energy efficient, resilient facilities. The material is extremely durable, fire-resistant, and able to withstand severe weather conditions. The mass of the concrete could insulate the interior and have the ability to limit air leakage, but no areas of the hospital appear to be sealed. There is no insulation on the concrete walls. On the interior, wood-framed walls are commonly used to separate spaces.

Various Campus Building Types

Rooftop Examples: Multiple types and materials throughout the campus

Rooftops are a combination of concrete construction and metal roofing panels or different colors. Some of the flat roofs had membranes installed to limit leakage. The temperatures measured on each roof type varied greatly, with the black membrane reaching as high as 137˚F, and the white roofs at 87˚F. (The ambient temperature was recorded at 86˚F). Maintenance staff report that many roofs require some ongoing maintenance as leaking membranes are a regular occurrence.

Heat Maps: South View

Windows and Openings

Due to the climate, most construction has focused on leaving the buildings naturally ventilated. The buildings incorporate metal louver (“jalousie”) windows and some limited glazing on newer buildings. Exterior doors are uninsulated, and there are no vestibules used for entrances. A limited number of buildings have integrated exterior window shading devices.

Air sealing the building envelope is one of the most critical features of an energy efficient building. The escape of freshly cooled air via open windows or doors results in a room that remains hot even while the air conditioner is running under full load, burning energy, and decreasing the equipment's useful life. Detected leaky areas need to be sealed in order to mitigate infiltration as well as potential leakage of the cool, conditioned air supply in places where there is an AC system installed.

Most of the hallways are open-air and unconditioned, and multiple courtyards allow for natural lighting to reach most areas of the buildings. Natural light and ventilation is important to both human health and staff productivity. Replacing large artificial lighting and conditioning systems with access to natural elements has proved to be beneficial for the health, productivity, and safety of building occupants, as well as economically beneficial from use reduction. Natural light helps maintain good health and can alieve some medical ailments. The pleasant environment created by natural light also decreases stress levels for patients and staff.

Recommendations

DNV GL suggests the following measures:

1. **Window replacements with insulated glazing**

   The buildings were designed for natural ventilation, and metal louver windows are typical. Many rooms are conditioned using split units; however the windows are not sealed, thus causing significant energy losses.

   Installing a double-glazed window will have insulating air- or gas-filled spaces between each pane will improve the U-Value. A double-glazed, low-emittance glass with gas between the panes has a U-factor of about 0.32, effectively tripling the current thermal resistance. More importantly, double-glazed windows with proper mounting prevents infiltration and limits air leakage when the air conditioners are active, reducing the cooling power requirement.

   Existing louver windows are recommended to be replaced with insulated glazing windows with assembly U value of 0.5 or lower.

2. Automatic door closers and door sealing

Doors were found to be open or improperly sealed, limiting the effectiveness of the cooling systems. The most cost effective strategy to automatically close the door is using a surface-mounted regular arm door closer attached behind the door frame where a spring mechanism is used to close the door. This ensures pressurization and limits infiltration, reducing the cooling power requirement.

Improperly sealed doors often are a significant source for leakage of conditioned air, causing excess energy use. A 0.125-inch gap around a typical entryway door is the equivalent of drilling a 5.5-inch-diameter hole through an outside wall. A weather seal system includes weather stripping, which covers the sides and top of the door, and a sweep, which fills the space between the threshold and the door bottom. Foam, felt, plastic, or tubular silicone weather stripping products are designed for this purpose.

3. Air Seals on Doors / Windows

Where ventilated block is used structurally and replacement is infeasible, a border should be installed to retain an insulated window pane firmly against the border material, thus creating an airtight seal between the existing block, the border material and the new pane with appropriate adhesive and sealing compounds applied to ensure an airtight seal.

4. Cool roof installation

There is a multitude of roof types on this campus including bare concrete, membranes, corrugated metal, metal sheets, and asphalt. Each of these materials has different thermal properties, with some being much more heat resistant than others. An energy savings technique is to reduce the heating load of the roof and thereby decreasing air conditioning needs. An energy efficient Cool Roof is designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles.

The concern at this building is that a Cool Roof will always improve thermal comfort, but only provides energy savings when the space below is conditioned. Since many spaces under the roof are unconditioned, the cost of a Cool Roof is not justified by the savings.

It should be noted that rooftop solar PV provides roof shading, which offers the same cooling benefit as a cool roof. On rooftops which receive solar PV, we do not recommending spending additional capital on cool roofs.

Table 2. Envelope Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Window Replacements with Insulated Glazing	Saving calculation from infiltration derives from the improved R-value.	14,150	$39,691	10.7 years
Automatic Door Closers	Saving is based on infiltration due to temperature difference.	10,586	$2,693	1.0 years
Air Seals on Doors	Saving is based on improved R-value.	675	$987	5.5 years

2.4.2 Mechanical and Electrical Systems

Existing conditions

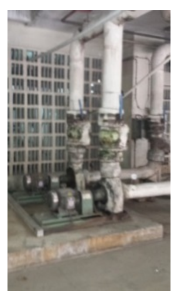
The systems have evolved over time, but are built in a ring structure, and all facilities are essentially interconnected including when under emergency power generation.

A central steam plant is in place, but its network has been reduced in scale to support only a sterilization facility. Surgical and delivery facilities require large amounts of sterile equipment, and use large steam autoclaves fed by the facilities' boiler systems. The live steam injected into the pressure chamber is held for a period of time to ensure sterilization, with fifteen to twenty loads be sterilized per day.

Steam Plant: -Two Cleaver Brooks Boilers

1) **10,461 MBH**
2) **8,368 MBH**

A central chiller system supports the KPH ground and 1st floors, and the operating theater. Two air cooled chillers (each 16 years old) supply the air handling units (AHUs) in the main hospital building. Maintenance and parts replacement was being conducted at the time of the visit.



Chilled Water System

System Components

2 x Air Cooled Chillers

2 x CV Supply Pumps (40HP)

2 x CV Return Pumps (15HP)

3 x Air Handling Units

1 – Ground Floor

2 – ¾ first floor

3 – Operating Theater

Hundreds of mini-split AC units have been installed in wards, offices, and treatment rooms. There are a variety of manufacturers and unit capacities. All of the systems used basic remote-control systems with no temporal programming capabilities. Many of the condensing units have not been installed with manufacturer recommended spacing, limiting their effectiveness. In addition, numerous condensing units were observed to have been placed either near open windows or directly above the extremely hot steam transfer line.

These systems placed a heavy toll on the maintenance staff, and a substantial number of the units were out of service. It was repeatedly observed that staff were requesting repairs to their cooling systems throughout the walkthrough.

In 2015, the first Variable Refrigerant Flow (VRF) Systems on the campus were installed to service a clinics area and wards, with condenser bank capacities of between 60-100 tons. Individual units ranged from 40-70kW cooling output. The systems appear to be intentionally oversized for future expansion. The staff expressed interest in expanding the systems to reduce the HVAC maintenance burden.

Mini-Split AC Units are the primary cooling source

Clinics: VRF System

Two Kitchen Exhaust Fans (CV)

There are two large exhaust vents (one functioning at the time of the site visit) that are constantly running for kitchen services. These fans are estimated to be 10 HP each, and run ~12 hours per day. Makeup air is provided by open-air windows and large window fans.

Recommendations

DNV GL suggests the following measures:

1. **Variable Refrigerant Flow (VRF) Systems**

   A VRF system is a centralized ductless split system that employs multiple indoor evaporator units connected to an outdoor condenser unit in a layout where refrigerant flow are modulated according to the exact demand of individual areas. Due to the inverter technology to support the variable speed compressor, a two-pipe VRF system can save energy in comparison to the existing conventional split systems. Additional key benefits of the VRF system include flexibility to expand or reconfigure the space to add additional capacity and sophisticated controls.

   In addition, it is recommended that programmable setback thermostats be installed to better manage internal environments according to scheduling. Each individual unit can be controlled by a programmable thermostat, or a centralized control option would enable facility management to monitor and control the entire system from a single location.

   It is recommended that VRF systems should replace the existing split systems where a large number of split units are concentrated through the facilities. Maintenance cost of the VRF system should be similar to a DX unitary system where consistent preventive maintenance to change filters and clean coil are recommended. Savings are based on the VRF typical efficiency of 18 EER in comparison to a typical split system efficiency (based on ASHRAE 90.1 2007) of 9.2 EER.

2. **Replace remaining split systems with high efficiency, inverter-driven units**

   It is recommended that a high-efficiency inverter system should replace the existing split systems as they are approaching their end of useful life. Maintenance cost of the VRF system should be similar to a Direct Expansion (DX) unitary system where consistent preventive maintenance to change filters and clean coil are recommended.

3. **Proper spacing behind condensing units**

   Outdoor condensing units appear to be installed without proper clearance requirements behind units. Clearance behind air-cooled condensing units is critical for both space comfort and cooling system efficiency because the air used to reject heat is pulled from behind the condensing units. Current spacing between walls and condensing units hinders airflow, resulting in reduced cooling capacity and reduced coefficient of performance (COP.)

   It is recommended that the contractor measure current condensing unit spacing and increase spacing to one inch greater than manufacturers minimum clearance requirements in order to ensure condensing units are meeting design requirements. In the event that the air conditioning system is being replaced, ensure new condensing units are installed per the manufacturer's specifications.

4. **VFD Installation on Kitchen Fans**

   A Variable Frequency Drive (VFD) is a controller that provides adjustable speeds for an electric AC motor by varying the voltage and frequency. Adding the VFD on exhaust fan will vary fan speed to vary as needed when there is smoke or fumes from the kitchen to meet the required ventilation rates.

   Installing a demand control controlled ventilation system to operate the exhaust fan is recommended. This system would include the VFD to control the exhaust fan motor, a digital controller, temperature probe, and smoke probe in the cooking hood to control the exhaust fan. Existing exhaust fan motor may need to be replaced with inverter duty motor.

5. VFD Installation on Chiller Pumps and Fans

The existing constant flow pumping system for the chilled water loop provides constant flow to meet the supply temperature set point regardless of the demand. Variable flow primary pumping systems save energy during part load operation because water flow is reduced and less pump energy is required. Moreover, with reduced water flow, less compressor energy is required to meet the cooling demand.

Installation of VFD on supply and return fans is recommended. Typically to control the fan speed, additional sensors are installed along the duct and calibrated to adjust the fan speed depend on the air flow demand. Alternatively, the fan speed can be pre-programmed to meet air flow requirement in cooling or heating modes for smaller units. A control interface board that matches fan speed to each equipment air flow requirement is required unless the control of the VFD is integrated and controlled by the Building Automation System.

This recommendation involves installing a variable frequency drive (VFD) on the pump and a differential pressure sensor with a VFD controller unless it is integrated with the Building Automation System.

6. Boiler Downsizing

The heating needs of the hospitals have changed, and a centralized steam system is potentially unnecessary for the current operations. An oversized steam plant requires the boiler to either run at a suboptimal condition, or overproduce to the distribution system. Either is a waste of energy and cost. Boiler "short-cycling" is likely occurring, which involves the boiler quickly reaching the system demand and shutting down, resulting in extremely wasteful startup efficiencies, followed by losses during the shutdown purging cycle.

The kitchens and laundry facilities have been capped, and the steam system current requirements are only for autoclaves, which are currently supplied by an approximately 1500ft / 450 meter partially insulated above ground pipeline. This pipeline is extremely long, is insufficiently insulated, and was observed and reported to have multiple leaks along the many capped branches.

Figure 1. Steam Distribution System

The steam plant consists of equipment that uses a large quantity of high combustion-emission fuel oil, and the installation of a system with reduced-size boilers adjacent to the autoclaves will result in improved response to load variation, high efficiency operation, and reduced maintenance. Upgrading this system will result in mechanical efficiency savings, steam leak savings, and air emissions savings.

This recommendation is not feasible at present; however discussions indicated that Kingston was in the process of upgrading from heavy oil to a natural gas system, which is a preferred fuel source. A conversion from these Intermediate Fuel boilers to a localized condensing natural-gas fired steam boiler will provide a significant savings annually. Staged gas-fired boiler can scale production up or down in response to demand. Should this fuel become available, this investment is highly recommended.

Table 3. Electrical and Mechanical Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Split Systems to VRFs	Saving is based on the increased in unit efficiency.	749,190	$1,173,000	6.2 years
Replace split systems with high efficiency, inverter-driven units	Saving is based on the increased in unit efficiency.	143,617	$215,000	5.9 years
Proper Spacing between Split Units	Estimated savings are based on an estimate in increased efficiency.	40,806	$25,800	2.5 years
VFD on Kitchen Fans	Savings are based on the reduced power demand at lower fan speeds.	39,091	$8,000	< 1 Year
VFD on Chiller Pumps and Fans	Savings are based on the reduced power demand at lower pump speeds.	104,419	$70,000	2.6 years

2.4.3 Lighting

Existing conditions

The typical interior lighting configuration in KPH and VJH is a manual-switch controlled set of T12 linear fluorescent fixtures (4ft and 6ft). While most of the lamps were T12 In many rooms, very few of the fixtures were filled to their capacity. It was also observed that often the lamps were left off due to sufficient natural lighting.

Typical Interior Fixtures

Most spaces in the building are not adequately lit with a illuminance range of 12 to 20 footcandles (FC) for the patient and administration areas. The Illuminating Engineering Society of North America (IESNA) Lighting Handbook Reference & Application recommends an illuminance of 28 FC for general ward lighting, 46 FC for simple examination areas and 93 FC for examination and treatment.

Exterior lighting is a mixture of pole and wall-mounted fixtures, with fluorescent tubes, CFLs, mercury vapor and metal halide lamps. These lamps were in various levels of repair.

Typical Exterior Fixtures

Recommendations

DNV GL suggests the following measures:

7. Full LED retrofit

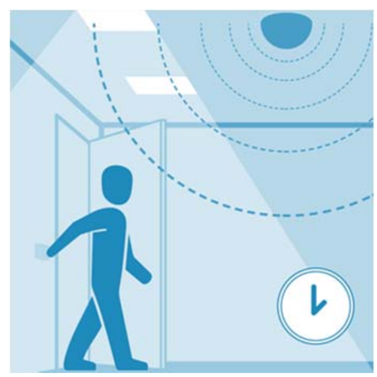
LED retrofits are one of the most beneficial and cost effective energy savings practices available. A typical 2-lamp T12 linear fluorescent bulb with a magnetic ballast uses up to 94 Watts. An equivalent LED tube fixture (no ballast needed) can produce the same lighting levels with a single tube is rated at only 18W.

LED fixtures provide equivalent lighting levels and better light quality in comparison to fluorescent fixtures while achieving 30%+ in energy savings. The average life of LED tube lamps is typically 5 times as long as a fluorescent light, resulting in higher net present value long-term. There is also no longer a need to replace ballasts, further reducing maintenance and materials costs.

Many LEDs support lighting control capabilities such as full dimming and directional illuminance that allow custom adjustments to achieve preferred visual comforts and ensure adequate distributed light levels exactly where it is needed. Unlike fluorescents, LEDs contain no mercury, making them safe for the environment and resulting less additional recycling cost.

It is recommended to replace all existing fluorescent fixtures to dimmable LED fixtures with an LED lighting retrofit kit. Alternatively, simply installing LED tubes with a ballast bypass into the existing fixture can be more cost-effective with a simple wiring change. T12 fixtures already have a non-shunted rapid start lamp holder, and T8 fixtures need a replacement lamp holder for use with the LED tube.

8. Lighting controls



A recommended improvement is to install occupancy sensors to lighting for timed shutoff in non-continuously occupied areas.

Due to the prevalence of natural light, should LED's be installed, daylighting photocells can be tied into the lighting controls. These controls measure the ambient light levels to appropriately match the artificial lighting with the natural light present in the space. This "daylight harvesting" technique provides energy savings, allows for the automatic control of lights, and has the additional benefit of providing appropriate task lighting for the students.

Utilizing an Integrated Room Control (IRC) combines these technologies, and meets ASHRAE 90.1 requirements of lighting by combining receptacle control, occupancy sensing, space control, lighting control, and automatic shutoff.

Table 4. Lighting Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Payback
Full LED Retrofit	Savings are derived from the lower power requirement (wattage per fixture) of LED fixtures.	892,302	$422,280	1.9 years
Lighting Controls	Savings are derived from the discounted diversity factor when occupancy sensor is installed.	97,332	$37,648	1.5 years

2.4.4 Water Consumption

Existing conditions

The city of Kingston has a public water supply, and the campus keeps a 20,000 gallon storage tank with full pumping capabilities for pressurization. A 3000 gallon rainwater collection system is active on the roof of VJH, and is pumped through the facility as a backup system.

Medical facility and laboratory water use typically ranges from 250 to 800 gallons per bed due to a number of medical water-using processes:

- sterilizers and central sterile operations
- water-cooled laboratory and therapeutic equipment
- equipment scrubbers
- X-ray equipment and film developers
- water-treatment systems for kidney dialysis and laboratory water
- vacuum systems
- medical air and compressor equipment
- therapeutic baths and treatment.

Rainwater Collection System

The primary use of hot water in the facility is limited to the main Kitchen on the first floor. The kitchen is able to provide 2100-2500 meals per day. Water had previously been heated using the central steam plant, but due to large leaks, the system was capped, and all hot water is provided through propane stoves.

Kitchen Operations

Recommendations

DNV GL suggests the following measures:

9. Rainwater catchment system

The typical site weather pattern reveals that precipitation occurs for approximately 25% of the year, presenting an opportunity to collect the water independently on site. There are several methods to collect rain water such as rooftop capture to rain barrels, collection from fog through nets, or using a reservoir. It is recommended that rain barrels be used to collect the rainwater from gutters and the roofs where the first flush occurs for the first 2 inches of rainwater. Typically, rainwater is used for irrigation and toilet flushing. However, we recommend additional proper filtration and treatment system is added to make the water potable and meet drinking water standards.

The total roof area for KPH and VJH is approximately 115,000 ft^2. The average maximum rainfall volume from roof capture is estimated to be 1.76 million gallons per year. Utilizing rainwater would significantly reduce the site water demand from the municipal supply and induce to substantial pump energy savings. In case of dry seasons where water resources are scarce and in case of natural disaster that hinder the municipal supply pipeline, the site would have the rain catchment system to provide some water resource.

10. Solar thermal water heaters

Hospitals have a high hot water load due to a number of medical water using processes. Significant reduction in fossil energy consumption can occur if a solar thermal system is installed to meet the hospital's hot water demand. The hospital's hot water consumption was unable to be obtained and therefore calculations on the solar thermal savings could not be performed at this time. It is recommended that the sizing of the solar thermal system is conducted once realistic data on hot water usage in the facility is obtained.

A typical solar water heating system consists of solar collectors, piping, and insulated water storage tanks. Heat is generated from incoming solar radiation energy transferred to water or glycol circulating through the panel and back to a storage tank. The heated fluid is either directly used, or a heat exchanger is used with potable water. The fluid can either be actively pumped, or use gravity and a density/pressure differential in a passive flow.

Glazed Flat Plate Collector with Storage

Evacuated Tube Collector with Storage

Table 5. Water Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Potential Water Capture (Gal)**	**Estimated Cost (USD)**	**Payback (Years)**
Rainwater Catchment System	Savings are based on the annual average rainfall and the roof areas.	1,756,242	$40,000	< 1 year

2.4.5 Process Systems

Existing conditions

Plug loads refer to energy used by equipment that is plugged into an outlet. The plug load in the hospital consists of medical equipment, computers, monitors, printers, task lighting, and specialty equipment. There are not any plug load control strategies evident on site. Low cost plug load control strategies are available which use manual controls or automatic sensors/timers to ensure the building isn't operating when vacant, and using energy-efficient equipment.

The hospital employs multiple high-energy process systems for medical uses. Medical equipment requires reliable compressor and vacuum systems for highly sensitive applications. The compressor system was noted to activate approximately every minute during the site visit, indicating a potential leak in the system.

Compressed Gasses and Vacuum Systems

The facility team was able to provide an inventory of process and medical equipment that summarized the high equipment loads in the hospital, summarized in the tables below.

Table 6. Process System Load Inventory

Area	Equipment	Quantity
Central Systems	Vacuum System	3
	Medical Air System	3
	Water Pumps	8
	Sewage Pumps	2
Kitchen	Ovens (Gas	2
	Stoves (Gas)	2
	Ranges (Gas)	2
	Fryer	1
	Meat grinder	1
	Refrigerated cold room	4

	Freezer	2
Laundry	Dryers	2 **estimate*
	Washers	2 **estimate*
	Compressors	2 **estimate*

Table 7. Medical Support System Load Inventory		
Area	Equipment	Quantity
Kingston Public Hospital		
Sterilizers	Autoclaves (Steam)	5
	Medical Air System	3
A&E Dept- KPH	Patient monitors	12
	Konica X-Ray Processor	2
	Anesthesia System (Ohmeda Modulus II)	1
Wards -KPH	Patient monitors	9
ICU	Patient monitors	15
	Ventilators	15
General Surgery	Patient monitors	2
	Electrosurgical Machine (ConMed5000)	1
OPD South	Patient monitors	5
	Anesthesia System (Ohmeda Modulus II)	2
	Bovie Aaron 2250 Electrosurgical Generator	1
Theatres	Patient Monitors	12
	Anesthesia System	4
Victoria Jubilee Hospital		
Labor Ward	Patient Monitors	7
	Sterilizer	2
OT	Patient Monitors	8
	Anesthesia System	1

	ConMed Electrosurgical Machine	1
FCU Theatre	Patient monitors	6
	Electrosurgical Generator	1
	Anesthesia System	1

Recommendations

DNV GL suggests the following measures:

11. Compressed Air System Investigation

Compressed Air leaks cause a fluctuating air pressure which stresses both the system and tools, increased run frequency and time of compressor package, increased maintenance, and decreased service life.

Air leakage in compressed air system is a significant waste of energy that often contribute up to 20-30% of excess system usage. Leakage induces to additional pressure drop in the system, leading the compressor to work harder and causing fluctuating air pressure that stresses the system and tools. Subsequently, overworking the compressor than it needs to can force short cycling, ultimately increasing maintenance and shortening the equipment's useful life. The most common areas where leakage occurs are typically in joints, connections, pressure regulators, open condensate traps, shut off valves, and thread sealants.

Efforts to detect leakage through an ultrasonic acoustic detector on a periodic basis through preventive maintenance program is recommended. Since air leaks are not always visible, recognizing high frequency hissing sounds associated with air leaks is a recommended training for dedicated maintenance staffs. Depend where the leakage occurs, fixing leaks can be as simple as tightening a connection to replacing a faulty component.

The compressed air system was activating approximately every 45 seconds, indicating potential leaks. It is recommended to perform a Leak Detection investigation and repair leaks. Post-adjustment, it is likely that the compressor controls will need to be adjusted to match repaired system demand such that the air pressure of the system be reduced to the lowest practical range that is needed on the demand side in order to reduce the leakage rates and alleviate unnecessary stress for the system.

12. Plug Load Efficiency

Plug load is an unregulated demand in terms of building energy code requirements. A plug load reduction program is to reduce energy use during non-business hours, as certain equipment acts as a parasitic energy load, and creates waste. In the case of receptacle load for a hospital, there are many areas such as the administration, offices, and computers where equipment are left unoccupied for long periods of time.

In the case of computer labs, a timer or manual on/off vacancy control device could ensure all machines power down when not needed. For individual devices, a primary/secondary power strip can be used which uses a load sensing device to disable power to some outlets when select outlets are not being used. A primary load, such as a computer, would operate independently, and when turned on would cause the device to activate secondary outlet loads, such as a monitor.

Using an Advanced Power Strip (APS) in these areas will save energy by controlling the power supplied to plug-in devices during unoccupied periods. A variety of APS technologies exist on the market that vary in complexity, control strategies, data collection abilities, and costs. Even the simplest power strips can be switched off in times of no usage could reduce the 'standby mode' energy consumption.

One key step in reducing receptacle energy use is to create procurement policy programs (refer to ENERGY STAR® for guidance). Policies must be improved as needed to stay current with technologies. There should be ENERGY STAR® appliances installed for kitchen and breakrooms to further reduce electrical consumption in these spaces.

Table 8. Process System Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Payback
Compressed Air Leakage	Estimated savings derived from reducing the operating pressure.	34,120	$10,000	1.2 years

2.4.6 Smart Building Controls

Existing conditions

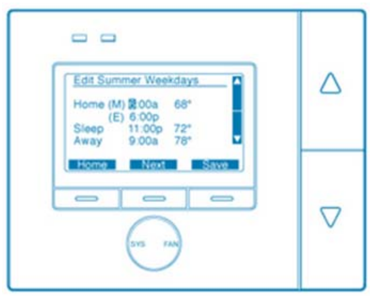
There are currently no controls available for any of the buildings on the campus. Each room's lighting and HVAC systems are controlled by manual switches or remote controls. The chiller system controls only a constant supply temperature.

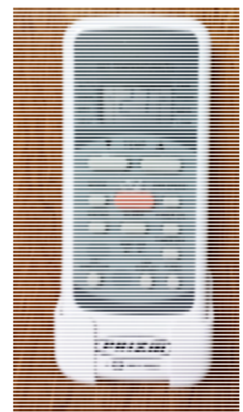
Recommendations

DNV GL suggests the following measures:

13. Programmable thermostats and lighting controls

Referenced in previous sections, programmable thermostats and lighting controls allow the facility managers to more accurately manage energy use throughout the facility, and to be more informed on any activity deviations.





Typical Split-System Remote Control

14. Chiller Controls

Chillers uses substantial amount of energy because it is responsible for the cooling of the entire facility where hydronic coils are used. The chiller systems are outdated, and have an insufficient level of controls installed. The chillers run at a constant temperature output, and do not appear to have been integrated with the appropriate level of controls for the range of zones that they control.

Centralized chiller controls not only establish a greater level of control over the equipment, but they enable the ability to implement multiple low-cost control strategies and to provide an interface to enable easy troubleshooting or maintenance long term. Energy efficiency strategies such as chiller lockout, chiller supply temperature reset, optimal start/stop, and scheduling can better serve the variable load in the building and provide up to 5 to 10% of facility total electrical consumption.

Table 9. Advanced Chiller Control Benefits

Benefits	Description
Scheduling	An optimized daily on/off period can be set to better match the operational peak load of the building.
Lockouts	Restricted use dependent on specified conditions, such as outdoor temperature, calendar date, etc.
Resets	Ensure equipment operates at the minimum needed capacity by automatically resetting operation to match weather conditions.
Diagnostics	Data monitoring of temps, flows, pressures, and actuator positions identifies if equipment is operating incorrectly or inefficiently.

15. Submetering

There are multiple buildings on this campus that are used on inconsistent schedules and with dissimilar equipment. While there are no direct savings associated with metering, the availability of submeters empowers the facility manager to review trends and consumption, and react to deviations.

The installation of submeters would allow the facility managers to track the energy use of the individual activities more closely and to bill facility rentals more accurately.

Table 10. Smart Building Controls Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Cost (USD)	Payback (Years)
Chiller Controls	Saving is based on various chiller control strategies based on outside air.	67,353	$40,000	2.3 years

2.4.7 Renewable Energy Generation

Existing Conditions

There are currently no renewable energy systems in place on the campus. There are a large number of flat, concrete roofs with very little shading, and peak energy use is during daytime hours, which are ideal for solar and hot water generation.

Recommendations

1. Solar Photovoltaic System

A solar analysis was performed for KPH & VJ Hospital to illustrate the potential solar opportunity at the site.

The following assumptions were made regarding roof areas:

- 80% of flat roof area was assumed to be solar ready (20% unavailable for mechanical equipment, structural and misc. equipment on roof)
- 75% of pitched roof area was assumed to be solar ready (25% unavailable for mechanical equipment, structural and misc. equipment on roof)
-

Table 11. System Installation Criteria

Module Type	Crystalline Silicon
Array Type	Fixed (open rack)
System Losses (%)	14
Tilt (deg)	20
Azimuth (deg)	Varies with roof orientation
Roof Area Availability	80% (flat roof) 75% (pitched roof)

The analysis was performed using National Renewable Energy Laboratory (NREL)'s PVWatts® Calculator. This is a web application that estimates the electricity production of a grid-connected roof based on square footage available. The location of the hospital site, basic design parameters such as azimuth of roof and tilt of panel and system economics were inputs for the tool. A cost per watt of $3 (NREL,2015) was used for the capital cost of PV installation. A utility cost of $0.25/kWh was used as an average utility rate of electricity for the Jamaican region.

As of 2015, JPS no longer allows for a net billing or net metering strategy for commercial facilities. This drastically affects the amount of solar photovoltaics that can cost effectively be installed on a building. Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation, we have assumed significant energy savings based on the report's other energy efficiency recommendations.

- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.

- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 12. KPH VJ Hospital Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings	Simple Payback	ROI
Net Zero Energy	2,803 kW	$8,408,544	4,434,106 kWh	$1,122,134	7.5 years	13.3%
Maximize Onsite Opportunity	1,081 kW	$3,241,500	1,709,351 kWh	$432,583	7.5 years	13.3%
Load Matched System	764 kW	$2,291,328	1,208,294 kWh	$305,781	7.5 years	13.3%

The following map shows the roof areas considered in the solar analysis and the table shows the results of the solar feasibility study conducted for the site.

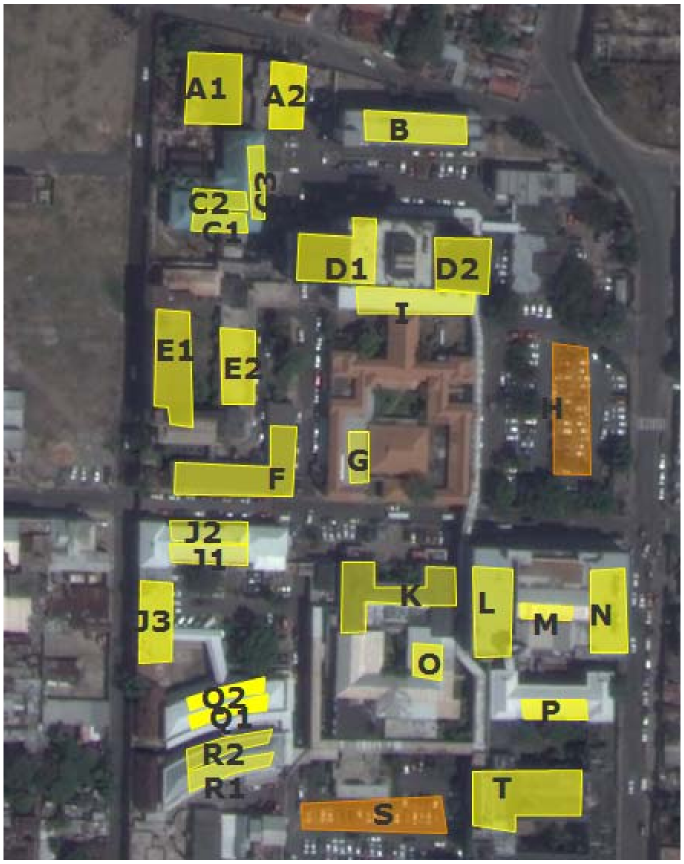


Table 13. KPH & VJ Hospital Renewable Potential							
Area	**Azimuth**	**Collector Area (square meters)**	**Collector Area (square feet)**	**KWdc**	**Capital Cost (USD)**	**Annual Energy Generation (kWh)**	**Annual Cost Savings**
A1	180	397	4273	59.6	$178,800	100,199	$25,357
A2	180	227	2443	34.1	$102,300	57,329	$14,508
B	180	305	3283	45.8	$137,400	76,999	$19,486
C1	180	91	980	13.7	$41,100	23,032	$5,829
C2	0	91	980	13.7	$41,100	18,528	$4,689
C3	90	57	614	8.5	$25,500	13,105	$3,316
D1	180	441	4,747	66.1	$198,300	111,127	$28,123
D2	180	223	2,400	33.5	$100,500	56,320	$14,253
E1	180	343	3,692	51.5	$154,500	86,582	$21,911
E2	180	321	3,455	48.2	$144,600	81,034	$20,507
F	180	401	4,316	60.1	$180,300	101,040	$25,570
G	180	124	1,335	18.6	$55,800	31,270	$7,913
H	180	364	3,918	54.6	$163,800	91,793	$23,230
I	180	311	3,348	46.6	$139,800	78,344	$19,826
J1	180	155	1,668	23.2	$69,600	39,004	$9,871
J2	0	155	1,668	23.2	$69,600	31,376	$7,940
J3	180	255	2,745	38.3	$114,900	64,390	$16,295
K	180	431	4,639	64.7	$194,100	108,774	$27,527
L	180	336	3,617	50.5	$151,500	84,901	$21,486
M	180	83	893	12.5	$37,500	21,015	$5,318
N	180	313	3,369	47	$141,000	79,016	$19,996
O	180	112	1,206	18.3	$54,900	30,766	$7,786
P	180	204	2,196	30.7	$92,100	51,613	$13,062
Q1	180	188	2,024	28.3	$84,900	47,578	$12,041
Q2	0	188	2,024	28.3	$84,900	38,273	$9,686
R1	180	117	1,259	17.6	$52,800	29,589	$7,488
R2	0	117	1,259	17.6	$52,800	23,802	$6,024
S	180	289	3,111	43.3	$129,900	72,796	$18,422
T	180	549	5,909	82.4	$247,200	138,531	$35,058
TOTAL		**7,188**	**77,371**	**1,081**	**$3,241,500**	**1,788,126**	**$452,519**

Disclaimer: The production estimates that PVWatts® calculates do not account for many factors that are important in the design of a photovoltaic system. These calculations should not be used to help design a system, rather seek a qualified professional to make final design decisions using more detailed engineering design and financial analysis tools. (NREL, 2015.)

2.4.8 Miscellaneous Systems

The power factor of the campus was measured to be 0.72. This is an extremely low reading, indicating that there is lagging (less than 1.0) causing additional energy loss because more current is required to deliver the apparent amount of power. Besides being a large waste of energy, a low power factor could lead to stressing of the internal electricity infrastructure which in turn may cause unnecessary overheating and equipment degeneration. Poor power factor can also lead to lower than "normal" voltages and consequently present unreliable equipment performance

Power outages occurred every two months. Three (3) backup generators for the hospital are in place, one of which was installed recently. The backup generators support the entire energy system of the campus, but do not have the capacity to cover all operations at peak demand.

Table 14. Generator Inventory

Area	Manufacturer	Model
VJH	Dole	MMS2/715/DLE
VJH	Magma Max	741NSL404S
KPH	Lectern	

2.4.9 Training

Building automation allows us to turn old facilities into smart buildings. However, the smartest control system within a building is the brain of the people who use it daily. Training of facilities staff as well as nurses, doctors, janitors and administrative staff enables the energy efficiency measures implemented within the building to work correctly. Training can help us ensure that unnecessary lights are off, thermostats are set correctly, and the right people are notified in the event of system failure.

Recommendations

1. Maintenance Staff – 2-day post-retrofit initial training

When the project is complete, it is important that members of the maintenance staff are fully trained on any new building systems. Without this key final project close-out item, energy efficiency measures are destined to fail. This circumstance has been noted during our visits to some facilities in Jamaica.

We recommend the maintenance staff is trained by the contractor team after initial installation of all energy efficiency measures to ensure that the staff knows the operational requirements of all new or upgraded equipment. This should be written into the energy efficiency implementation contract.

Training shall include preventative maintenance training such as: recommended filter replacement cycle, oil change cycles, refrigerant testing, valve testing, cleaning of solar panels, and other preventative items specific to each energy efficiency measure.

2. Facility Mangers – Annual Energy Workshop with other Hospitals FMs

As facility managers test and implement new energy efficiency measures and training, it is important to share lessons learned among other hospital facility managers in the country. This provides an excellent opportunity for cross-learning and collaboration on a variety of issues. The annual workshop will enable a project that was successful at one hospital to be implemented by staff at other hospitals. We recommend holding the annual energy workshop in a rotating hospital in a major city each year. Meeting location should be determined based on whichever hospital has most recently received energy upgrades.

3. All Staff – Quarterly Energy Awareness Training

Facility managers are not the only occupants who determine building energy use. Any building occupant armed with knowledge about energy efficiency can help reduce on-site energy usage. Closing doors to air conditioned spaces, turning off lights, properly setting thermostats, and turning equipment off when not in use is the job of the building occupant and is critical to minimizing energy use. Karl Heusner Memorial Hospital in Belize has shown a successful. We recommend the facility staff provide a quarterly energy awareness training to all staff to teach doctors, nurses, and other employees how equipment works and how to minimize energy use in their daily lives. This will have the added benefit of helping them to save energy use at home, reducing their monthly costs as well as their carbon footpring.

2.5 RECOMMENDATION SUMMARY

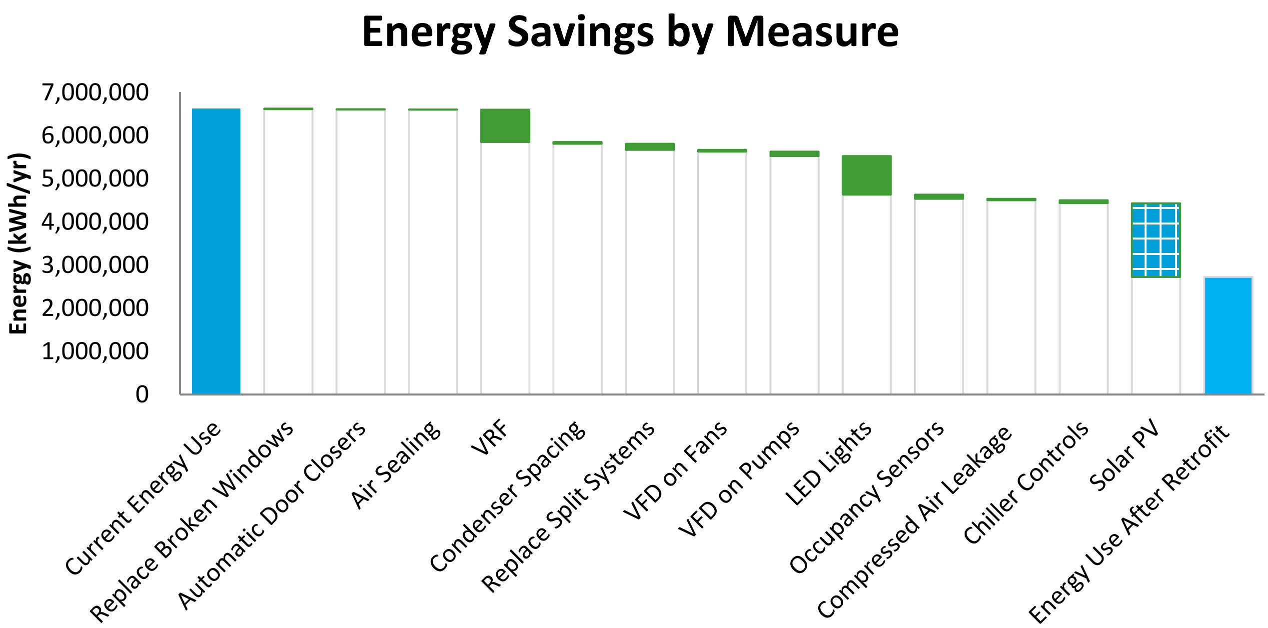
Kingston Public Hospital and Victoria Jubilee Hospital hospitals provide an excellent opportunity for energy savings and associated carbon reduction. These savings will result in a decrease in oil dependence for the island of Jamaica, a decrease in the annual energy bill for the GoJ, and will help increase in-country capacity for energy efficiency implementation. The table below outlines the energy efficiency recommendations for the project. We recommend that the GoJ take the following steps:

1. Perform an Investment Grade Audit of the facility to provide more in-depth analysis of building energy use as well as more accuracy for energy savings of each energy efficiency measure
2. Determine applicable funding and scope for the project
3. Draft Request for Proposal for energy efficiency implementation
4. Engage an Energy Services Company (ESCO) to install energy efficiency measures and distributed renewable energy

Based on the technical assessment performed, the following energy efficiency opportunities exist at the hospital.

Measure Description	Annual Energy and Cost Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Window Replacements with Insulated Glazing	14,150	$3,581	$39,543	9.1%	11.04
Automatic Door Closers	10,586	$2,679	$2,693	99.5%	1.01
Air Seals on Doors	675	$171	$987	17.3%	5.78
Variable Refrigerant Flow (VRF) Systems	749,190	$189,597	$1,173,000	16.2%	6.19
Proper Spacing between Split Units	40,806	$10,327	$25,800	40.0%	2.50
Replace split systems with high efficiency, inverter-driven units	143,617	$36,345	$215,000	16.9%	5.92
VFD Installation on Kitchen Fans	39,091	$9,893	$8,000	123.7%	0.81
VFD Installation on Chiller Pumps	104,419	$26,425	$70,000	37.8%	2.65
Fluorescent to LED Fixture Retrofit	892,302	$225,814	$422,280	53.5%	1.87
Occupancy Sensor for Interior Lights	97,332	$24,632	$37,648	65.4%	1.53
Compressed Air Leakage	34,120	$8,635	$10,000	86.3%	1.16
Centralized Chiller Controls	67,353	$17,045	$40,000	42.6%	2.35
Solar PV	1,709,351	$432,583	$3,241,500	13.3%	7.49
				0.0%	
Total	3,902,992	$987,726	$5,286,451	18.7%	5.35
Total (Not Including Renewable Sources)	2,193,641	$555,142	$2,044,951	27.1%	3.68

Savings of non-renewable EEMs	33%
Annual GHG Savings (metric tons CO2)	2,486
15 year GHG Reduction (metric tons CO2)	37,293



Renewable Energy Recommendations

Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations. The energy use to roof ratio is so high at KPH/VJ that net zero energy is not possible on the site.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 15. KPH VJ Hospital Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings	Simple Payback	ROI
Net Zero Energy	NA	NA	NA	NA	NA	NA
Maximize Onsite Opportunity	1,081 kW	$3,241,500	1,709,351 kWh	$432,583	7.5 years	13.3%
Load Matched System	764 kW	$2,291,328	1,208,294 kWh	$305,781	7.5 years	13.3%

3 CORNWALL REGIONAL HOSPITAL

An Investment Grade Audit (IGA) was performed by DNV GL Energy Engineers of government buildings in Jamaica. The two-day visit of Cornwall Regional Hospital was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation. The team included the facility managers, Ministry of Science Energy & Technology (MSET), representatives from the utility Petroleum Corporation of Jamaica (PCJ), and the Ministry in charge of managing the building.

The goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. GoJ facilities use 12% of electricity consumed in Jamaica. Of that GoJ usage, 14.5% powers healthcare and educational facilities. The facilities visited in April represent a quarter of energy use of those sectors. The project is commissioned by the IDB and the goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. The expected results of the project are:

- Reduced electricity consumption within government facilities
- Decreased oil imports through improved EE
- Reduced GHG emissions which can contribute to Jamaica's INDC commitment
- An increased capacity to promote and supervise electricity planning in Jamaica

Utility analysis shows the campus energy consumption has been decreasing annually. Opportunities to further lower energy consumption, identified as Energy Efficiency Measures (EEMs), are summarized in Table 1. Additionally, the renewable energy analysis indicates potential electric generation that would provide large savings, implying that there is a large potential for the facility to achieve net zero.

3.1 Site Visit Summary

On June 9-10, 2016, an Energy Conservation and Efficiency Team Technical Visit was conducted, beginning at 9:00AM EST. The initial kickoff was attended by representatives from MSET, PCJ, Inter-American Development Bank (IDB), DNV GL Energy Services and Cornwall Regional Hospital's Operations and Maintenance staff.

An investment grade audit was conducted with appropriate personnel familiar with the physical condition and day-to-day operation of the facility and equipment. Through the facility profile established during the kickoff meeting, the following systems were specifically targeted:

- Lighting Systems
- Mini-split air conditioning Systems
- Chiller plant
- Back-up generators
- Boiler hot water and steam distribution system
- Kitchen operations
- Laundry operations

- Rainwater collection and distribution
- Solar PV Potential

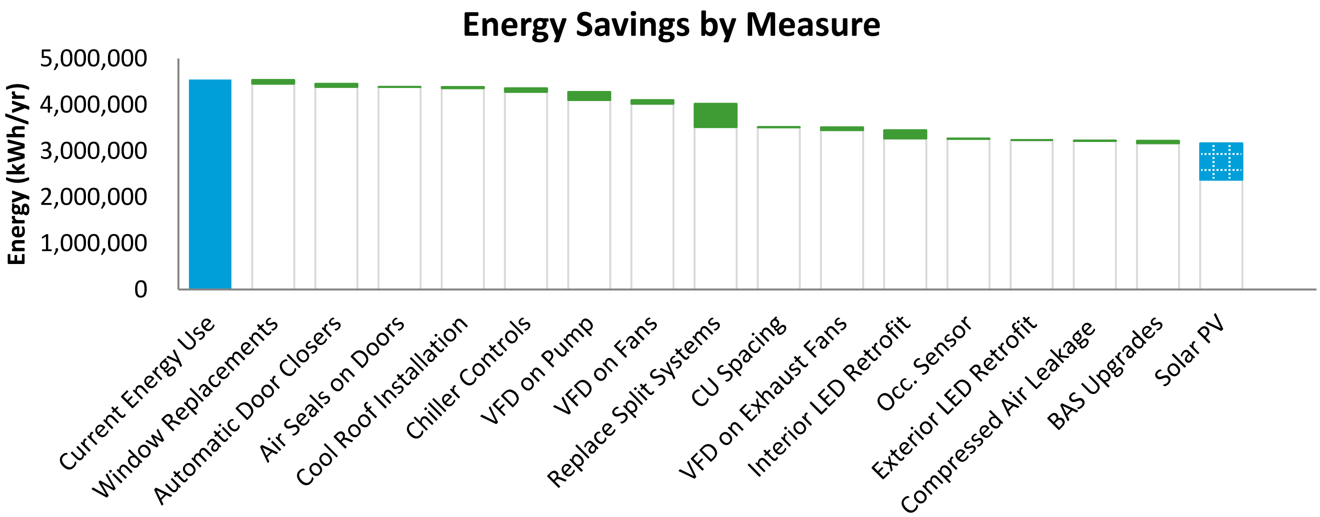
The following staff attended the site visit:

Table 16. Cornwall Western Regional Hospital Site Visit Attendee List			
Dates: 6/9/2016 & 6/10/2016			
Name	**Organization**	**Phone**	**Email**
Kevin Green	WRHA	559-7480	kevingreenjmi@gmail.com
Joseph Ramsay	WRHA	375-7444	joseph_ramsay33@yahoo.com
Charles	PCJ		
Kent Dahlquist	DNV GL	619-309-7441	kent.dahlquist@dnvgl.com
Joe St. John	DNV GL	781-418-5748	joseph.st.john@dnvgl.com

3.2 Key Recommendations

The following table outlines key recommendations for the project. Please note that the total recommended measures include solar photovoltaics (PV).

Cornwall Key Recommendations Overview					
Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Window Replacements	80,566	$18,892	$90,080	21%	4.8
Automatic Door Closers	70,060	$16,428	$5,699	288%	0.3
Air Seals on Doors	1,349	$316	$1,945	16%	6.1
Centralized Chiller Controls	81,686	$19,155	$45,000	43%	2.3
VFD on constant volume pumps	34,965	$8,199	$10,555	78%	1.3
VFD on supply and return fans	78,910	$18,504	$5,672	326%	0.3
High Efficiency Split Systems	506,903	$118,865	$687,507	17%	5.8
Proper Spacing between Split Units	3,185	$747	$864	86%	1.2
VFD on Exhaust Fans	62,899	$14,749	$6,934	213%	0.5
Interior LED Retrofit	178,091	$41,761	$53,072	79%	1.3
Occupancy Sensor for Interior Lights	10,123	$2,374	$5,925	40%	2.5
Exterior Light Retrofit to LED	35,830	$8,402	$9,433	89%	1.1
Compressed Air Leakage	4,832	$1,133	$5,000	23%	4.4
BAS Upgrades	53,995	$12,662	$75,000	17%	5.9
Total (Recommended Measures)	1,989,331	$466,484	$2,493,086	18.7%	5.3
Total (Not Including Renewables)	1,149,398	$269,525	$927,686	29.1%	3.4



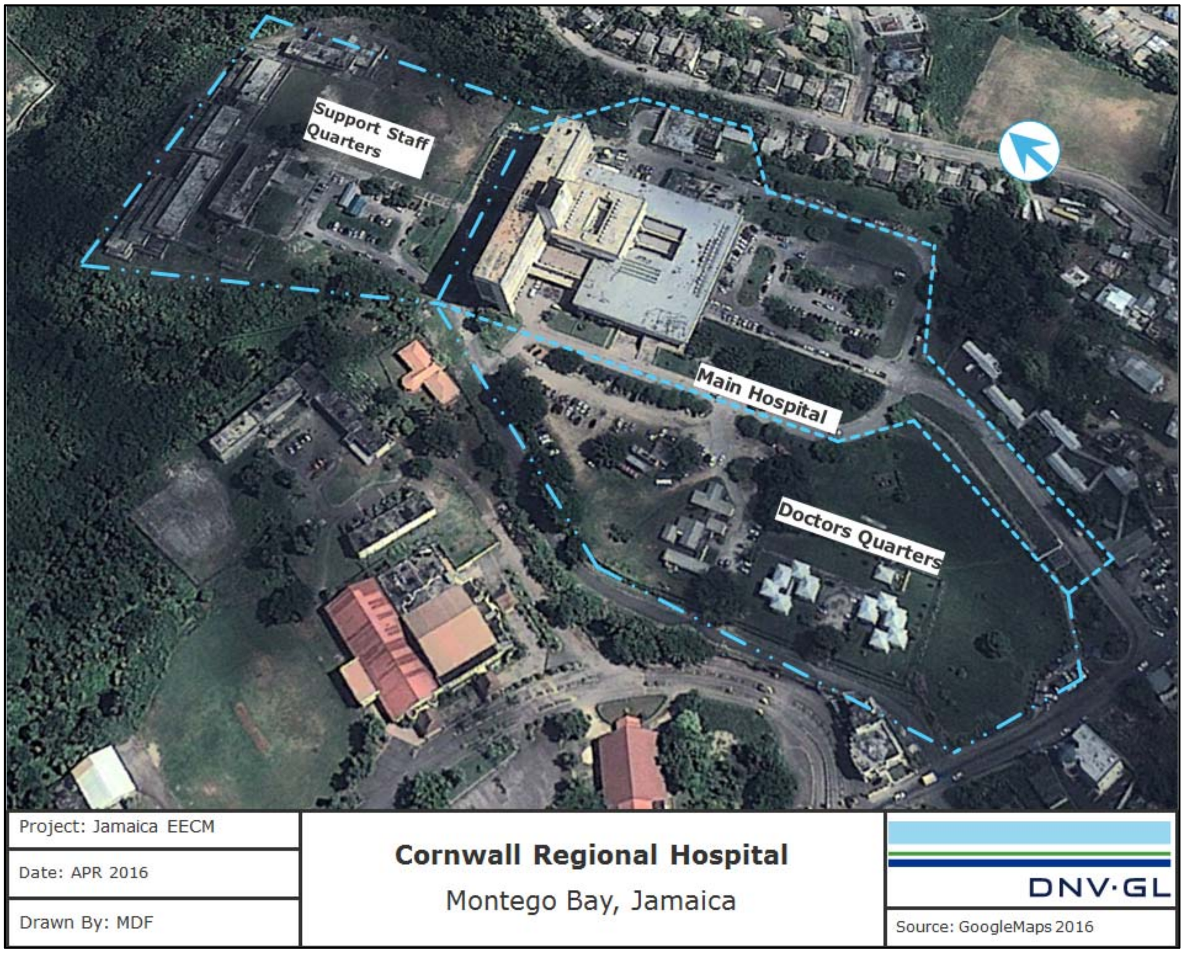
3.3 FACILITY OVERVIEW

The Cornwall Regional Hospital (CRH) is located 2 miles from the center of Montego Bay, on a hill in Mt. Salem. It is a 10 story, 400-bed capacity multidisciplinary institution that was built in 1964 and is primarily in a 24/7 operational status. The number of outpatients for the hospital ranges between 5,500 – 7,000 patients per month. The CRH is a Type 'A' hospital providing specialist services, and is the only hospital outside of Kingston providing most of the specialist services in the region.

The site has 5 electrical meters but only 1 electrical meter serves the building (noted as Main Line in supporting documents). The other 4 meters serve the staff quarters, staff quarters exterior lighting, security street lighting and Sewell Avenue.

During time of visit, local electricity generation systems were being converted to LPG fuel by Jamaica Public Service (JPS) resulting in up to 6 power outages a day at the hospital.

Contractors are used for all non-routine maintenance. Water is all city-supplied, and there no rainwater collection or pumping system in place.



Campus Aerial View

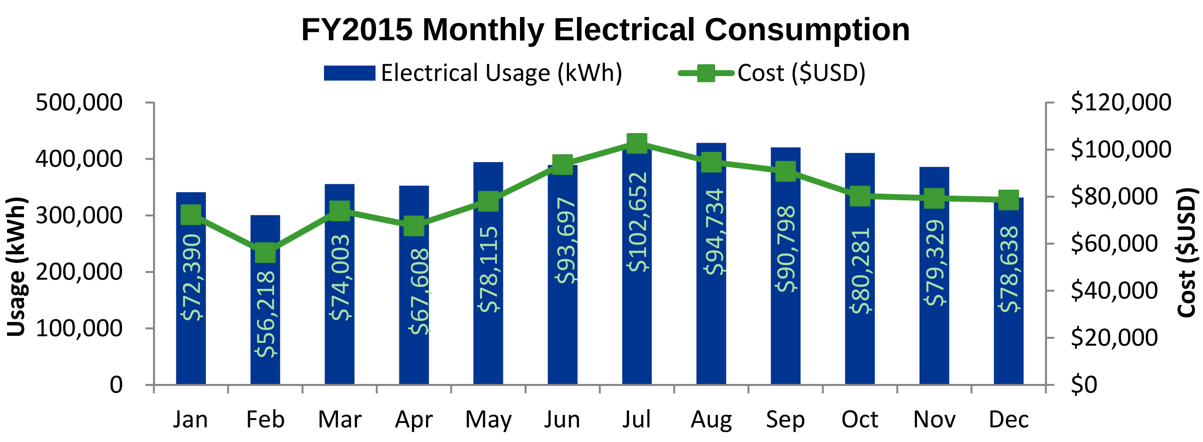
3.4 UTILITY ANALYSIS

Utility data were evaluated for period 2011 through 2015. Based on the provided information, electricity is the primary fuel used with diesel fuel only utilized for the emergency generator. Water utility and other fuel types were requested but were not made available for data analysis. The table below summarizes the annual utility profile.

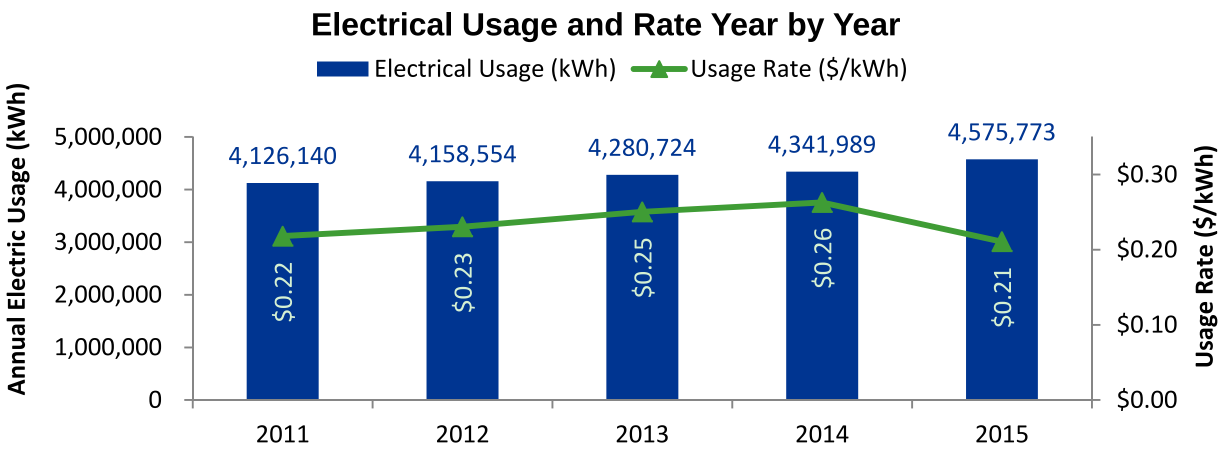
3.4.1 Electricity

Electrical Usage

Electricity is supplied by Jamaica Public Service Company (JPS). The facility is served by two (2) electric meters, but one (1) meter is inactive. The facility annual assumption for year 2015 is approximately 4,537,430 kWh where the annual peak demand is 1,080 kVA. As shown in the figure below, monthly electrical energy consumption stays relatively consistent with slight seasonable variation to reflect the typical weather pattern in Jamaica where the hottest months are from July to September. The small variance in electrical consumption between hotter months and other months is expected for a hospital that has comfort cooling. There is currently no renewable energy used on site at this time.

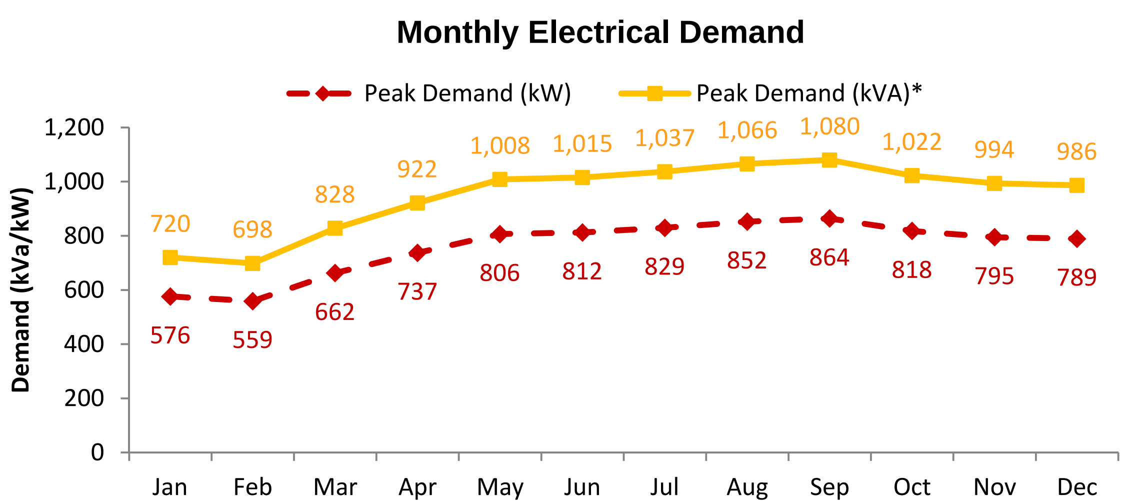


Year by year consumption trend shows that there was an increase in energy usage from 2011 to 2015 as shown in the figure below. The average utility rate from 2011 to 2015 is $0.23 USD per kWh. To account for the potential rate fluctuation in the future, this average utility rate is used to project energy saving costs.



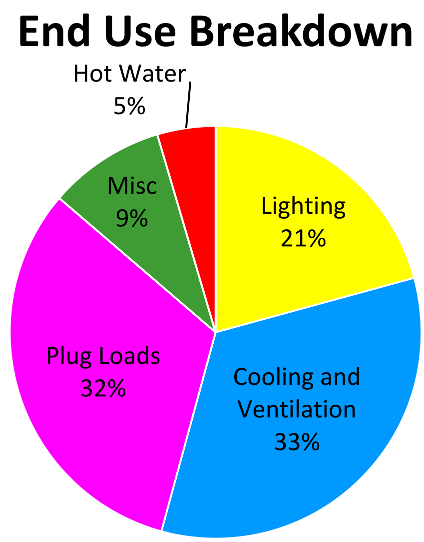
Electrical Demand

The figure below shows the Peak Demand in kVA (the demand charged by the utilities) and the Peak Demand in kW (actual demand of site). The Peak Demand in kW is calculated based on the power factor and the Peak Demand in kVA. Because measurement could not take place on site, the power factor was estimated to be 0.8 from similar sites' observations. The U.S. standard for power factor is 0.9 or higher. Typical causes of low power factor include lowly loaded induction motors and lack of capacitors in transformer.



Load Profile Evaluation

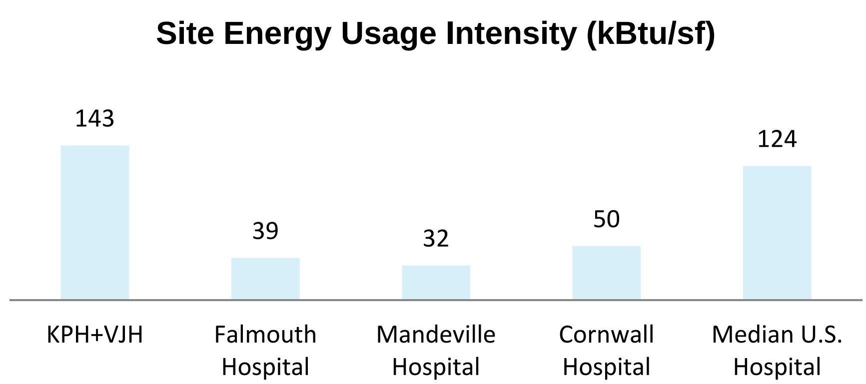
The building electrical use profile is divided into different end-use categories shown on the pie chart below. The annual end use breakdown will vary based on occupancy, operational changes, equipment maintenance, and occupant behavior. More accuracy can be garnered by adding sub-metering systems throughout the facility, which is recommended should a major electrical systems overhaul be undertaken.



3.4.2 Benchmarking

Energy use benchmarking is defined as the process that compares the energy use of a building with other similar structures. It is a critical evaluation for organizations with a large building portfolio to identify building performance and the factors that drive their energy use. The U.S. Department of Energy EnergySTAR program has developed an energy performance rating for commercial and institutional facilities.

The median hospital energy usage intensity (EUI) from EnergySTAR is 124 kBtu/sf annually. Cornwall hospital uses 50 kBtu/sf annually, which is approximately 59% less than the median U.S. hospital EUI. The low EUI is most likely because the facility is similar to a class C type hospital that has lower equipment load and cooling load.



3.5 SAVINGS OPPORTUNITIES AND RECOMMENDATIONS

3.5.1 Building Envelope

Existing Conditions

Site Context and Orientation

The Cornwall Regional Hospital is located on a hill in Mt Salem about two miles from center of Montego Bay in Cornwall County. The orientation of the hospital is south-east facing and it is located in an urban setting of Montego Bay (the country's second largest city by area) on Jamaica's north coast. It is the tallest building in the area, located in an open plot, and receives no shading from any source.

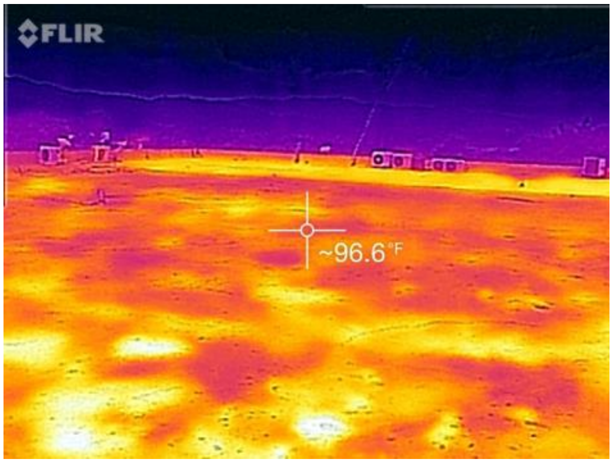
General Building Description

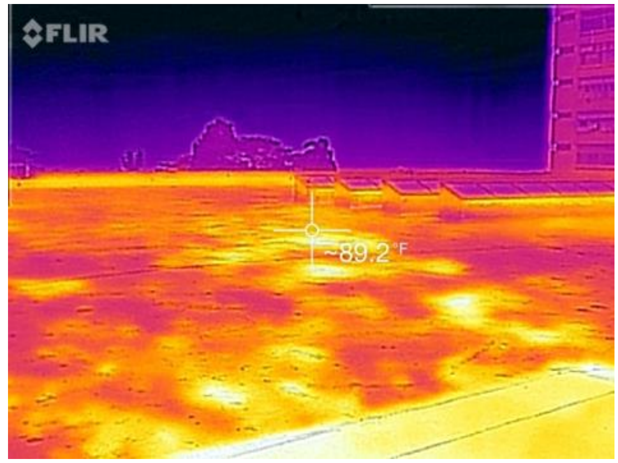
The building has, at its tallest, ten floors and is built entirely of concrete construction. Long, open air balconies stretch the length of the south eastern perimeter of the building. These balconies are the predominant shading devices for the building. There is an atrium three stories high at the entrance of the hospital that acts as the central circulation point for the facility.

Wall and Roof Elements

The exterior walls are composed of concrete with no insulation and the roof is concrete with membrane and asphalt on the exterior. The roof requires some ongoing maintenance as there were portions of the membrane completely removed from the surface. Pools of water were observed on some areas of the roof which indicate inadequate drainage. Due to the high demand for patient care, additional rooms have been added within the atriums using wood-framed walls. A two story addition to the South side is currently underway.


Exterior wall and roof of hospital





Heat maps: Roof

The building structure has a high level of air leakage with infiltration evident through unsealed windows, doors and envelope. Unsealed openings are also present in rooms such as the maternity and nurse's wards that also had air conditioning systems installed. Windows in rooms with non-functioning AC units often leave their windows open for ventilation, while adjacent rooms would leave AC units on. Freshly cooled air immediately escapes the room via the adjacent open window, which results in a room that remains hot even while the air conditioner is running at full load, burning energy, and decreasing the equipment's useful life. Air sealing the building envelope is one of the most critical features of an energy efficient building. Room sealing will mitigate infiltration as well as reduce potential leakage of the cool, conditioned air supply in places where there is an AC system installed.

Windows and Openings

Most of the windows in the hospital were unglazed 'jalousie' louver type. These metal louvers are present in most of the window openings in place of panes of glass. As a result, natural ventilation (both cross-flow and stack strategies) is the predominant cooling method for most of the perimeter spaces and the open air atrium.

Open atrium and metal louver windows

Recommendations

DNV GL suggests the following measures:

1. Window Replacements with Insulated Glazing

The buildings were designed for natural ventilation, and metal louver windows are typical. Many rooms are conditioned using split units, however the windows are not sealed, causing significant energy losses.

Installing a double-glazed window will have insulating air- or gas-filled spaces between each pane will improve the U-Value. A double-glazed, low-emittance glass with gas between the panes has a U-factor of about 0.32, effectively tripling the current thermal resistance. More importantly, double-glazed windows with proper mounting prevents infiltration and limits air leakage when the air conditioners are active, reducing the cooling power requirement.

Existing louver windows are recommended to be replaced with insulated glazing windows with assembly U value of 0.5 or lower.

Alternatively, in areas where sufficient outdoor air can be achieved, another option could be the use of acrylic panel-covers with solar film. This would reduce the need for building alterations in removing the louvres and replacing them.

2. Automatic Door Closers and Door Sealing

Doors were found to be open or improperly sealed, limiting the effectiveness of the cooling systems. The most cost effective strategy to automatically close the door is using a surface-mounted regular arm door closer attached behind the door frame where a spring mechanism is used to close the door. This ensures pressurization and limits infiltration, reducing the cooling power requirement.

Improperly sealed doors often are a significant source for leakage of conditioned air, causing excess energy use. A 0.125-inch gap around a typical entryway door is the equivalent of drilling a 5.5-inch-diameter hole through an outside wall. A weather seal system includes weather stripping, which covers the sides and top of the door, and a sweep, which fills the space between the threshold and the door bottom. Foam, felt, plastic, or tubular silicone weather stripping products are designed for this purpose.

3. Air Seals on Doors / Windows

Where ventilated block is used structurally and replacement is infeasible, a border should be installed to retain an insulated window pane firmly against the border material, thus creating an airtight seal between the existing block, the border material and the new pane with appropriate adhesive and sealing compounds applied to ensure an airtight seal.

4. Cool Roof Installation

There is a multitude of roof types on this campus including bare concrete, membranes, corrugated metal, metal sheets, and asphalt. Each of these materials has different thermal properties, with some being much more heat resistant than others. An energy savings technique is to reduce the heating load of the roof and thereby decreasing air conditioning needs. An energy efficient Cool Roof is designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles.

The concern at this building is that a Cool Roof will always improve thermal comfort, but only provides energy savings when the space below is conditioned. Since many spaces under the roof are unconditioned, the cost of a Cool Roof is not justified by the savings.

It should be noted that rooftop solar PV provides roof shading, which offers the same cooling benefit as a cool roof. On rooftops which receive solar PV, we do not recommending spending additional capital on cool roofs.

Table 17. Envelope Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Window Replacements	Saving is based on improved R-value.	80,566	90,080	4.8 years
Air Seals on Doors	Saving is based on improved R-value.	1,349	1,945	6.1 years
Automatic Door Closers	Saving is based on infiltration due to temperature difference.	70,060	5,699	< 1 Year

3.5.2 Electrical and Mechanical Systems

Existing conditions

The hospital rooms were designed to be supplied by a central chiller system; however it was taken offline in the 1990s, and hundreds of mini-split units were distributed throughout the building.

Steam Plant: -One Cleaver Brooks Boilers (8369 MBH)

A central boiler plant provides steam for the autoclaves, kitchen, and adjacent laundry building. Recently, the boiler was upgraded to a 2013 CleaverBrooks natural gas fired boiler with a specified gross output of 8369 MBH and thermal efficiency of 82%. It was noted that the steam was being provided supplied at 350F. The infrared photo shown below shows the exterior of this steam pipe at >248F. The old CleaverBrooks boiler of 1993 vintage is still installed on site but not in use.

In a concentrated effort to modernize to international medical standards, a new chilled water system was designed for critical care areas specifically ensure appropriate outside fresh air levels and establish infection control protocols. Recently a York chiller was installed to supply the 4th and 5th floors, and was purposely oversized for future expansion. Another York chiller has also been installed to serve the ICU, which is currently under construction. There are 4 constant speed chilled water pumps installed for the chiller system (2 per chiller). For the chilled water system's air loop, 3 York air handlers (AHU-5, 6 and 7) were installed to serve the 4th and 5th floors and the new ICU. This is the only central cooling system installed in the building.

System Components

2 x Air Cooled Chillers
4 x CV CHW Pumps (60HP total)
2 x CV Return Pumps (15HP)
3 x York Air Handling Units
- AHU S5 (10 tons)– Operating Theater on 5h Floor
- AHU S6 (10 tons)– Operating Theater on 4th Floor
- AHU S7 (7.5 tons)– 4th & 5th floors

5 x Packaged DX systems (51.5 tons total)

+400 x mini split systems (1 ton – 3 tons)

1 x Natural Gas Hot Water Boiler

Air handlers serving the ICU and one of the air cooled chillers.

Over 400 mini-split AC units have been installed in wards, offices, and treatment rooms. There are a variety of manufacturers and unit capacities. All of the systems used basic remote-control systems with no temporal programming capabilities. Many of the condensing units have not been installed with manufacturer recommended spacing, limiting their effectiveness. In addition, numerous condensing units were observed to have been placed near open windows.

These systems placed a heavy toll on the maintenance staff, and a substantial number of the units were out of service. It was repeatedly observed that medical staff were requesting repairs to their cooling systems throughout the walkthrough.

Mini-Split AC Units are the primary cooling source

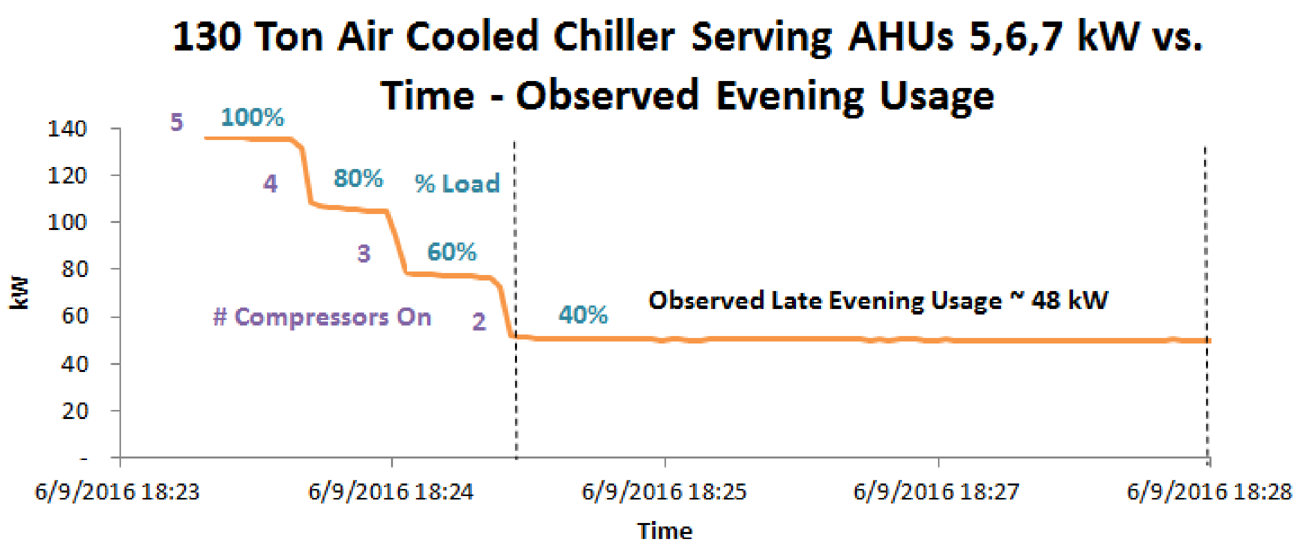
There are 7 constant volume exhaust fans (ranging from 5 – 15 HP) that exhaust air from kitchen, laundry, storage and restroom areas. The kitchen hood exhaust fans are operated continuously from 7am – 8pm daily. The rest of the exhaust fans are run intermittently. No make-up air is provided to the kitchen or laundry spaces.

Kitchen exhaust hoods (CV)

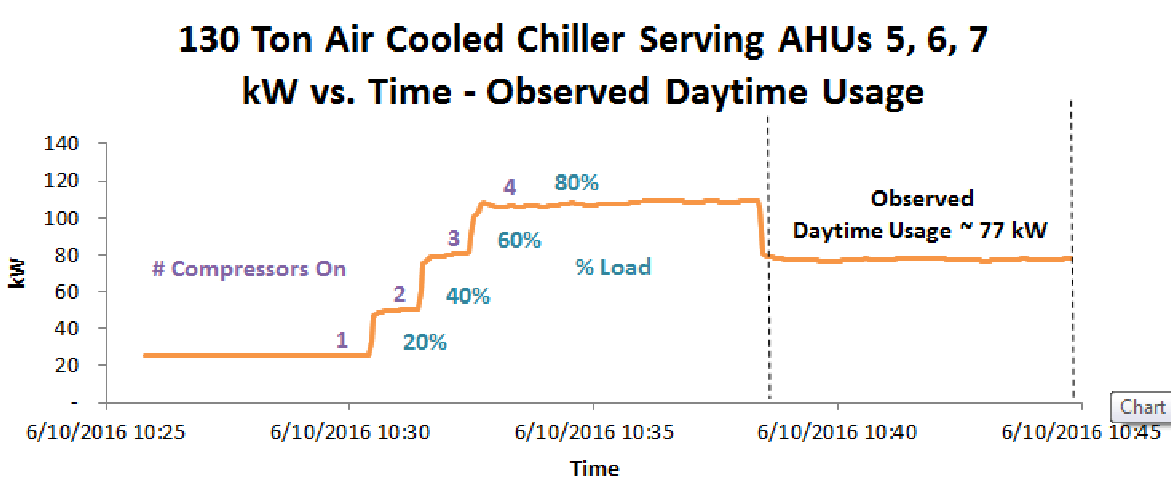
Monitoring Data

1. Air-cooled Chiller

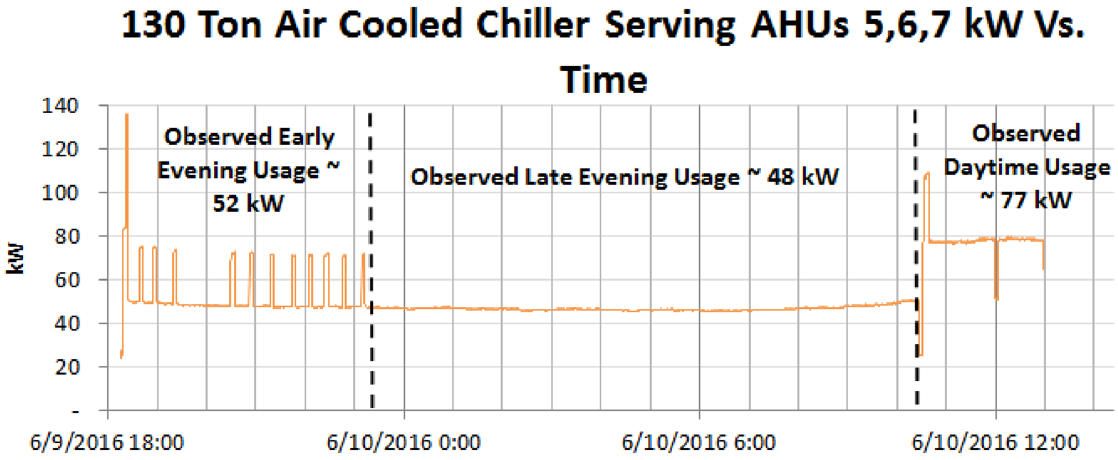
The 130 ton York chiller serving floors 4 and 5 was logged for a period of 18 hours to better understand usage throughout a typical day's cycle, and to better estimate the chiller's annual operating cost. Loggers were installed in the late afternoon of June 9th, and retrieved the following day around lunchtime. During this time period, the chiller ran about 42 kW during the evening, 20% load, and in the morning, ramped back up to 77 kW, or 60% load. The third chart in the series below shows that the chiller turns on and off during the shoulder period of the day.



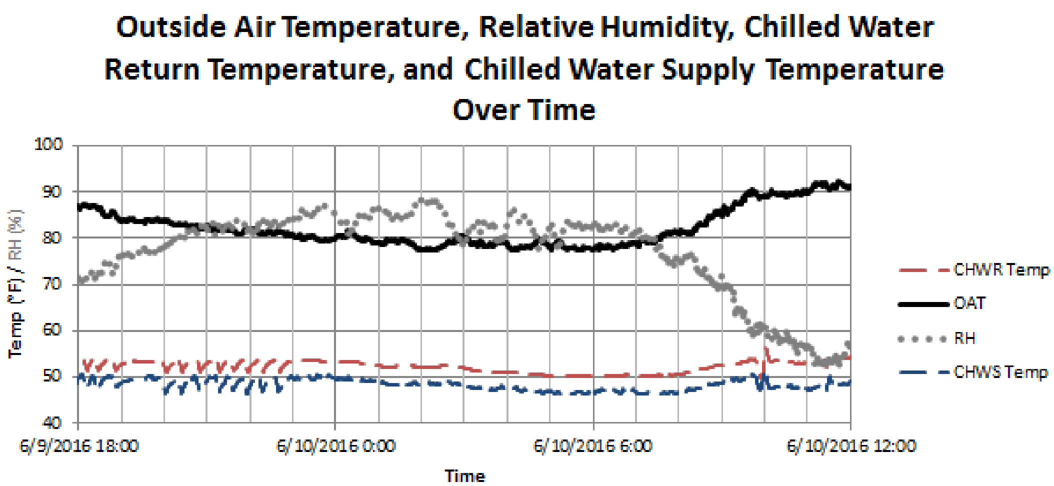
The chart below shows the chiller coming on in the morning around 10:30 AM, turning on compressors 3, 4, and 5, and then settling on keeping just 3 of the 5 compressors on at 60% load. While on-site we were told that it was abnormal for the chiller to have turned on this late in the morning, and the cause for it turning on this late in the morning had to do with one of the supply fans being left off during the previous evening, resulting in a lower load on one of the cooling coils served by this chiller.



The following data shows the full range of chiller kW data measured from the afternoon of June 9th to around noon on July 10th. As is seen in the chart, there appear to be three operating regimes: late evening usage, daytime usage, and a shoulder period in the early evening.



The chart below shows the results of the temperature and humidity sensors installed on or near the chilled water system during the site visit. Data on supply and return chilled water temperatures were collected, which showed a consistent delta T of around 4° F for most of the evening usage, and around 6 °F during the daytime period between 10:30 AM and 12:00 PM, which is the same time frame when the chiller goes to 60% load from the evening load of 40%. That additional load is likely the result of the increased outdoor air temperature, which rises from 80 °F to about 90°F.

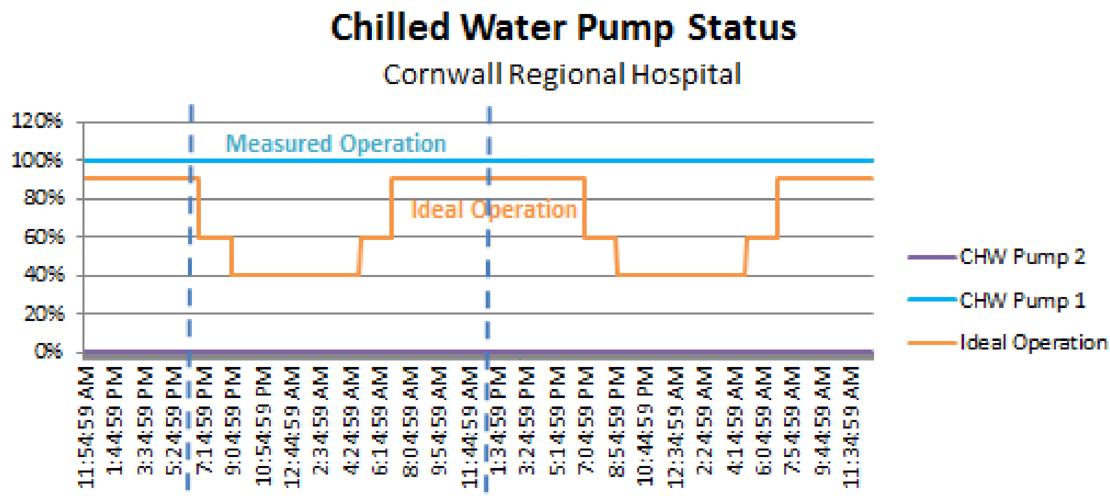


Results:

	Nominal Tonnage	Hours/Year	Average kW	Annual kWh	Est. Operating Cost
Current Energy Use	130	8760	59	516,840	$129,210

2. Chilled Water Pumps

The (2) chilled water pumps serving the chiller on the 6th floor carry a nameplate rating of 15 HP and appear to run at a constant speed during all 8760 hours of the year. A simple on/off logger was installed on the pump to determine if this operation is correct.

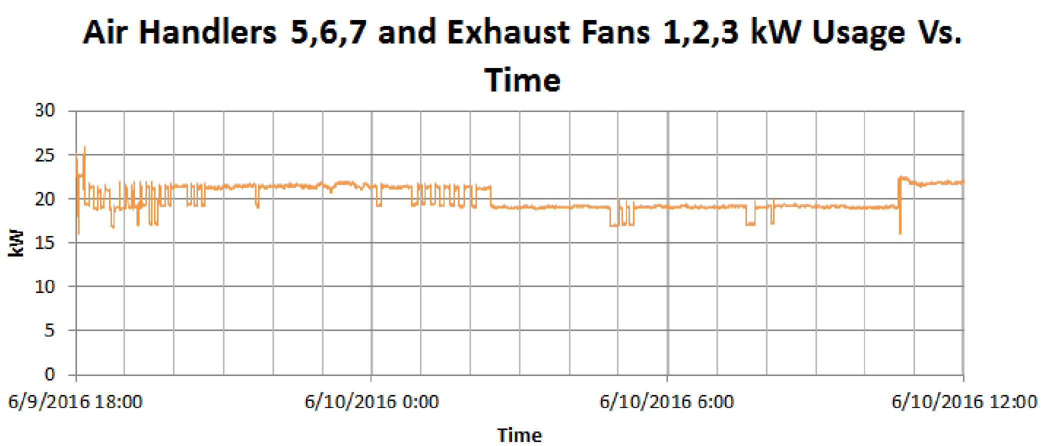


Results:

	HP	Assumed bHP	kW	Annual kWh	Est. Operating Cost
Current Energy Use	15	12.75	9.5	83,287	$20,822

3. Air Handling Units

A power logger was installed on an electric breaker which served (3) air handlers and (3) exhaust fans. These air handlers are served by the air cooled chiller described above, and in total they represent an estimated connected HP of 35.



Results:

	HP	kW	Annual kWh	Est. Operating Cost
Current Energy Use	~35	22	192,720	$48,180

Recommendations

DNV GL suggests the following measures:

1. **VFD on constant volume pumps from chiller / boiler loops**

The existing constant flow pumping system for the centralized chilled water system provides constant flow to meet the supply temperature setpoint regardless of the demand. Variable flow primary pumping system save energy during part load operation because water flow is reduced and less pump energy is required. Moreover, with reduced water flow, less compressor energy is required to meet the cooling demand.

This recommendation involves installing a variable frequency drive (VFD) on the pump and a differential pressure sensor with a VFD controller unless it is integrated with the Building Automation System. Additionally, the existing terminal three-way valves coils should be converted to two-way valves coils while leaving the worst case zone to have three-way valve coil if applicable.

2. **VFD on supply and return fans**

Variable Frequency Drive (VFD) is a controller that provides adjustable speeds for an electric AC motor by varying the voltage and frequency. Installment of a VFD on fans would leads to significant savings at part load due to the nature of fan laws. For instance, just by reducing the fan speed by 20% can lead to up to 42% of fan energy savings. Furthermore, additional savings also result from reducing the need for reheating from overcooling, deepening energy savings and enhancing precision in occupancy comfort control.
Installation of VFD on supply and return fans is recommended. Typically to control the fan speed, additional sensors are installed along the duct and calibrated to adjust the fan speed depend on the air flow demand. Alternatively, the fan speed can be pre-programmed to meet air flow requirement in cooling or heating modes for smaller units. A control interface board that matches fan speed to each equipment air flow requirement is required unless the control of the VFD is integrated and controlled by the Building Automation System.

3. **Replace remaining split systems with high efficiency, inverter-driven units**

It is recommended that a high-efficiency inverter system should replace the existing split systems as they are approaching their end of useful life. Maintenance cost of the VRF system should be similar to a Direct Expansion (DX) unitary system where consistent preventive maintenance to change filters and clean coil are recommended.

4. **Proper spacing behind condensing units**

Outdoor condensing units appear to be installed without proper clearance requirements behind units. Clearance behind air-cooled condensing units is critical for both space comfort and cooling system efficiency because the air used to reject heat is pulled from behind the condensing units. Current spacing between walls and condensing units hinders airflow, resulting in reduced cooling capacity and reduced coefficient of performance (COP.)

It is recommended that the contractor measure current condensing unit spacing and increase spacing to one inch greater than manufacturers minimum clearance requirements in order to ensure condensing units are meeting design requirements. In the event that the air conditioning system is being replaced, ensure new condensing units are installed per the manufacturer’s specifications.

5. VFD on exhaust fans

Variable Frequency Drive (VFD) is a controller that provides adjustable speeds for an electric AC motor by varying the voltage and frequency. Adding the VFD on exhaust fan will vary fan speed to vary as needed when there is smoke or fumes from the kitchen to meet the required ventilation rates.

Installing a demand control controlled ventilation system to operate the exhaust fan is recommended. This system would include the VFD to control the exhaust fan motor, a digital controller, temperature probe, and smoke probe in the cooking hood to control the exhaust fan. Existing exhaust fan motor may need to be replaced with inverter duty motor.

Table 18. Mechanical Savings Recommendations Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
High Efficiency Split Systems	Savings are based on the improved efficiency of the inverter driven units.	506,903	$687,507	8.0 years
VFD on supply and return fans	Savings are based on the reduced power demand at lower fan speeds.	78,910	$5,672	< 1 Year
VFD on Exhaust Fans	Savings are based on the reduced power demand at lower fan speeds.	62,899	$6,934	< 1 Year
VFD on constant volume pumps	Savings are based on the reduced power demand at lower pump speeds.	34,965	$10,555	1.3 Years
Compressed Air Leakage	Estimated savings derived from reducing the operating pressure.	4,832	$5,000	4.4 years
Proper Spacing between Split Units	Estimated savings are based on an estimate in increased efficiency.	3,185	$864	1.2 years

3.5.3 Lighting

Existing Conditions

Lighting fixtures for the hospital were typically T12 or T8 fluorescent tubes with no reflectors or diffusers, causing inefficient and poor lighting. There is an ongoing phase out of T12 ballast technology by the maintenance team.

Typical Interior Fixtures

Most spaces in the building are not adequately lit with an illuminance range of 12 to 20 footcandles (FC) for the patient and administration areas. In the operating rooms and the examination areas an illuminance of 32 FC was recorded however; these spaces were not occupied at the time so not all fixtures were turned on. The Illuminating Engineering Society of North America (IESNA) Lighting Handbook Reference & Application recommends an illuminance of 28 FC for general ward lighting, 46 FC for simple examination areas and 93 FC for examination and treatment.

There were roof monitors installed to top light the outpatient clinics and waiting rooms. Although require cleaning, these monitors still provide some day light for the areas below on a sunny day. The atrium also allows for an abundance of natural light for the central transition areas.

Existing natural daylighting (multi storey atrium and roof monitors)

Exterior lighting is a mixture of pole and wall-mounted fixtures, with fluorescent tubes, CFLs, mercury vapor and metal halide lamps. These lamps were in various levels of repair.

Typical Exterior Fixtures

Recommendations

6. Full LED Retrofit

LED retrofits are one of the most beneficial and cost effective energy savings practices available. A typical 2-lamp T12 linear fluorescent bulb with a magnetic ballast uses up to 94 Watts. An equivalent LED tube fixture (no ballast needed) can produce the same lighting levels with a single tube is rated at only 18W.

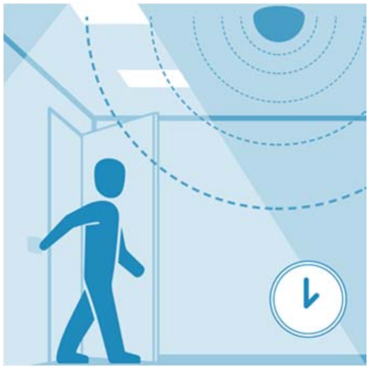
LED fixtures provide equivalent lighting levels and better light quality in comparison to fluorescent fixtures while achieving 30%+ in energy savings. The average life of LED tube lamps is typically 5 times as long as a fluorescent light, resulting in higher net present value long-term. There is also no longer a need to replace ballasts, further reducing maintenance and materials costs.

Many LEDs support lighting control capabilities such as full dimming and directional illuminance that allow custom adjustments to achieve preferred visual comforts and ensure adequate distributed light levels exactly where it is needed. Unlike fluorescents, LEDs contain no mercury, making them safe for the environment and resulting less additional recycling cost.

It is recommended to replace all existing fluorescent fixtures to dimmable LED fixtures with an LED lighting retrofit kit. Alternatively, simply installing LED tubes with a ballast bypass into the existing fixture can be more cost-effective with a simple wiring change. T12 fixtures already have a non-shunted rapid start lamp holder, and T8 fixtures need a replacement lamp holder for use with the LED tube.

7. Lighting Controls

A recommended improvement is to install occupancy sensors to lighting for timed shutoff.



Due to the prevalence of natural light, should LED's be installed, daylighting photocells can be tied into the lighting controls. These controls measure the ambient light levels to appropriately match the artificial lighting with the natural light present in the space. This "daylight harvesting" technique provides energy savings, allows for the automatic control of lights, and has the additional benefit of providing appropriate task lighting for the students.

Utilizing an Integrated Room Control (IRC) combines these technologies, and meets ASHRAE 90.1 requirements of lighting by combining receptacle control, occupancy sensing, space control, lighting control, and automatic shutoff.

Table 19. Lighting Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Interior LED Retrofit	Savings are derived from the lower power requirement (wattage per fixture) of LED fixtures.	178,091	$53,072	1.3 years
Occupancy Sensor for Interior Lights	Savings are derived from the discounted diversity factor when occupancy sensor is installed.	10,123	5,925	2.5 years
Exterior Light Retrofit to LED	Savings are derived from the lower power requirement (wattage per fixture) of LED fixtures.	35,830	9,433	1.1 years

3.5.4 Water Consumption

Existing Conditions

The city of Montego Bay has a public water supply, and the campus keeps a storage tank with full pumping capabilities for pressurization. A 5000 gallon rainwater collection system is active on the roof of the laundry, and is pumped through the facility as a backup system.

Medical facility and laboratory water use typically ranges from 250 to 800 gallons per bed due to a number of unique water-using processes:

- sterilizers and central sterile operations
- water-cooled laboratory and therapeutic equipment
- equipment scrubbers
- X-ray equipment and film developers
- water-treatment systems for kidney dialysis and laboratory water
- vacuum systems
- medical air and compressor equipment
- therapeutic baths and treatment.

Rainwater Collection System

There are 70 Chromagen solar thermal panels installed on site that are not in operation on two separate roofs (4th and 6th floor).

Cornwall was part of a demonstration initiative from which other hospitals were meant to be modelled in which the installation of the solar water heaters was completed July 2007. The system was originally designed to be connectable to the steam boiler system. It is unknown why the solar thermal system does not currently operate.

The primary use of hot water in the facility is limited to the main Kitchen on the first floor. The kitchen is able to provide 1200 meals per day.

Chromagen solar thermal system on site

Recommendations

8. Rainwater Catchment System

The typical site weather pattern reveals that precipitation occurs for approximately 25% of the year, presenting an opportunity to collect the water independently on site. There are several methods to collect rain water such as rooftop capture to rain barrels, collection from fog through nets, or using a reservoir. It is recommended that rain barrels be used to collect the rainwater from gutters and the roofs where the first flush occurs for the first 2 inches of rainwater. Typically, rainwater is used for irrigation and toilet flushing. However, we recommend additional proper filtration and treatment system is added to make the water potable and meet drinking water standards.

The total roof area for Cornwall Regional Hospital is approximately 67,000 ft^2. The average maximum rainfall volume from roof capture is estimated to be 1.96 million gallons per year. Utilizing rainwater would significantly reduce the site water demand from the municipal supply and induce to substantial pump energy savings. In case of dry seasons where water resources are scarce and in case of natural disaster that hinder the municipal supply pipeline, the site would have the rain catchment system to provide some water resource.

9. Solar Thermal Water Heaters

Hospitals have a high hot water load due to a number of medical water using processes. Significant reduction in fossil energy consumption can occur if a solar thermal system is installed to meet the hospital's hot water demand. The hospital's hot water consumption was unable to be obtained and therefore calculations on the solar thermal savings could not be performed at this time. It is recommended that the sizing of the solar thermal system is conducted once realistic data on hot water usage in the facility is obtained.

A typical solar water heating system consists of solar collectors, piping, and insulated water storage tanks. Heat is generated from incoming solar radiation energy transferred to water or glycol circulating through the panel and back to a storage tank. The heated fluid is either directly used, or a heat exchanger is used with potable water. The fluid can either be actively pumped, or use gravity and a density/pressure differential in a passive flow.

INACTIVE: Significant solar thermal system in place

3.5.5 Process Systems

Existing Conditions

The hospital employs multiple high-energy process systems for medical uses. Medical equipment requires reliable compressor and vacuum systems for highly sensitive applications. The central vacuum and medical air system were both located in the plant room of the hospital and were of Amico and Omeda type. The compressors had 2 x 15 HP motors.

Compressed Air and Vacuum Systems

The facility team at Cornwall was able to provide an inventory of process and medical equipment that summarized the high equipment loads in Cornwall hospital. (The full list has been provided in the Appendix of this document). This list has been summarized in the table below.

Table 20. Process Equipment Load Inventory		
Area	**Equipment**	**Quantity**
Laundry	Cissell dryer	2
	ADC dryer	2
	Milnor washers	2
	Small Milnor washer	1
	Compressors	2
Kitchen	Ovens	2
	Gas stoves	2
	Fryer	1
	Meat grinder	1
	Refrigerated cold room	2
	Freezer	1
Plant Room	Central vacuum system	1
	Central medical air System	1

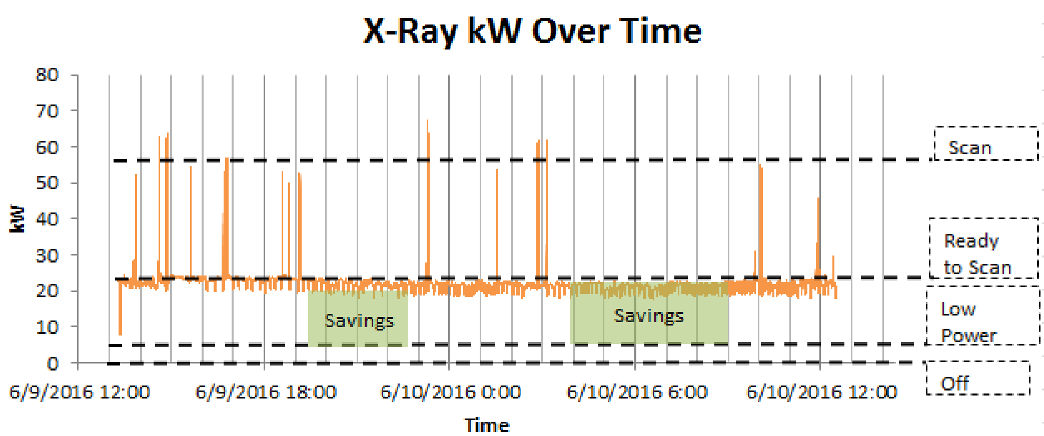
Table 21. Medical Equipment Load Inventory		
Area	**Equipment**	**Quantity**
Hemodialysis	Fresenius dialysis machines	18
	Renatron processing unit	2
	Culligan water softener system	1
Radiology	Phillips Computed Tomography (CT) Unit	1
	GE Proteus X-Ray unit	3
	Konica X-Ray processor	2
	GE ultrasound machine	2
	Phillips fluoroscopic machine	1
Radiotherapy	Simulator	1
	Phenix cobalt unit	1
	X-Ray film processor	1
Laboratory	Abbott chemistry analyzer	2
	Microtome reader	1
	Tissue processor	2
	Tissue embedder	1
	Leica cryostat	1

The plug load in the hospital consists of miscellaneous medical equipment throughout the facility, desktop computers in the doctor and nurses office areas, microwaves and refrigerators in staff areas for individual use.

Monitoring Data

10. Fluoroscopic X-Ray

A current transducer was placed on the Philips Fluoroscopic X-ray machine to determine energy use. The X-ray uses up to 70 kW during a scan, and draws approximately 23kW when the machine is idle. If the machine operates year round as was observed during the site visit, it is possible this x-ray accounts for $50,000 USD in annual energy costs at the facility. While it is important that the x-ray is ready to scan during daytime hours, the hospital should consider adding automation to turn the machine off at night. This could yield savings of up to $16,000 per year per machine.



Results:

	Name	Make and Model	Scan kW	Ready to Scan kW	Annual kWh	Est. Operating Cost
Current Energy Use	Fluoroscopic X-Ray	Philips CE0123	65	23	200,000	$50,000

Recommendations

11. Compressed Air System Investigation

Compressed Air leaks cause a fluctuating air pressure which stresses both the system and tools, increased run frequency and time of compressor package, increased maintenance, and decreased service life.

Air leakage in compressed air system is a significant waste of energy that often contributes up to 20-30% of excess system usage. Leakage induces to additional pressure drop in the system, leading the compressor to work harder and causing fluctuating air pressure that stresses the system and tools. Subsequently, overworking the compressor than it needs to can force short cycling, ultimately increasing maintenance and shortening the equipment's useful life. The most common areas where leakage occurs are typically in joints, connections, pressure regulators, open condensate traps, shut off valves, and thread sealants.

Efforts to detect leakage using an ultrasonic acoustic detector on a periodic basis through a preventive maintenance program is recommended. Since air leaks are not always visible, recognizing high frequency hissing sounds associated with air leaks is a recommended training for dedicated maintenance staffs. Depend where the leakage occurs, fixing leaks can be as simple as tightening a connection to replacing a faulty component.

Once leaks are repaired, it is likely that the compressor controls will need to be adjusted to match the altered system demand. The air pressure of the system will be reduced to the lowest practical range that is needed on the demand side in order to reduce the leakage rates and alleviate unnecessary stress for the system.

12. Plug Load Efficiency

Receptacle load (also referred to as plug load) is an unregulated load in terms of building energy code requirements. One key step in reducing receptacle energy use is to institutionalize measures through procurement decisions and policy programs (refer to ENERGY STAR® for guidance). Policies must be improved as needed to stay current with technologies.

A key step in any plug load reduction program is to reduce energy use during non-business hours, as it is generally wasted. In the case of receptacle load for a hospital, there are many areas such as the administration, outpatient offices and nurses stations where computers are left unoccupied for long periods of time. Employing power strips that can be switched off in times of no usage could reduce the 'standby mode' energy consumption.

There should be ENERGY STAR® appliances installed for kitchen and breakrooms to further reduce electrical consumption in these spaces.

3.5.6 Smart Building Controls

Existing Conditions

A new automated control system was installed as well with commercial off-the-shelf (COTS) software. Only the air handlers serving the fourth and fifth floors (AHU-5, AHU-6 and AHU-7) are linked up to the building management system but there is a Commercial-off-the-shelf (COTS) platform for future expansion.

Sample of existing building management system

Recommendations

13. Chiller Controls

The chiller systems are for the hospital are relatively new, and have an sufficient level of controls installed that could be further optimized for efficiency. Currently, the chillers run at a constant temperature output, and do not appear to have been integrated with the appropriate level of controls for the range of zones that they control.

Centralized chiller controls not only establish a greater level of control over the equipment, but they enable the ability to implement multiple low-cost control strategies and to provide an interface to enable easy troubleshooting or maintenance long term. Energy efficiency strategies such as chiller lockout, chiller supply temperature reset, optimal start/stop, and scheduling can better serve the variable load in the building and provide up to 5 to 10% of facility total electrical consumption.

Table 22. Chiller Control Benefits

	Description
Scheduling	An optimized daily on/off period can be set to better match the operational peak load of the building.
Lockouts	Restricted use dependent on specified conditions, such as outdoor temperature, calendar date, etc.
Resets	Ensure equipment operates at the minimum needed capacity by automatically resetting operation to match weather conditions.
Diagnostics	Data monitoring of temps, flows, pressures, and actuator positions identifies if equipment is operating incorrectly or inefficiently.

14. BAS Upgrades

A Building Automation System (BAS) is an autonomous control system for the entire facility, including lighting, mechanical equipment, security, irrigation, and other systems. Historically, the mechanical system is the primary integrated to BAS due to its complexity and high saving returns. Hence, integration of the mechanical system as well as lighting system into the BAS is recommended.

The main advantage of BAS is the supervision and controls across all mechanical equipment to work cohesively and maintain the building climate within a specified range. Moreover, a building controlled by BAS is often referred to as "smart building" where there has been proven reduction in building energy and maintenance cost compared to a non-controlled building. Vital functions such as statuses, alarms, tuning the control loops, scheduling, and lockout provide a critical tool for faster responding to issues. Furthermore, low-cost to no-cost energy savings strategy such as simply changing a setpoint, tailoring the equipment schedule to match occupancy, and removing a temporary manual override are just a few common strategies that will lead up to 20% or more of energy savings.

Table 23. Controls Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
BAS Upgrades	Saving is based on an estimated savings percentage.	53,995	$75,000	5.9 years
Centralized Chiller Controls	Savings is based on an estimated savings percentage.	81,686	$45,000	2.3 years

3.5.7 Renewable Energy Generation

Existing Conditions

There is currently an inactive solar thermal system installed on site consisting of 70 Chromagen panels. It is unknown when the system was operating and when it became inoperable. There are a large number of flat concrete roofs with very little shading. Peak energy use is during daytime hours making an ideal situation for solar and hot water generation.

Recommendations

15. Solar Photovoltaic System

A solar analysis performed for Cornwall Regional Hospital illustrates the potential solar opportunity at the site.

The following assumptions were made regarding roof areas:

- 80% of flat roof area was assumed to be solar ready (20% unavailable for mechanical equipment, structural and misc. equipment on roof)
- 75% of pitched roof area was assumed to be solar ready (25% unavailable for mechanical equipment, structural and misc. equipment on roof)

Table 24. System Installation Criteria

Module Type	Crystalline Silicon
Array Type	Fixed (open rack)
System Losses (%)	14
Tilt (deg)	20
Azimuth (deg)	Varies with roof orientation
Roof Area Availability	80% (flat roof) 75% (pitched roof)

The analysis was performed using National Renewable Energy Laboratory (NREL)'s PVWatts® Calculator. This is a web application that estimates the electricity production of a grid-connected roof based on square footage available. The location of the hospital site, basic design parameters such as azimuth of roof and tilt of panel and system economics were inputs for the tool. A cost per watt of $3 (NREL,2015) was used for the capital cost of PV installation. A utility cost of $0.25/kWh was used as an average utility rate of electricity for the Jamaican region.

As of 2015, JPS no longer allows for a net billing or net metering strategy for commercial facilities. This drastically affects the amount of solar photovoltaics that can cost effectively be installed on a building. Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.

- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.

- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 25. Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings	Simple Payback	ROI
Net Zero Energy	2039 kW	$6,117,084	3,225,742 kWh	$756,413	8.1 years	12.4%
Maximize Onsite Opportunity	971 kW	$2,911,800	1,535,489 kWh	$360,061	8.1 years	12.4%
Load Matched System	497 kW	$1,490,400	785,938 kWh	$184,297	8.1 years	12.4%

The following map shows the roof areas considered in the solar analysis and the table shows the results of the solar feasibility study conducted for the site.

Map of Potential Solar Array Opportunities on Site

Table 26. Renewable Potential							
Area	**Azimuth**	**Collector Area (square meters)**	**Collector Area (square feet)**	**KWdc**	**Capital Cost (USD)**	**Annual Energy Generation (kWh)**	**Annual Cost Savings**
A	180	444	4,779	66.6	$199,800	111968	$26,256
B	180	640	6,889	96	$288,000	161395	$37,846
C	180	254	2,734	38.1	$114,300	64054	$15,020
D	180	271	2,917	40.6	$121,800	68257	$16,006
E	180	376	4,047	56.5	$169,500	94987	$22,274
F	180	377	4,058	56.5	$169,500	94988	$22,274
G	180	924	9,946	138.6	$415,800	233014	$54,640
H	180	154	1,658	23.1	$69,300	38836	$9,107
I	180	211	2,271	31.7	$95,100	53294	$12,497
J	180	1332	14,338	199.8	$599,400	335903	$78,767
K	180	503	5,414	75.4	$226,200	126762	$29,725
L	180	496	5,339	74.4	$223,200	125081	$29,331
M	180	489	5,264	73.3	$219,900	123232	$28,897
TOTAL		**6,471**	**69,653**	**971**	**$2,911,800**	**1,631,771**	**$382,638**

Disclaimer: The production estimates that PVWatts® calculates do not account for many factors that are important in the design of a photovoltaic system. These calculations should not be used to help design a system, rather seek a qualified professional to make final design decisions using more detailed engineering design and financial analysis tools. (NREL, 2015.)

3.5.8 Miscellaneous Systems

Existing Conditions

There was a Siemens Power Factor Controller Unit system installed on site that was not working at time of site visit. No actual power factor measurements were taken on site because it was deemed unsafe. The transformers were coming through as bars and not lines which meant it was hard to clamp the power meter on and take a measurement.

Three backup generators for the hospital are in place, one of which was installed in 2015. Due to an active utility transition from oil to LPG, power outages are common, up to 6 times per day. The backup generators were installed to cover the critical loads of the hospital only.

System Components

1 x Broad Crown Generator
880 kW
1 x FG Wilson P175HE Generator
140 kW
1 x Mecc Alte SPA
140 kW

3.5.9 Training

Building automation allows us to turn old facilities into smart buildings. However, the smartest control system within a building is the brain of the people who use it daily. Training of facilities staff as well as nurses, doctors, janitors and administrative staff enables the energy efficiency measures implemented within the building to work correctly. Training can help us ensure that unnecessary lights are off, thermostats are set correctly, and the right people are notified in the event of system failure.

Recommendations

16. Maintenance Staff – 2-day post-retrofit initial training

When the project is complete, it is important that members of the maintenance staff are fully trained on any new building systems. Without this key final project close-out item, energy efficiency measures are destined to fail. This circumstance has been noted during our visits to some facilities in Jamaica.

We recommend the maintenance staff is trained by the contractor team after initial installation of all energy efficiency measures to ensure that the staff knows the operational requirements of all new or upgraded equipment. This should be written into the energy efficiency implementation contract.

Training shall include preventative maintenance training such as: recommended filter replacement cycle, oil change cycles, refrigerant testing, valve testing, cleaning of solar panels, and other preventative items specific to each energy efficiency measure.

17. Facility Mangers – Annual Energy Workshop with other Hospitals FMs

As facility managers test and implement new energy efficiency measures and training, it is important to share lessons learned among other hospital facility managers in the country. This provides an excellent opportunity for cross-learning and collaboration on a variety of issues. The annual workshop will enable a project that was successful at one hospital to be implemented by staff at other hospitals. We recommend holding the annual energy workshop in a rotating hospital in a major city each year. Meeting location should be determined based on whichever hospital has most recently received energy upgrades.

18. All Staff – Quarterly Energy Awareness Training

Facility managers are not the only occupants who determine building energy use. Any building occupant armed with knowledge about energy efficiency can help reduce on-site energy usage. Closing doors to air conditioned spaces, turning off lights, properly setting thermostats, and turning equipment off when not in use is the job of the building occupant and is critical to minimizing energy use. Karl Heusner Memorial Hospital in Belize has shown a successful. We recommend the facility staff provide a quarterly energy awareness training to all staff to teach doctors, nurses, and other employees how equipment works and how to minimize energy use in their daily lives. This will have the added benefit of helping them to save energy use at home, reducing their monthly costs as well as their carbon footprint.

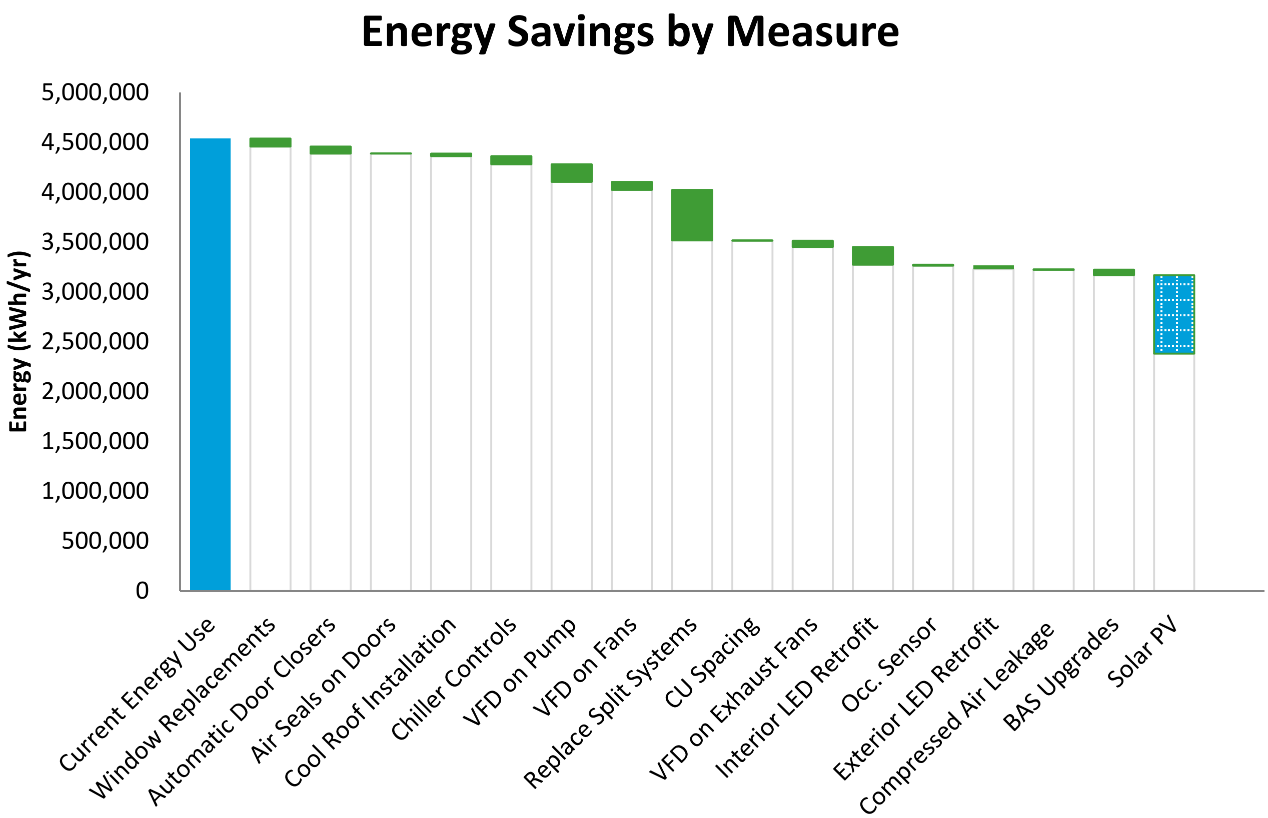
3.6 RECOMMENDATIONS SUMMARY

Cornwall Hospital provides an excellent opportunity for energy savings and associated carbon reduction. These savings will result in a decrease in oil dependence for the island of Jamaica, a decrease in the annual energy bill for the GoJ, and will help increase in-country capacity for energy efficiency implementation. The table below outlines the energy efficiency recommendations for the project. We recommend that the GoJ take the following steps:

5. Perform an Investment Grade Audit of the facility to provide more in-depth analysis of building energy use as well as more accuracy for energy savings of each energy efficiency measure
6. Determine applicable funding and scope for the project
7. Draft Request for Proposal for energy efficiency implementation
8. Engage an Energy Services Company (ESCO) to install energy efficiency measures and distributed renewable energy

Based on the technical assessment performed, the following energy efficiency opportunities exist at the hospital:

Cornwall Key Recommendations Overview					
Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Window Replacements	80,566	$18,892	$90,080	21%	4.8
Automatic Door Closers	70,060	$16,428	$5,699	288%	0.3
Air Seals on Doors	1,349	$316	$1,945	16%	6.1
Centralized Chiller Controls	81,686	$19,155	$45,000	43%	2.3
VFD on constant volume pumps	34,965	$8,199	$10,555	78%	1.3
VFD on supply and return fans	78,910	$18,504	$5,672	326%	0.3
High Efficiency Split Systems	506,903	$118,865	$687,507	17%	5.8
Proper Spacing between Split Units	3,185	$747	$864	86%	1.2
VFD on Exhaust Fans	62,899	$14,749	$6,934	213%	0.5
Interior LED Retrofit	178,091	$41,761	$53,072	79%	1.3
Occupancy Sensor for Interior Lights	10,123	$2,374	$5,925	40%	2.5
Exterior Light Retrofit to LED	35,830	$8,402	$9,433	89%	1.1
Compressed Air Leakage	4,832	$1,133	$5,000	23%	4.4
BAS Upgrades	53,995	$12,662	$75,000	17%	5.9
Total (Recommended Measures)	1,989,331	$466,484	$2,493,086	18.7%	5.3
Total (Not Including Renewables)	1,149,398	$269,525	$927,686	29.1%	3.4



Renewable Energy Recommendations

Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 27. Solar Renewable Options						
Solar Option	**System Size**	**Capital Cost (USD)**	**Annual Energy Generation**	**Annual Cost Savings**	**Simple Payback**	**ROI**
Net Zero Energy	2039 kW	$6,117,084	3,225,742 kWh	$756,413	8.1 years	12.4%
Maximize Onsite Opportunity	971 kW	$2,911,800	1,535,489 kWh	$360,061	8.1 years	12.4%
Load Matched System	497 kW	$1,490,400	785,938 kWh	$184,297	8.1 years	12.4%

4 FALMOUTH HOSPITAL

An Investment Grade Audit (IGA) was performed by DNV GL Energy Engineers of government buildings in Jamaica. The half-day site visit of Falmouth Hospital was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation. The team included the facility managers, MSET, representatives from the utility PCJ, and the Ministry in charge of managing the building.

The project is commissioned by the IDB and the goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. GoJ facilities use 12% of electricity consumed in Jamaica. Of that GoJ usage, 14.5% powers healthcare and educational facilities. The facilities visited in April represent a quarter of energy use of those sectors. The expected results of the project are:

- Reduced electricity consumption within government facilities
- Decreased oil imports through improved EE
- Reduced GHG emissions which can contribute to Jamaica's INDC commitment
- An increased capacity to promote and supervise electricity planning in Jamaica

Utility analysis shows the campus energy consumption decreased in 2015. Nevertheless, opportunities to lower energy consumption, identified as Energy Efficiency Measures (EEMs), are summarized in Table 1. Additionally, renewable energy analysis indicates potential electric generation that would provide large savings, implying that there is a large potential for the facility to achieve net zero energy.

4.1 Site Visit Summary

On June 3rd, 4th, and 8th 2016, an Energy Conservation and Efficiency Team Technical Visit was conducted, beginning at 10:00AM. The initial kickoff was attended by representatives from Ministry of Health, Ministry of Science Energy & Technology (MSET), Petroleum Corporation Of Jamaica (PCJ), Inter-American Development Bank (IDB), DNV GL Energy Services (DNVGL) and Academy Operations and Maintenance staff.

A walk-through assessment was conducted with appropriate personnel familiar with the physical condition and day-to-day operation of the facility and equipment. Through the facility profile established during the kickoff meeting, the following systems were specifically targeted:

- Lighting Systems
- Ducted air conditioning systems
- Mini-split air conditioning Systems
- Kitchen operations
- Laundry operations
- Rainwater collection and distribution
- Solar PV Potential

The following staff attended the site visit:

Table 28. Site Visit Attendee List			
Dates: 6/3/2016, 6/4/2016, & 6/8/2016			
Name	**Organization**	**Phone**	**Email**
Marcia Clarke	WRHA	318-1209	
Joseph Ramsay	WRHA	375-7444	joseph_ramsay33@yahoo.com
Janel James	PCJ		Janelle.james@pcj.com
Kent Dahlquist	DNV GL	619-309-7441	kent.dahlquist@dnvgl.com
Joe St. John	DNV GL	781-418-5748	joseph.st.john@dnvgl.com

4.2 Key Recommendations

The following table outlines key recommendations for the project. If all measures are selected from the recommendations below, the project will attain 24% energy savings for a cost of $83,756 USD with a 1.97 year payback. Without including solar renewable energy systems, the measures below result in 39% energy savings at a capital cost of $500,923 USD with a payback of approximately 5 years.

Table 29. Falmouth Key Recommendations Overview

Measure Description	Savings and Cost			Payback	
	Electricity Savings (kWh)	Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Replace Broken Windows	1,352	$337	$2,072	16.2%	6.2
Automatic Door Close	2,971	$740	$600	123.3%	< 1
Air Seals on Doors and Windows	2,437	$607	$2,470	24.6%	4.1
Cool Roof Installation	13,068	$3,254	$10,000	32.5%	3.1
Proper Spacing Behind Condenser Units	15,862	$3,950	$13,350	29.6%	3.4
VFD on supply and return fans	70,993	$17,680	$24,000	73.7%	1.4
Split Units Replacement	8,541	$2,127	$11,968	17.8%	5.6
Fluorescent to LED Fixture Retrofit	44,601	$11,107	$18,049	61.5%	1.6
Exterior Light Retrofit to LED	11,248	$2,801	$1,246	224.9%	< 1
Occupancy Sensor for Interior Lights	20,709	$5,157	$8,527	60.5%	1.7
BAS Upgrades	31,263	$7,786	$40,000	19.5%	5.1
Solar PV	194,396	$48,412	$368,640	13.1%	7.61
Total Savings (Recommended Measures)	417,440	$103,959	$500,923	49.8%	4.82
Total Savings (Without Renewable)	171,072	$42,604	$83,756	52.4%	1.97

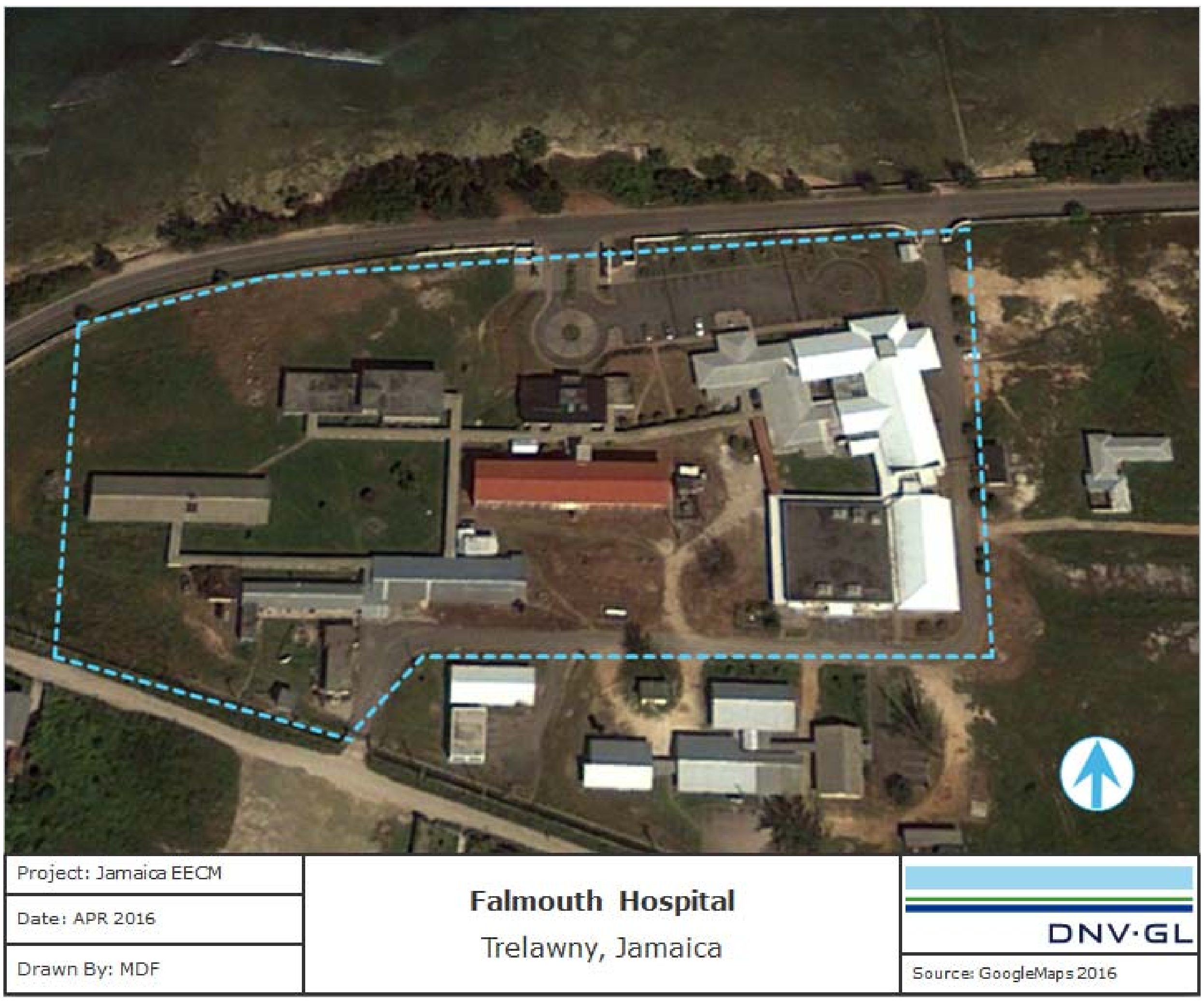
Savings of non-renewable EEMs	24%
Annual GHG Savings (metric tons CO2)	266
15 year GHG Reduction (metric tons CO2)	3,989

4.3 FACILITY OVERVIEW

Falmouth Hospital is located on the Northern coast in Trelawny parish, and is currently providing preventative and curative health care to the local region. It is owned by the Western Regional Health Authority, a Jamaican government agency. The original facility was built in 1954, and an expansion began in 2007. This expansion is ongoing, however when complete will include two new operating theaters and additional service areas. A partial renovation is ongoing and approximately 110 beds are available, with 50 outpatients processed per day.

Electricity is supplied by Jamaica Public Service Company. The facility is served by two (2) electrical meters, but one (1) meter is inactive. During time of visit, the hospital was being converted to LPG fuel by Jamaica Public Service (JPS) and as a result was experiencing up to 6 power outages a day.

Contractors are used for all non-routine maintenance. Water is all city-supplied, and there no rainwater collection or pumping system in place.



Campus Aerial View

4.4 UTILITY ANALYSIS

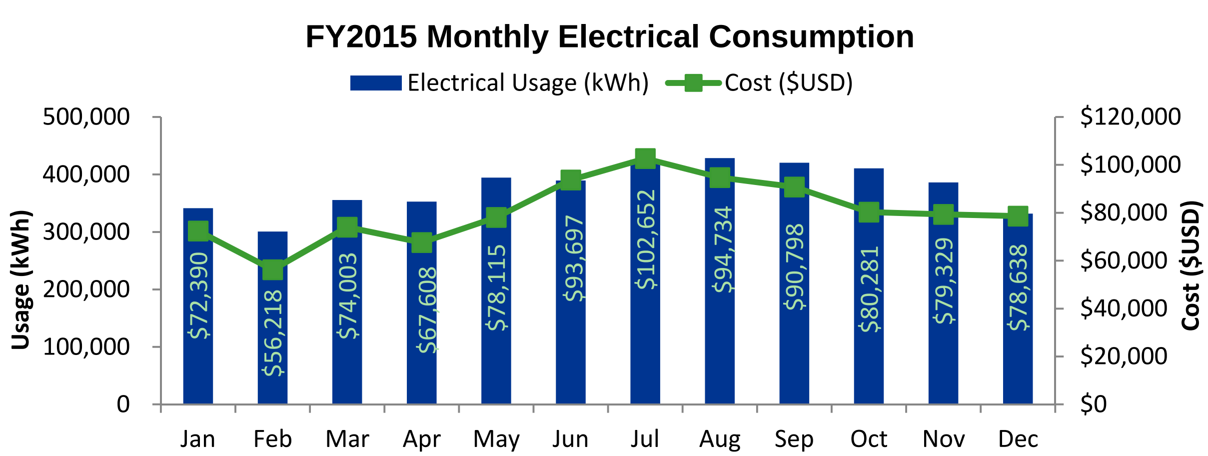
Utility data were evaluated for period 2012 through 2015. Based on the provided information, electricity is the primary fuel used with diesel fuel only utilized for the emergency generator. Water utility and other fuel types were requested but were not made available for data analysis. The table below summarizes the annual utility profile.

Annual Utility Profile Summary							
Utility	Usage*	Unit	Cost*	Avg Unit Cost in USD	Energy (MMBTU)	Cost %	Energy %
Electricity	703,799	kWh	$156,569	$0.25	2,401	100%	100%
Natural Gas	#N/A	Therm	#N/A		#N/A	#N/A	#N/A
Water	#N/A	Gallons	#N/A		#N/A	#N/A	#N/A
Annual Sum			$156,569		2,401		
Per Floor Area			$3		0.039		
Floor Area=		62,000	square feet		1 MMBTU =	1,000,000	Btu
Correction Power Factor =		Not Available			1 kWh =	3412	Btu
*From 2015 utility bills					1 Natural Gas Therm =	100,000	Btu

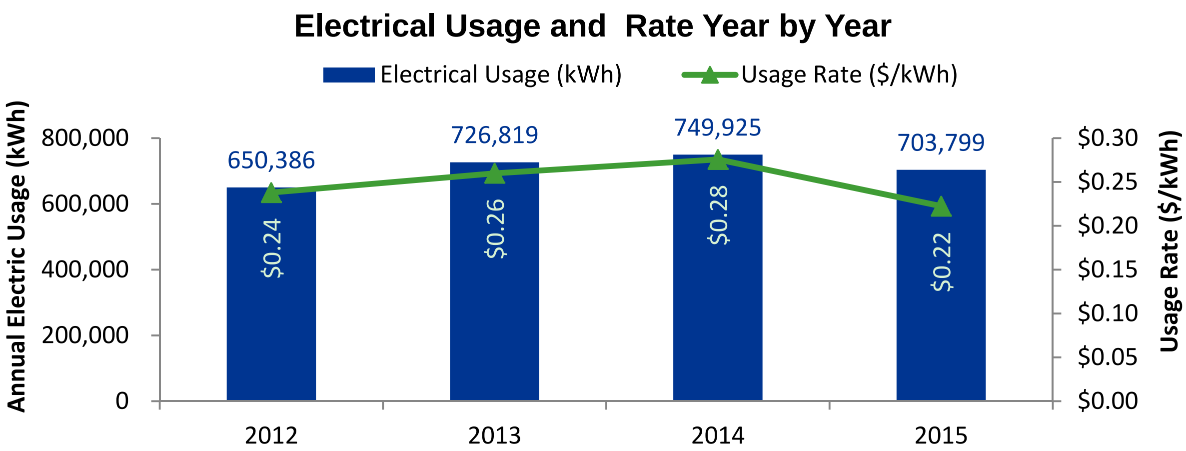
4.4.1 Electricity

Electrical Usage

Electricity is supplied by Jamaica Public Service Company (JPS). The facility is served by two (2) electric meters, but one (1) meter is inactive. The facility annual assumption for year 2015 is approximately 703,799 kWh where the annual peak demand is 205 kVA. As shown in the figure below, monthly electrical energy consumption stays relatively consistent with slight seasonable variation to reflect the typical weather pattern in Jamaica where the hottest months are from July to September. The small variance in electrical consumption between hotter months and other months is expected for a hospital that has comfort cooling. There is currently no active renewable energy used on site at this time.

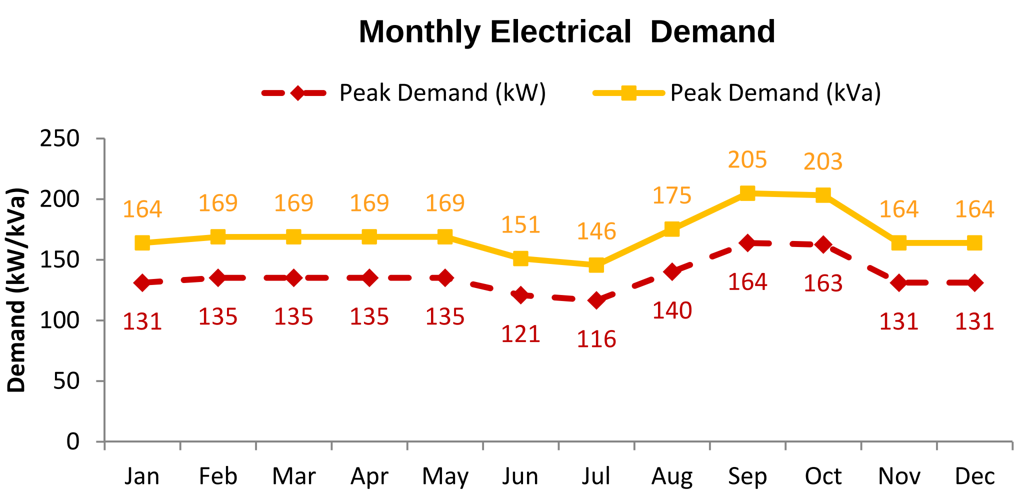


Year by year consumption trend shows that there was an increase in energy usage from 2011 to 2014 as shown in the figure below. The average utility rate from 2012 to 2015 is $0.25 USD per kWh. To account for the potential rate fluctuation in the future, this average utility rate is used to project energy saving costs.



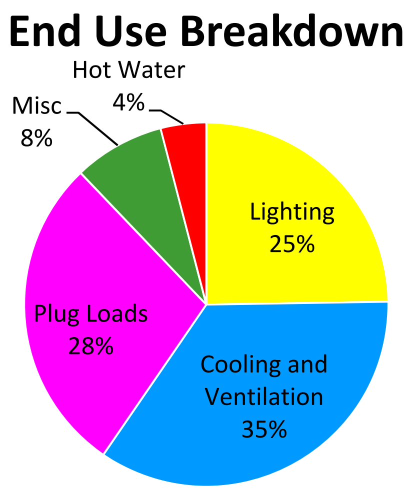
Electrical Demand

The figure below shows the Peak Demand in kVA (the demand charged by the utilities) and the Peak Demand in kW (actual demand of site). The Peak Demand in kW is estimated to be 0.8 based on similar sites' observations since it was not measured due to unfavorable safety conditions. The U.S. standard for power factor is 0.9 or higher. Typical causes of low power factor include lowly loaded induction motors and lack of capacitors in transformer.



Load Profile Evaluation

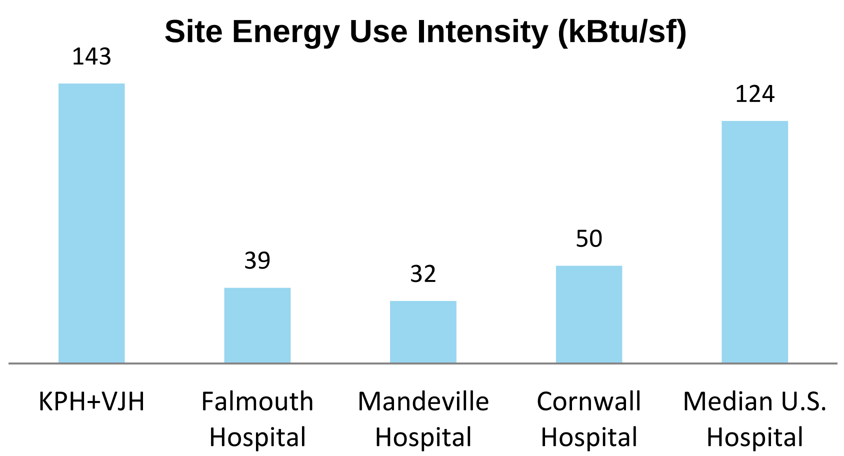
The building electrical use profile is divided into different end-use categories shown on the pie chart below. The annual end use breakdown will vary based on occupancy, operational changes, equipment maintenance, and occupant behavior. More accuracy can be garnered by adding sub-metering systems throughout the facility, which is recommended should a major electrical systems overhaul be undertaken.



4.4.2 Benchmarking

Energy use benchmarking is defined as the process that compares the energy use of a building with other similar structures. It is a critical evaluation for organizations with a large building portfolio to identify building performance and the factors that drive their energy use. The U.S. Department of Energy EnergySTAR program has developed an energy performance rating for commercial and institutional facilities.

The median hospital energy usage intensity (EUI) from EnergySTAR is 124 kBtu/sf annually. Falmouth hospital uses approximately 39 kBtu/sf annually, which is 69% below the median U.S. hospital EUI. The low EUI is because Falmouth is similar to a Type C hospital that has lower equipment load and cooling load. Note that Falmouth has a comparable EUI to both Mandeville and Cornwall Hospitals.



4.5 SAVINGS OPPORTUNITIES AND RECOMMENDATIONS

4.5.1 Building Envelope

Existing conditions

Site Context and Orientation

Falmouth Hospital is located on the coast in the northwest part of Falmouth. The orientation of the hospital is north facing and it is located in a rural setting (surrounded by the small town of Falmouth). The hospital is made up of many single-story buildings in the area, located in an open plot, and receives no shading from any source. As it is a coastal location, the hospital experiences some heavy wind gusts at times (maximum of 17mph), and averaging around 7 mph for most of the year.

General Building Description

Most of the buildings are single-story with the patient ward building being the only two-story on site. All of the buildings on site have 10 foot roof overhangs that provide solar shading; the buildings are also connected by an open, covered pathway.

Wall and Roof Elements

There are 9 main buildings that are concrete block constructed, with mostly corrugated roofs. The two newly-constructed buildings house the operating theatre and accident/emergency, and have an insulated concrete roof with gravel. The kitchen and laundry are both located in standalone wood frame, single-story structures. There is no ceiling or insulation in either the roof or wall constructions. The temperature of the underside of the laundry room roof was recorded to be 102°F at time of visit.

Exterior wall and roof of hospital

Windows and Openings

Most of the windows in the hospital are single pane and of the operable ‘awning’ type. As a result, natural ventilation (cross-flow strategy) is the predominant cooling method for most of the perimeter spaces and the open air atrium. There were a number of windows that were broken throughout the site. The common cause observed was a broken crank operator or sagging window hinge.

Awning windows

The building structure has a high level of air leakage with infiltration evident through unsealed windows, doors and envelope. Unsealed openings are also present in rooms such as the maternity and nurse’s wards that also had air conditioning systems installed. Windows in rooms with non-functioning AC units often leave their windows open for ventilation, while adjacent rooms would leave AC units on. Freshly cooled air immediately escapes the room via the adjacent open window, which results in a room that remains hot even while the air conditioner is running at full load, burning energy, and decreasing the equipment's useful life. Air sealing the building envelope is one of the most critical features of an energy efficient building. Room sealing will mitigate infiltration as well as reduce potential leakage of the cool, conditioned air supply in places where there is an AC system installed.

There was some daylighting occurring via side lighting (windows) to most of the interior spaces on site due to the single storied, narrow in width building form. In the case of Falmouth hospital, most of the windows were not providing adequate amount of natural light to the interior because they were heavily shaded by the exterior walkways.

Recommendations

DNV GL suggests the following measures:

5. Window replacements with insulated glazing

The buildings were designed for natural ventilation, and metal louver windows are typical. Many rooms are conditioned using split units; however the windows are not sealed, thus causing significant energy losses.

Installing a double-glazed window will have insulating air- or gas-filled spaces between each pane will improve the U-Value. A double-glazed, low-emittance glass with gas between the panes has a U-factor of about 0.35, effectively tripling the current thermal resistance. More importantly, double-glazed windows with proper mounting prevents infiltration and limits air leakage when the air conditioners are active, reducing the cooling power requirement. In Jamaica Solar Heat Gain Coefficient (SHGC) is more critical than U-Value. SHGC should be below 0.28 on all East, West, and South facing glazing.

Existing louvre windows are recommended to be replaced with insulated glazing windows with assembly U value of 0.5 or lower.

6. Automatic door closers

Doors were found to be open or improperly sealed, limiting the effectiveness of the cooling systems. The most cost effective strategy to automatically close the door is using a surface-mounted regular arm door closer attached behind the door frame where a spring mechanism is used to close the door. This ensures pressurization and limits infiltration, reducing the cooling power requirement.

Improperly sealed doors often are a significant source for leakage of conditioned air, causing excess energy use. A 0.125-inch gap around a typical entryway door is the equivalent of drilling a 5.5-inch-diameter hole through an outside wall. A weather seal system includes weather stripping, which covers the sides and top of the door, and a sweep, which fills the space between the threshold and the door bottom. Foam, felt, plastic, or tubular silicone weather stripping products are designed for this purpose.

7. Air Seals on Doors / Windows

Where ventilated block is used structurally and replacement is infeasible, a border should be installed to retain an insulated window pane firmly against the border material, thus creating an airtight seal between the existing block, the border material and the new pane with appropriate adhesive and sealing compounds applied to ensure an airtight seal.

8. Cool roof installation

There is a multitude of roof types on this campus including bare concrete, membranes, corrugated metal, metal sheets, and asphalt. Each of these materials has different thermal properties, with some being much more heat resistant than others. An energy savings technique is to reduce the heating load of the roof and thereby decreasing air conditioning needs. An energy efficient Cool Roof is designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles.

The concern at this building is that a Cool Roof will always improve thermal comfort, but only provides energy savings when the space below is conditioned. Since many spaces under the roof are unconditioned, the cost of a Cool Roof is not justified by the savings.

It should be noted that rooftop solar PV provides roof shading, which offers the same cooling benefit as a cool roof. On rooftops which receive solar PV, we do not recommending spending additional capital on cool roofs.

Table 30. Envelope Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Replace Broken Windows	Saving is based on improved R-value.	1,352	$5,346	15.9 years
Air Seals on Doors and Windows	Saving is based on improved R-value.	2,437	$2,470	4.1 years
Automatic Door Close	Saving is based on infiltration due to temperature difference.	2,971	$600	< 1 Year
Cool Roof Installation	Saving calculation is based on improved roof R value and decrease in surface heat loss.	13,068	$10,000	3.1 years

4.5.2 Mechanical and Electrical Systems

Existing conditions

The air conditioning system for Falmouth hospital consists of multiple ducted split systems serving major areas, mini-split systems serving patient and administration areas and a boiler steam plant. There are 4 ducted split systems that serve 2 of the old operating theaters, the accidental/emergency space and 4th serving the X Ray center. Two brand new operating theaters which will be served by a new Carrier central unit were still under construction at time of site.

Steam Plant: - One Cleaver Brooks Boiler (1674 MBH)

There is a boiler steam plant that consists of a 2013 Cleaver Brooks boiler and supplies the laundry, sterilization and operating theaters on site. The steam was being supplied at 300F and hot water was returned at 130F. There was also a State residential water heater located in the new Operating Theater to provide supplemental/booster hot water heating for procedures.

There are approximately 25 mini-split systems.

As noted in the existing conditions of the envelope, the mini-split units are not operating efficiently due to all the open windows.

Carrier rooftop condenser

System Components

4 x Split systems ducted

- AC-1 (25 tons, SF – 7.5HP) - Operating Theater #1
- AC-2 (25 tons, SF – 10HP) - Operating Theater #2
- AC-3 (25 tons, SF – 10HP) – Accident/Emergency
- AC-4 (25 tons, SF – 7.5HP) – XRay

1 x central packaged unit – Nurses Prep Area New Operating Theaters

+25 x mini split systems (1 ton – 3 tons)

1 x Natural Gas Hot Water Boiler

1 x Residential Water Heater

Supply fan and condenser units on the roof

Approximately 25 mini-split AC units have been installed in wards, offices, and treatment rooms. There are a variety of manufacturers and unit capacities. All of the systems used basic remote-control systems with no temporal programming capabilities. Many of the condensing units have not been installed with manufacturer recommended spacing, limiting their effectiveness. In addition, numerous condensing units were observed to have been placed either near open windows or directly above the extremely hot steam transfer line.

Mini-Split AC Units

These systems placed a heavy toll on the maintenance staff, and a substantial number of the units were out of service. It was repeatedly observed that the staff were requesting repairs to their cooling systems throughout the walkthrough.

Kitchen exhausts and pedestal fan in the laundry

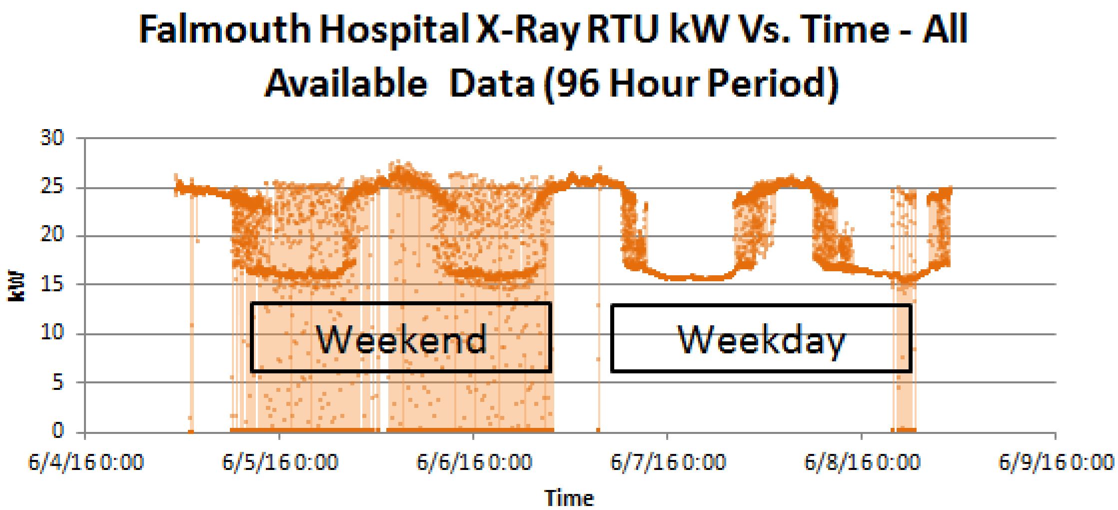
There are 3 constant volume exhaust fans that exhaust air from kitchen. These units were extremely old with no nameplate data evident. The kitchen exhaust fans are operated continuously from 6am – 7pm daily. No make-up air is provided to the kitchen. Pedestal standing fans are used to provide comfort to the occupants in the unconditioned laundry. On the interior surface of the laundry roof, a radiant temperature of 102F was observed.

Monitoring Data

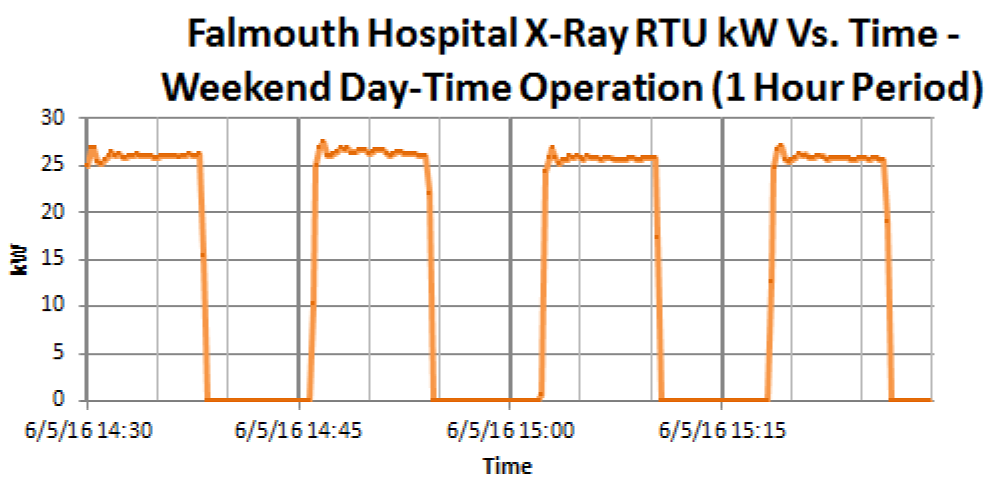
Rooftop Units

Power data on two rooftop packaged HVAC units (RTUs) serving the X-Ray department, and the nurses prep area was collected to determine energy use of the equipment. In addition, sensors were installed on the RTU serving the X-Ray department to take measurements on supply and return temperatures, as well as outside air conditions.

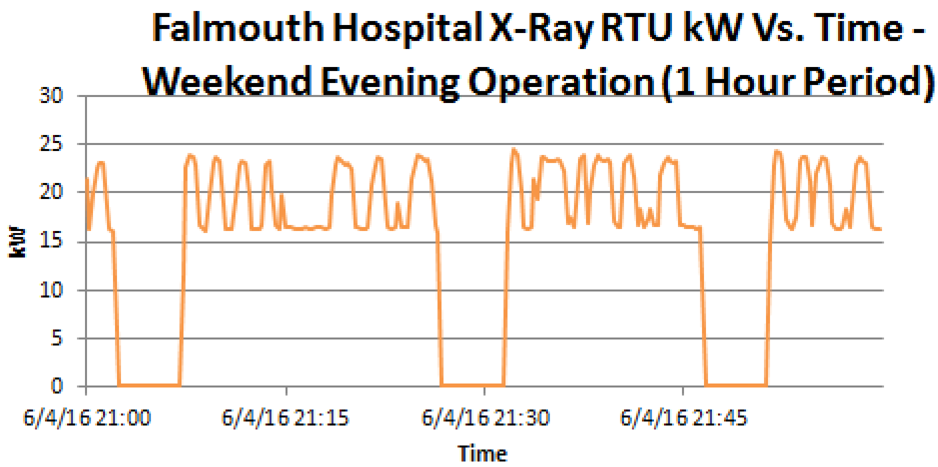
The rooftop unit serving the X-Ray department uses about 40% less energy during the night time than during the day however, during weekdays it pulls 15 kW or more nearly consistently, whether or not the X-Ray department is occupied. During the weekend that the logger was left on, the RTU serving the X-Ray department was found to cycle off every 10 minutes, and stay off for about 5 minutes, before turning on again, and starting the cycle over. This can be seen in the two charts below.



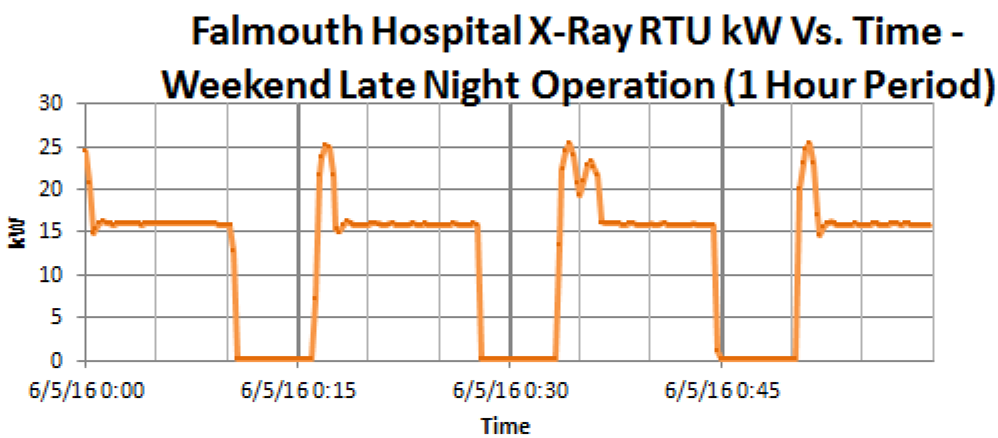
The chart below is a closer look at the chart above during daytime, weekend operation. During the day time on weekends, the RTU serving the X-Ray department vacillates between 26 kW and 0 kW.



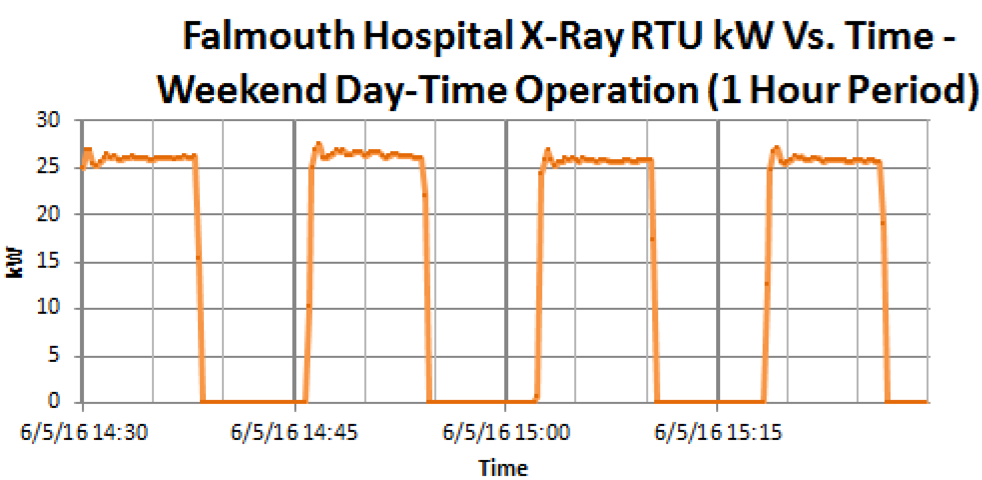
The chart below is a closer look at weekend early evening operation, when the ambient outside air temperature is lower than it is during the day time. During this time, the RTU cycles off for 5 minutes, comes on, and while it is on, vacillates between 15 kW and 23 kW for the following 10 minutes.



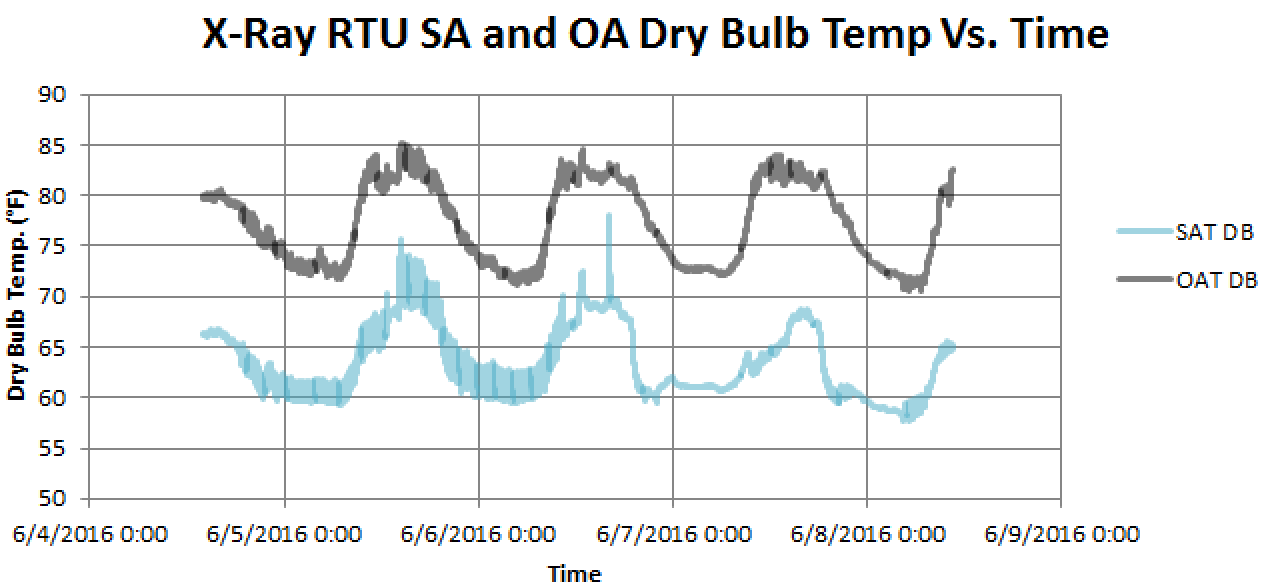
During the late evening on the weekends, the RTU was observed to cycle at approximately the same frequency, but when it came on, it would spend more time pulling 15 kW, than 25 kW.



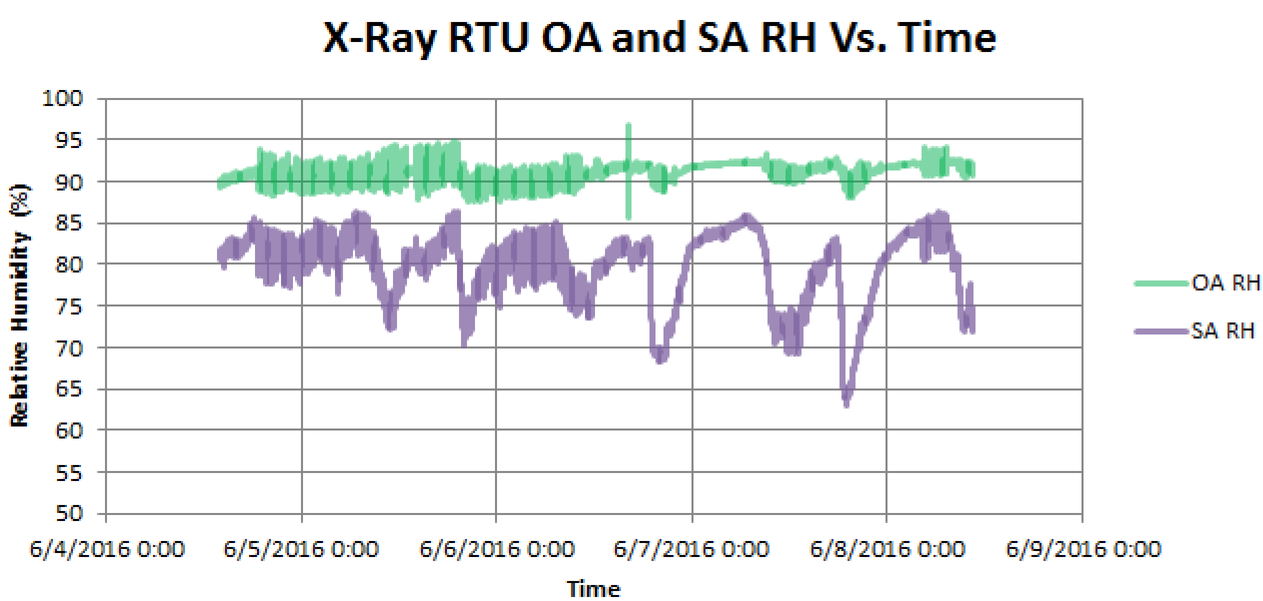
During the daytime on the weekend, the RTU would cycle on for about seven and a half minutes at 26 kW, and then cycle off for about seven and a half minutes, as demonstrated by the chart below.



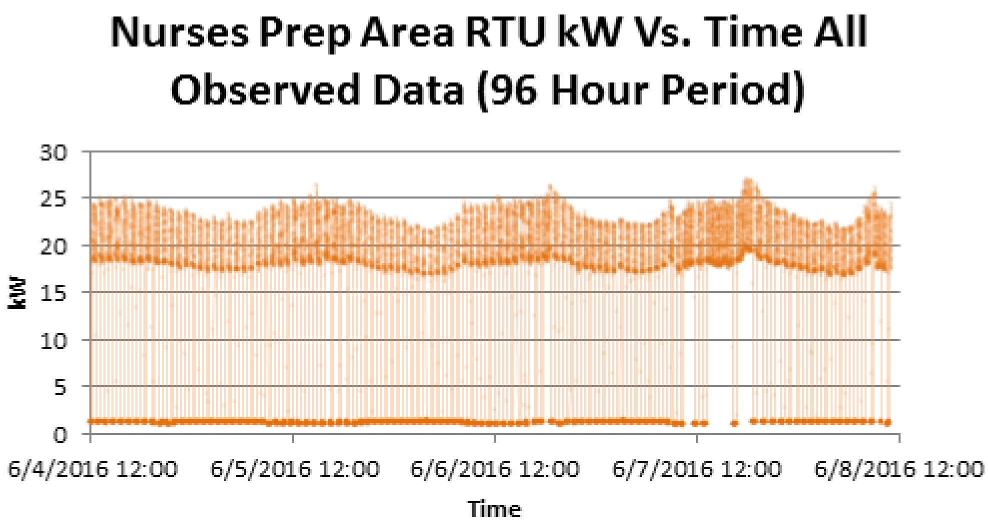
In addition to power measurements, loggers to detect supply, return, outside ambient temperature, and outside ambient relative humidity were also installed in close proximity to this RTU serving the X-Ray department. The results of those measurements are shown in the chart below.



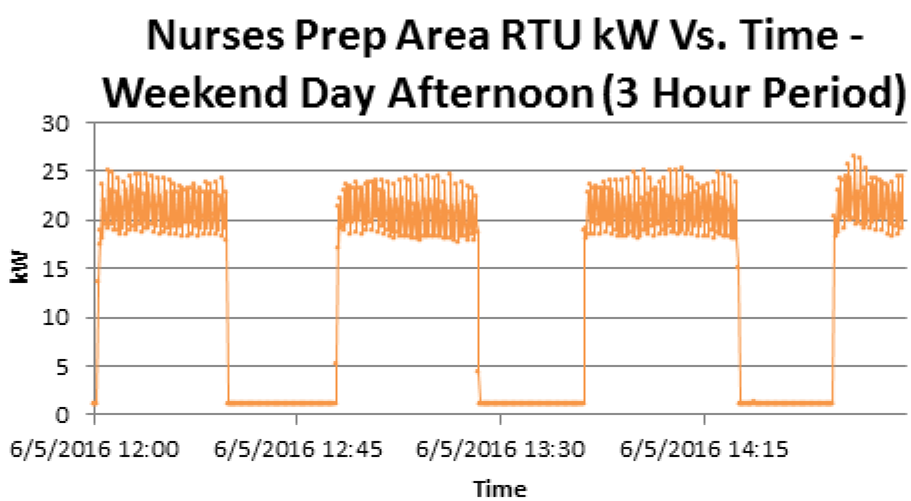
Below is the chart showing the outside air ambient relative humidity, and the supply air relative humidity. As can be seen in the chart, the outside air relative humidity stayed relatively constant at more than 90% for much of the measurement period, while the supply air relative humidity vacillated typically between 70 and 75%.



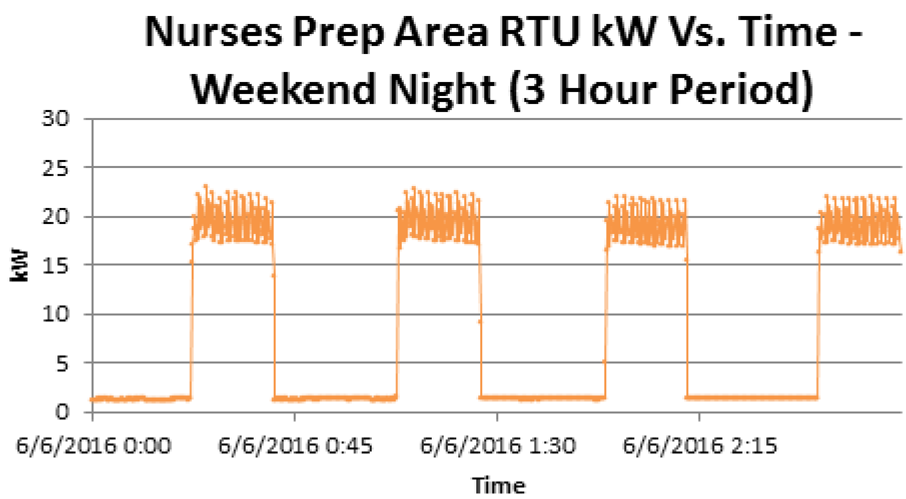
In addition to measurements taken on the RTU serving the X-Ray department, power measurements were also taken on the area serving the nurses preparation area. The nurses prep area is currently a lightly used area by the hospital, sometimes used for meetings. This may change as the two adjacent operating theatres are opened for use.   Below are the results of the logging data on his nurses prep area, and as can be seen, the unit cycles on and off during much of its operation, somewhat independent if it is during weekend or weekday operation, although a closer look will show that the amount of time it cycles off for does depend somewhat on whether it is a weekend during the day, during the night, or during a weekday in the early afternoon.



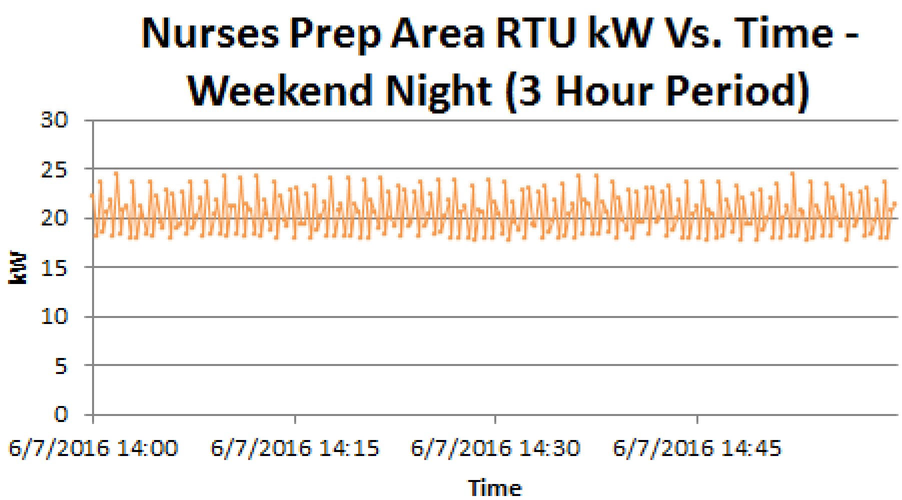
The chart below shows a closer look at the nurses prep area RTU energy use during the afternoon on a weekend, and shows that the unit cycles on for about 30 minutes, and cycles off for about 25 minutes.



This next chart below shows how the RTU was found to operate during a weekend evening period. It shows that the unit turned on for about 16 minutes, and shut down for about 28 minutes.



This final chart shows a period of time during a weekday afternoon when the unit did not cycle at all, which does not appear to be typical for this unit.



Results:

The two 25 ton outdoor units which were monitored are about (7) years old, and both serve areas that are used somewhat intermittently. The X-Ray department is open during normal business hours Monday-Friday, and the outdoor unit serving that area appears to be cycling off when it is not being used. One thing that could be investigated is whether or not it would be possible to widen the temperature set-point dead band during unoccupied times, so that the RTU could stay off for a larger percentage of the time (or possibly 100% of the time), during periods when that area is unoccupied. Similarly, one thing that could be investigated for the RTU serving the nurse's prep area is whether or not it would be possible to shut this unit off for longer periods of time, or completely, when the area is not being used.

	Nominal Tonnage	Hours/Year	Average kW	Annual kWh	Annual Operating Cost
X-Ray Department RTU Energy Use	23.4	8760	18	157,680	$39,420
Nurse's Prep Area RTU Energy Use	23.4	4,724	20	95,533	$23,833

Recommendations

DNV GL suggests the following measures:

9. Proper spacing behind condensing units

Outdoor condensing units appear to be installed without proper clearance requirements behind units. Clearance behind air-cooled condensing units is critical for both space comfort and cooling system efficiency because the air used to reject heat is pulled from behind the condensing units. Current spacing between walls and condensing units hinders airflow, resulting in reduced cooling capacity and reduced coefficient of performance (COP.)

It is recommended that the contractor measure current condensing unit spacing and increase spacing to one inch greater than manufacturers minimum clearance requirements in order to ensure condensing units are meeting design requirements. In the event that the air conditioning system is being replaced, ensure new condensing units are installed per the manufacturer's specifications.

10. Replace split systems with high efficiency, inverter-driven units

It is recommended that a high-efficiency inverter system should replace the older split systems as they are approaching their end of useful life. Additionally, new units should be specified to contain copper fins with protective coating against high humidity to delay deterioration. Maintenance cost of the higher efficiency units should be similar to a Direct Expansion (DX) unitary system where consistent preventive maintenance to change filters and clean coil are recommended.

11. VFD on supply and return fans

Variable Frequency Drive (VFD) is a controller that provides adjustable speeds for an electric AC motor by varying the voltage and frequency. Installment of a VFD on fans would leads to significant savings at part load due to the nature of fan laws. For instance, just by reducing the fan speed by 20% can lead to up to 42% of fan energy savings. Furthermore, additional savings also result from reducing the need for reheating from overcooling, deepening energy savings and enhancing precision in occupancy comfort control.

Installation of VFD on supply and return fans is recommended. Typically to control the fan speed, additional sensors are installed along the duct and calibrated to adjust the fan speed depend on the air flow demand. Alternatively, the fan speed can be pre-programmed to meet air flow requirement in cooling or heating modes for smaller units. A control interface board that matches fan speed to each equipment air flow requirement is required unless the control of the VFD is integrated and controlled by the Building Automation System.

12. VFD installation on kitchen Fans

A Variable Frequency Drive (VFD) is a controller that provides adjustable speeds for an electric AC motor by varying the voltage and frequency. Adding the VFD on exhaust fan will vary fan speed to vary as needed when there is smoke or fumes from the kitchen to meet the required ventilation rates.

Installing a demand control controlled ventilation system to operate the exhaust fan is recommended. This system would include the VFD to control the exhaust fan motor, a digital controller, temperature probe, and smoke probe in the cooking hood to control the exhaust fan. Existing exhaust fan motor may need to be replaced with inverter duty motor. More data is required for kitchen fan energy use. We recommend further investigation of this measure.

Table 31. Mechanical and Electrical Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Proper Spacing Behind Condenser Units	Saving is based on improved unit efficiency.	15,862	$13,350	3.4 years
Split Units Replacement	Saving is based on improved unit efficiency.	8,541	$11,968	5.6 years
VFD on supply and return fans	Saving is based on the reduced power demand at lower fan speeds.	70,993	$24,000	1.4 years

4.5.3 Lighting

Existing conditions

Lighting fixtures for the hospital were typically T12 or T8 fluorescent tubes with no reflectors or diffusers, causing inefficient and poor lighting. There is an ongoing phase out of T12 ballast technology by the maintenance team.

Typical Interior Fixtures

Most spaces in the building are not adequately lit with a illuminance range of 12 to 20 footcandles (FC) for the patient and administration areas. In the operating rooms and the examination areas an illuminance of 32 FC was recorded however; these spaces were not occupied at the time so not all fixtures were turned on. The Illuminating Engineering Society of North America (IESNA) Lighting Handbook Reference & Application recommends an illuminance of 28 FC for general ward lighting, 46 FC for simple examination areas and 93 FC for examination and treatment.

For the exterior hallways, mostly fluorescent tubes were installed. Magnetic induction, fluorescent fixtures were evident for the parking lot lighting. These lamps have similar performance to LED in terms of efficiency.

Typical Exterior Fixtures

Recommendations

DNV GL suggests the following measures:

13. Full LED retrofit

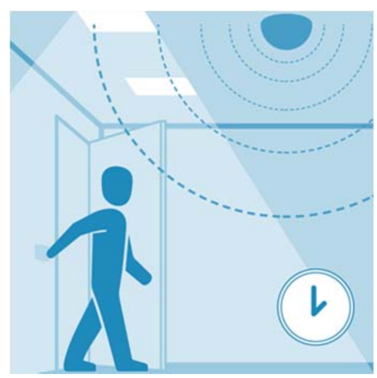
LED retrofits are one of the most beneficial and cost effective energy savings practices available. A typical 2-lamp T12 linear fluorescent bulb with a magnetic ballast uses up to 94 Watts. An equivalent LED tube fixture (no ballast needed) can produce the same lighting levels with a single tube is rated at only 18W.

LED fixtures provide equivalent lighting levels and better light quality in comparison to fluorescent fixtures while achieving 30%+ in energy savings. The average life of LED tube lamps is typically 5 times as long as a fluorescent light, resulting in higher net present value long-term. There is also no longer a need to replace ballasts, further reducing maintenance and materials costs.

Many LEDs support lighting control capabilities such as full dimming and directional illuminance that allow custom adjustments to achieve preferred visual comforts and ensure adequate distributed light levels exactly where it is needed. Unlike fluorescents, LEDs contain no mercury, making them safe for the environment and resulting less additional recycling cost.

It is recommended to replace all existing fluorescent fixtures to dimmable LED fixtures with an LED lighting retrofit kit. Alternatively, simply installing LED tubes with a ballast bypass into the existing fixture can be more cost-effective with a simple wiring change. T12 fixtures already have a non-shunted rapid start lamp holder, and T8 fixtures need a replacement lamp holder for use with the LED tube.

14. Lighting controls



A recommended improvement is to install occupancy sensors to lighting for timed shutoff in non-continuously occupied areas.

Due to the prevalence of natural light, should LED’s be installed, daylighting photocells can be tied into the lighting controls. These controls measure the ambient light levels to appropriately match the artificial lighting with the natural light present in the space. This “daylight harvesting” technique provides energy savings, allows for the automatic control of lights, and has the additional benefit of providing appropriate task lighting for the students.

Utilizing an Integrated Room Control (IRC) combines these technologies, and meets ASHRAE 90.1 requirements of lighting by combining receptacle control, occupancy sensing, space control, lighting control, and automatic shutoff.

Table 32. Lighting Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Fluorescent to LED Fixture Retrofit	Saving is derived from the lower power requirement (wattage per fixture) of LED fixtures.	44,601	$18,049	1.6 years
Exterior Light Retrofit to LED	Savings are derived from the lower power requirement (wattage per fixture) of LED fixtures.	11,248	$1,246	< 1 year

4.5.4 Water Consumption

Existing conditions

Falmouth hospital is located on the coast so fresh water is available in isolated areas where will pumping plans are controlling saltwater intrusion. The hospital has 10 x 500 gallon tanks on site for rainwater collection and storage.

Medical facility and laboratory water use typically ranges from 250 to 800 gallons per bed due to a number of medical water-using processes:

- sterilizers and central sterile operations
- water-cooled laboratory and therapeutic equipment
- equipment scrubbers
- X-ray equipment and film developers
- water-treatment systems for kidney dialysis and laboratory water
- vacuum systems
- medical air and compressor equipment
- therapeutic baths and treatment.

Rainwater Collection System

The kitchen, although relatively small for hospital standards, uses hot water to assist with cooking. The kitchen is able to provide 240 meals per day.

Kitchen Operations

Recommendations

DNV GL suggests the following measures:

15. Rainwater catchment system

The typical site weather pattern reveals that precipitation occurs for approximately 25% of the year, presenting an opportunity to collect the water independently on site. There are several methods to collect rain water such as rooftop capture to rain barrels, collection from fog through nets, or using a reservoir. It is recommended that rain barrels be used to collect the rainwater from gutters and the roofs where the first flush occurs for the first 2 inches of rainwater. Typically, rainwater is used for irrigation and toilet flushing. However, we recommend additional proper filtration and treatment system is added to make the water potable and meet drinking water standards.

The total roof area for Falmouth is approximately 48,800 ft^2. The average maximum rainfall volume from roof capture is estimated to be 1.52 million gallons per year. Utilizing rainwater would significantly reduce the site water demand from the municipal supply and induce to substantial pump energy savings. In case of dry seasons where water resources are scarce and in case of natural disaster that hinder the municipal supply pipeline, the site would have the rain catchment system to provide some water resource.

16. Solar thermal water heaters

Hospitals have a high hot water load due to a number of medical water using processes. Significant reduction in fossil energy consumption can occur if a solar thermal system is installed to meet the hospital's hot water demand. The hospital's hot water consumption was unable to be obtained and therefore calculations on the solar thermal savings could not be performed at this time. It is recommended that the sizing of the solar thermal system is conducted once realistic data on hot water usage in the facility is obtained.

A typical solar water heating system consists of solar collectors, piping, and insulated water storage tanks. Heat is generated from incoming solar radiation energy transferred to water or glycol circulating through the panel and back to a storage tank. The heated fluid is either directly used, or a heat exchanger is used with potable water. The fluid can either be actively pumped, or use gravity and a density/pressure differential in a passive flow.

Glazed Flat Plate Collector with Storage

Evacuated Tube Collector with Storage

4.5.5 Process Systems

Existing conditions

The hospital employs multiple high-energy process systems for medical uses. Medical equipment requires reliable compressor and vacuum systems for highly sensitive applications. There was an Industrial USA air compressor system with 5 HP rating and 80 gallon tank located in the laundry on site.


The facility team at Falmouth were able to provide an inventory of process and medical equipment that summarized the high equipment loads in Falmouth hospital. (The full list has been provided in the Appendix of this document). This list has been summarized in the table below.

Table 33. Process Equipment Load Inventory

Area	Equipment	Quantity
Laundry	Matag Dryer	1
	Washer	1
	Compressor	1
Kitchen	Ovens	2
	Gas stoves	2
	Fryer	1
	Meat grinder	1
	Fridges	2
	Deep freezers	2
	Television (CRT)	1
Plant Room	Central vacuum system	1
	Central medical air System	1

Table 34. Medical Equipment Load Inventory		
Area	**Equipment**	**Quantity**
Dental Unit	Auto clave sterilizer	1
Operating Theater	Aneasthetic machine	2
	Electrosurgical machine	3
	Mechanical ventilator	1
	Evaporators	6
	Defibrillator	1
	Suction machine	1
New Operating Theater	Defibrillator	1
X-ray	X-ray unit	3
	Sound unit	1

The plug load in the hospital consists of desktop computers in the doctor and nurses office areas, microwaves and refrigerators in staff areas for individual use.

Recommendations

DNV GL suggests the following measures:

17. Plug Load Efficiency

Receptacle load (also referred to as plug load) is an unregulated load in terms of building energy code requirements. One key step in reducing receptacle energy use is to institutionalize measures through procurement decisions and policy programs (refer to ENERGY STAR® for guidance). Policies must be improved as needed to stay current with technologies.

A key step in any plug load reduction program is to reduce energy use during non-business hours, as it is generally wasted. In the case of receptacle load for a hospital, there are many areas such as the administration, outpatient offices and nurses stations where computers are left unoccupied for long periods of time. Employing power strips that can be switched off in times of no usage could reduce the 'standby mode' energy consumption.

There should be ENERGY STAR® appliances installed for kitchen and break rooms to further reduce electrical consumption in these spaces.

4.5.6 Smart Building Controls

Existing conditions

There are no existing lighting controls installed currently in the hospital but the building could definitely benefit from motion sensor controls for most transition and sporadically occupied spaces in the building such as corridors, storage rooms, conference rooms, nurse and staff rooms, examination/treatment rooms, medical and restrooms.

Recommendations

DNV GL suggests the following measures:

18. Occupancy Sensors for Interior Lightings

Occupancy sensors allow lights to turn off when areas become unoccupied. Occupancy sensor can be programmed to be vacancy sensor where the lights turn off after periods of no occupancy, but require the light to be manually turned back on rather than automatically enabled. Furthermore, if occupancy sensors are integrated into the building automation system, the zone temperature set points can change to unoccupied mode, reducing the cooling power when it is not needed and leading to significant energy savings approximately up to 5%.

It is recommended that occupancy sensors are installed in Falmouth hospital.

19. Submetering

There are multiple buildings on this campus that are used on inconsistent schedules and with dissimilar equipment. While there are no direct savings associated with metering, the availability of submeters empowers the facility manager to review trends and consumption, and react to deviations.

The installation of submeters would allow the facility managers to track the energy use of the individual activities more closely and to bill facility rentals more accurately.

Table 35. Smart Building Controls Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Cost (USD)	Payback (Years)
Occupancy Sensor for Interior Lights	Saving is derived from the discounted diversity factor when occupancy sensor is installed.	19,932	$8,527	1.7 years

4.5.7 Renewable Energy Generation

Existing conditions

There are currently no renewable energy systems in place on the campus. There are a large number of flat, concrete roofs with very little shading, and peak energy use is during daytime hours.

Existing Conditions

There are currently no renewable energy systems in place on the campus. There are a large number of flat, concrete roofs with very little shading, and peak energy use is during daytime hours which are ideal for solar and hot water generation.

Recommendations

2. Solar Photovoltaic System

A solar analysis was performed for Falmouth Hospital to illustrate the potential solar opportunity at the site.

The following assumptions were made regarding roof areas:

- 80% of flat roof area was assumed to be solar ready (20% unavailable for mechanical equipment, structural and misc. equipment on roof)
- 75% of pitched roof area was assumed to be solar ready (25% unavailable for mechanical equipment, structural and misc. equipment on roof)
-

Table 36. System Installation Criteria

Module Type	Crystalline Silicon
Array Type	Fixed (open rack)
System Losses (%)	14
Tilt (deg)	20
Azimuth (deg)	Varies with roof orientation
Roof Area Availability	80% (flat roof) 75% (pitched roof)

The analysis was performed using National Renewable Energy Laboratory (NREL)'s PVWatts® Calculator. This web application estimates the electricity production of a grid-connected roof based on square footage available. The location of the hospital site, basic design parameters such as azimuth of roof and tilt of panel and system economics were inputs for the tool. A cost per watt of $3.00 (NREL, 2015) was used for the capital cost of PV installation. A utility cost of $0.25/kWh was used as an average utility rate of electricity for the Jamaican region.

As of 2015, JPS no longer allows for a net billing or net metering strategy for commercial facilities. This drastically affects the amount of solar photovoltaics that can cost effectively be installed on a building. Since there is uncertainty around the future of net billing on the island, it is difficult to determine the most cost-effective size of the PV system. Three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 37. Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings	Simple Payback	ROI
Net Zero Energy	328 kW	$983,944	518,867 kWh	$121,670	8.1 years	12.4%
Maximize Onsite Opportunity	536 kW	$1,607,100	847,477 kWh	$198,727	8.1 years	12.4%
Load Matched System	123 kW	$368,640	194,396 kWh	$45,584	8.1 years	12.4%

The following map shows the roof areas considered in the solar analysis and the table shows the results of the solar feasibility study conducted for the site.

Map of Potential Solar Array Opportunities on Site

Table 38. Falmouth Hospital Renewable Potential							
Area	Azimuth	Collector Area (square meters)	Collector Area (square feet)	KWdc	Capital Cost (USD)	Annual Energy Generation (kWh)	Annual Cost Savings
A1	180	167	1,798	25.1	$75,300	42,198	$9,895
A2	0	167	1,798	25.1	$75,300	33,945	$7,960
B1	180	52	560	7.8	$23,400	13,113	$3,075
B2	0	52	560	7.8	$23,400	10,549	$2,474
C1	180	180	1,938	27.0	$81,000	45,392	$10,644
C2	0	180	1,938	27.0	$81,000	36,515	$8,563
D1	180	190	2,045	28.4	$85,200	47,746	$11,196
D2	0	190	2,045	28.4	$85,200	38,408	$9,006
E	180	965	10,387	144.8	$434,400	243,438	$57,084
F1	180	65	700	9.7	$29,100	16,308	$3,824
F2	0	71	764	10.6	$31,800	14,335	$3,361
F3	270	74	797	11.0	$33,000	16,788	$3,937
F4	90	74	797	11.0	$33,000	16,960	$3,977
F5	180	33	355	5.0	$15,000	8,406	$1,971
G1	180	77	829	11.5	$34,500	19,334	$4,534
G2	0	77	829	11.5	$34,500	15,553	$3,647
G3	270	130	1,399	19.5	$58,500	29,760	$6,979
G4	90	130	1,399	19.5	$58,500	30,065	$7,050
H1	180	456	4,908	68.4	$205,200	114,994	$26,965
H2	270	122	1,313	18.3	$54,900	27,929	$6,549
H3	90	122	1,313	18.3	$54,900	28,215	$6,616
TOTAL		**3,574**	**38,470**	**535.7**	**$1,607,100**	**849,951**	**$199,307**

Disclaimer: The production estimates that PVWatts® calculates do not account for many factors that are important in the design of a photovoltaic system. These calculations should not be used to help design a system, rather seek a qualified professional to make final design decisions using more detailed engineering design and financial analysis tools. (NREL, 2016.)

4.5.8 Miscellaneous Systems

The power factor of the hospital was measured to be 0.80. While this is a low reading, a power factor correction device is unlikely to reduce the facility demand substantially.

There is one backup generator on site that covers the full load for the hospital and is run every week as part of the maintenance schedule.

Backup generator on site

4.5.9 Training

Building automation allows us to turn old facilities into smart buildings. However, the smartest control system within a building is the brain of the people who use it daily. Training of facilities staff as well as nurses, doctors, janitors and administrative staff enables the energy efficiency measures implemented within the building to work correctly. Training can help us ensure that unnecessary lights are off, thermostats are set correctly, and the right people are notified in the event of system failure.

Recommendations

4. Maintenance Staff – 2-day post-retrofit initial training

When the project is complete, it is important that members of the maintenance staff are fully trained on any new building systems. Without this key final project close-out item, energy efficiency measures are destined to fail. This circumstance has been noted during our visits to some facilities in Jamaica.

We recommend the maintenance staff is trained by the contractor team after initial installation of all energy efficiency measures to ensure that the staff knows the operational requirements of all new or upgraded equipment. This should be written into the energy efficiency implementation contract.

Training shall include preventative maintenance training such as: recommended filter replacement cycle, oil change cycles, refrigerant testing, valve testing, cleaning of solar panels, and other preventative items specific to each energy efficiency measure.

5. Facility Mangers – Annual Energy Workshop with other Hospitals FMs

As facility managers test and implement new energy efficiency measures and training, it is important to share lessons learned among other hospital facility managers in the country. This provides an excellent opportunity for cross-learning and collaboration on a variety of issues. The annual workshop will enable a project that was successful at one hospital to be implemented by staff at other hospitals. We recommend holding the annual energy workshop in a rotating hospital in a major city each year. Meeting location should be determined based on whichever hospital has most recently received energy upgrades.

6. All Staff – Quarterly Energy Awareness Training

Facility managers are not the only occupants who determine building energy use. Any building occupant armed with knowledge about energy efficiency can help reduce on-site energy usage. Closing doors to air conditioned spaces, turning off lights, properly setting thermostats, and turning equipment off when not in use is the job of the building occupant and is critical to minimizing energy use. Karl Heusner Memorial Hospital in Belize has shown a successful. We recommend the facility staff provide a quarterly energy awareness training to all staff to teach doctors, nurses, and other employees how equipment works and how to minimize energy use in their daily lives. This will have the added benefit of helping them to save energy use at home, reducing their monthly costs as well as their carbon footprint.

4.6 RECOMMENDATION SUMMARY

Falmouth Hospital provides an excellent opportunity for energy savings and associated carbon reduction. These savings will result in a decrease in oil dependence for the island of Jamaica, a decrease in the annual energy bill for the GoJ, and will help increase in-country capacity for energy efficiency implementation. The table below outlines the energy efficiency recommendations for the project. We recommend that the GoJ take the following steps:

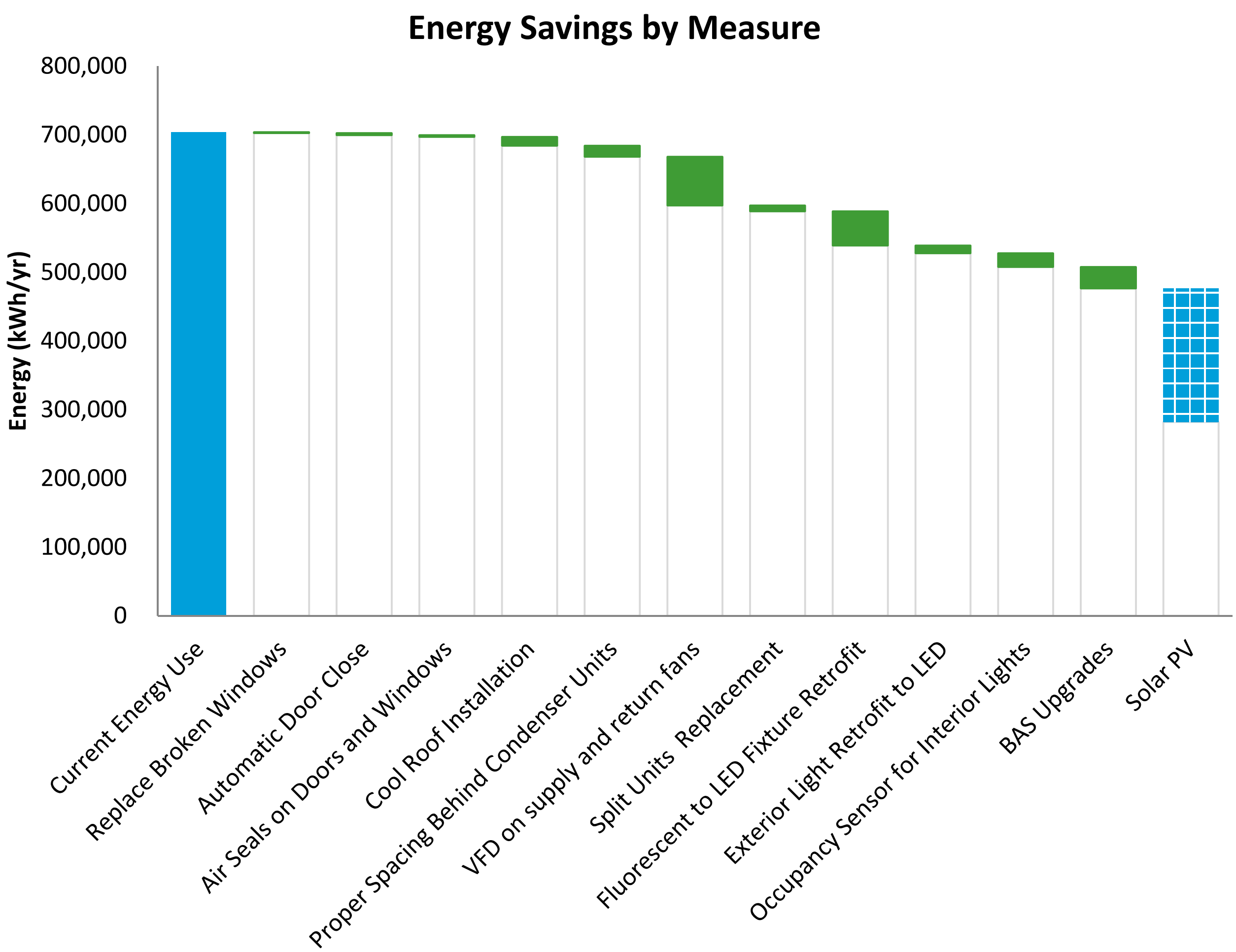
9. Perform an Investment Grade Audit of the facility to provide more in-depth analysis of building energy use as well as more accuracy for energy savings of each energy efficiency measure
10. Determine applicable funding and scope for the project
11. Draft Request for Proposal for energy efficiency implementation
12. Engage an Energy Services Company (ESCO) to install energy efficiency measures and distributed renewable energy

Based on the technical assessment performed, the following energy efficiency opportunities exist:

Table 39. Falmouth Key Recommendations Overview

Measure Description	Savings and Cost			Payback	
	Electricity Savings (kWh)	Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Replace Broken Windows	1,352	$337	$2,072	16.2%	6.2
Automatic Door Close	2,971	$740	$600	123.3%	< 1
Air Seals on Doors and Windows	2,437	$607	$2,470	24.6%	4.1
Cool Roof Installation	13,068	$3,254	$10,000	32.5%	3.1
Proper Spacing Behind Condenser Units	15,862	$3,950	$13,350	29.6%	3.4
VFD on supply and return fans	70,993	$17,680	$24,000	73.7%	1.4
Split Units Replacement	8,541	$2,127	$11,968	17.8%	5.6
Fluorescent to LED Fixture Retrofit	44,601	$11,107	$18,049	61.5%	1.6
Exterior Light Retrofit to LED	11,248	$2,801	$1,246	224.9%	< 1
Occupancy Sensor for Interior Lights	20,709	$5,157	$8,527	60.5%	1.7
BAS Upgrades	31,263	$7,786	$40,000	19.5%	5.1
Solar PV	194,396	$48,412	$368,640	13.1%	7.61
Total Savings (Recommended Measures)	417,440	$103,959	$500,923	49.8%	4.82
Total Savings (Without Renewable)	171,072	$42,604	$83,756	52.4%	1.97

Savings of non-renewable EEMs	24%
Annual GHG Savings (metric tons CO2)	266
15 year GHG Reduction (metric tons CO2)	3,989


Energy Savings by Measure
Energy (kWh/yr)
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Current Energy Use
Replace Broken Windows
Automatic Door Close
Air Seals on Doors and Windows
Cool Roof Installation
Proper Spacing Behind Condenser Units
VFD on supply and return fans
Split Units Replacement
Fluorescent to LED Fixture Retrofit
Exterior Light Retrofit to LED
Occupancy Sensor for Interior Lights
BAS Upgrades
Solar PV

Renewable Energy Recommendations

Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 40. Falmouth Hospital Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings	Simple Payback	ROI
Net Zero Energy	281 kW	$842,933	444,507 kWh	$104,234	8.1 years	12.4%
Maximize Onsite Opportunity	536 kW	$1,607,100	847,477 kWh	$198,727	8.1 years	12.4%
Load Matched System	123 kW	$368,640	194,396 kWh	$45,584	8.1 years	12.4%

5 MANDEVILLE HOSPITAL

An Investment Grade Audit (IGA) was performed by DNV GL Energy Engineers of government buildings in Jamaica. The half-day site visit of Mandeville Hospital was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation. The team included the facility managers, Ministry of Science, Energy and Technology (MSET), representatives from the utility Petroleum Corporation of Jamaica (PCJ), and the Ministry of Health.

The project is commissioned by the IDB and the goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. GoJ facilities use 12% of electricity consumed in Jamaica. Of that GoJ usage, 14.5% powers healthcare and educational facilities. The facilities visited in April represent a quarter of energy use of those sectors. The expected results of the project are:

- Reduced electricity consumption within government facilities
- Decreased oil imports through improved EE
- Reduced GHG emissions which can contribute to Jamaica's INDC commitment
- An increased capacity to promote and supervise electricity planning in Jamaica

Utility analysis shows the campus energy consumption has been fluctuating annually with operational intensity. Opportunities to lower energy consumption, identified as Energy Efficiency Measures (EEMs), are summarized in Table 1. Additionally, the renewable energy analysis indicates potential electric generation that would provide large savings, implying that there is a large potential for the facility to achieve net zero.

5.1 Site Visit Summary

On June 7, 2016, an Energy Conservation and Efficiency Team Technical Visit was conducted at Mandeville Hospital. It was attended by representatives from MSET, PCJ, Inter-American Development Bank (IDB), and Operations and Maintenance staff. The half-day site visit of the selected campus was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation.

An investment grade audit was conducted with appropriate personnel familiar with the physical condition and day-to-day operation of the facility and equipment. Through the facility profile established during the kickoff meeting, the following systems were identified for special consideration:

- Lighting Systems
- Mini-Split Air Conditioning Systems
- Air Handling Unit Fans
- Chilled Water System (Installed 3 years ago)
- Steam Plant (Laundry and autoclaves)
- Steam Distribution System
- Compressed Air Systems
- Kitchen Operations
- Refrigeration Systems
- Energy Management
- Rainwater collection and distribution (3 days reserve system in place, however, a water poor region)

- Non-functional Solar Thermal System
- Solar PV Potential
- Existing System Maintenance and Reliability

The following staff attended the site visit:

Table 41. Site Attendees List			
Date: 6/7/16			
Name	**Organization**	**Phone**	**Email**
Allwyn Miller	MPH		
Sheldon Henry	MPH		Sheldon.Henry@srha.gov.jm
Kevin Gallimore	PCJ	929-5380-9 ext. 341	Kevin.Gallimore@pcj.com
Kent Dahlquist	DNV GL	619-309-7441	kent.dahlquist@dnvgl.com
Joe St. John	DNV GL	781-418-5748	joseph.st.john@dnvgl.com

5.2 Key Recommendations

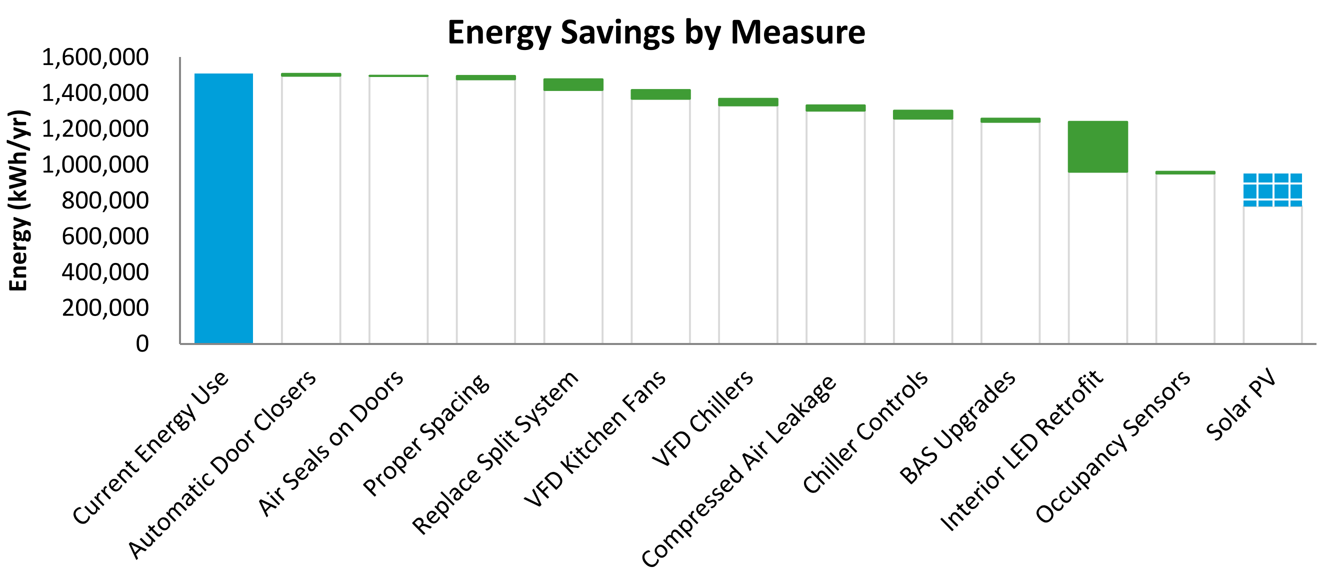
The following table outlines key recommendations for the project.

Table 42. Mandeville Hospital Key Recommendations Overview

Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Automatic Door Closers	11,027	$2,604	$2,980	87.4%	1.1
Air Seals on Doors	703	$166	$740	22.4%	4.5
Proper Spacing between Split Units	18,582	$4,389	$6,260	70.1%	1.4
Replace split systems with high efficiency, inverter-driven units	60,119	$14,199	$37,037	38.3%	2.6
VFD Installation on Kitchen Fans	48,864	$11,541	$15,516	74.4%	1.3
VFD Installation on Chiller Pumps	36,752	$8,680	$13,192	65.8%	1.5
Compressed Air Leakage	29,872	$7,055	$6,152	114.7%	< 1
Centralized Chiller Controls	44,303	$10,464	$30,000	34.9%	2.9
BAS Upgrades	17,954	$4,240	$50,000	8.5%	11.8
Fluorescent to LED Fixture Retrofit	278,493	$65,775	$31,297	210.2%	< 1
Occupancy Sensor for Interior Lights	10,181	$2,405	$6,395	37.6%	2.7
Exterior Light Retrofit to LED	22,531	$5,321	$880	604.7%	< 1
Solar PV	182,389	$43,077	$345,871	12.5%	8.0

Total Savings (Recommended Measures)	761,770	$179,916	$546,321	32.9%	3.0
Total Savings (Without Renewable)	579,381	$136,839	$200,449	68.3%	1.5

Savings of non-renewable EEMs	38%
Annual GHG Savings (metric tons CO2)	485
15 year GHG Reduction (metric tons CO2)	7,279

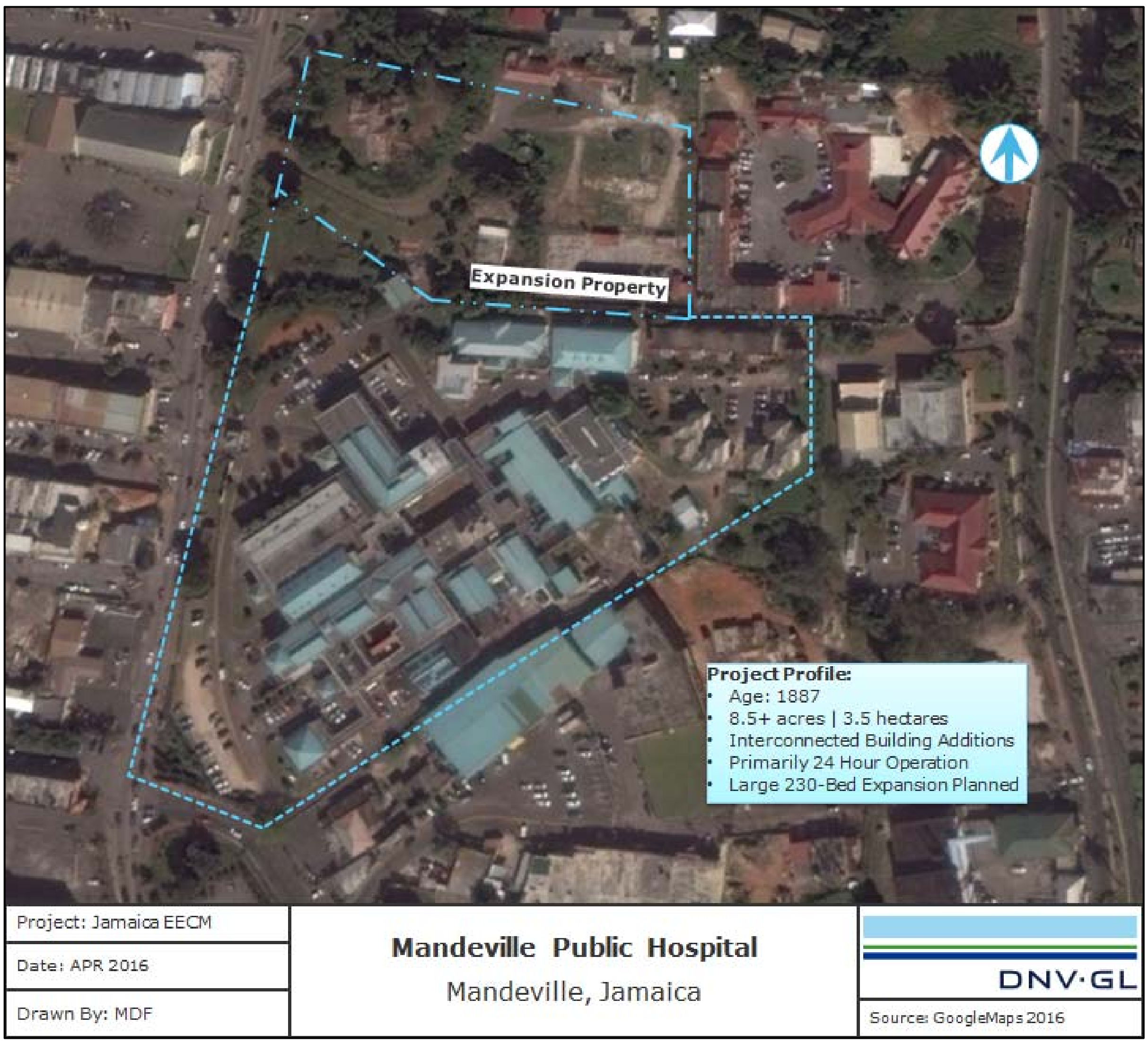


5.3 FACILITY OVERVIEW

Mandeville Regional Hospital is located on an inland plateau in the southern parish of Manchester. The hospital originally opened in 1887 and has expanded its footprint and services periodically. This 226-bed hospital is part of the Southern Regional Health Authority, and is approximately 160,000 square feet in size. The average bed occupancy during 2015 was 92%. It is a Type B Hospital, however an imminent expansion will further elevate its services to Type A supporting all final referral needs. The hospital has already procured neighboring property to the North, and an additional 230-bed facility is planned.

Maintenance is typically performed by the in-house team, comprised of multi-skilled technical staff. Contractors are used for all non-routine maintenance on typical 1-year service contracts.

Water is supplied through the National Water Commission (NWC) by pipeline to an on-site underground storage tank (130,000 gallons), and an extensive rainwater collection system associated with a large water tower (31,000 gallons).



Campus Aerial View

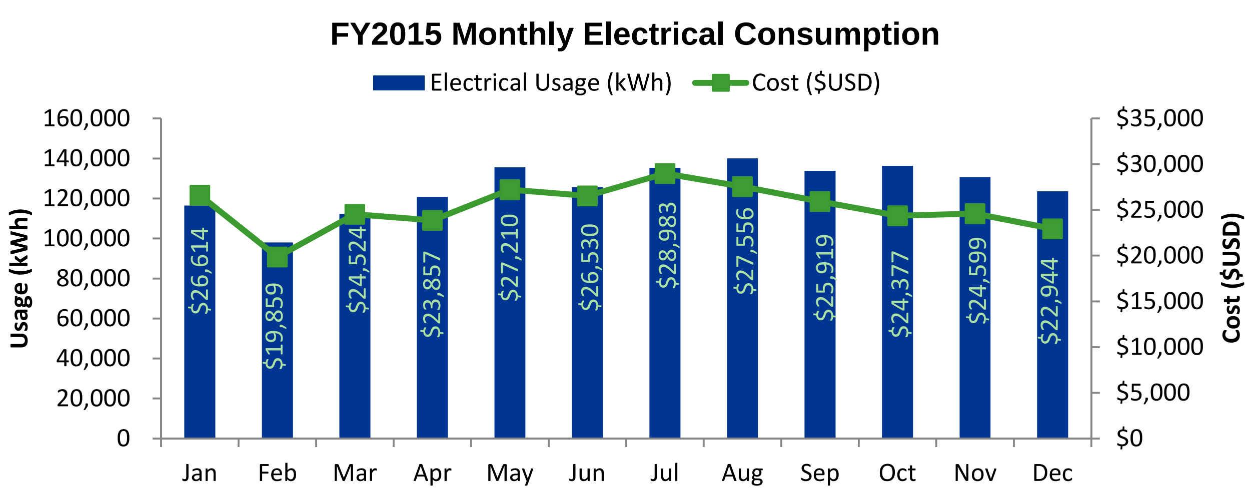
5.4 UTILITY ANALYSIS

Utility data was evaluated for 2010 through 2015. Based on the provided information, electricity is the primary fuel used, with diesel fuel only utilized for the emergency generator. Water utility and other fuel types were requested but were not made available for data analysis. The table below summarizes the annual utility profile.

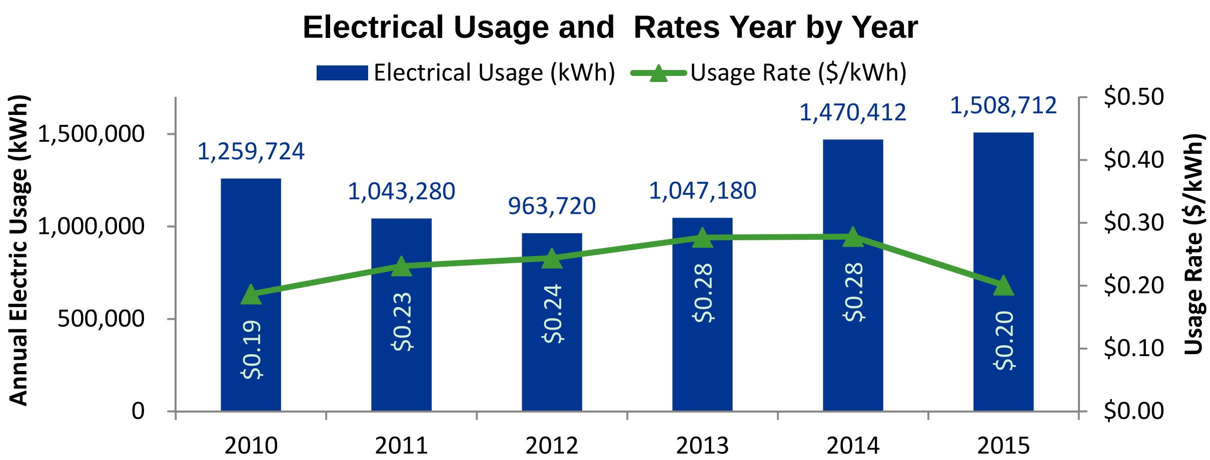
Annual Utility Profile Summary							
Utility	Usage*	Unit	Cost*	Avg Unit Cost ($USD/kWh)	Energy (MMBTU)	Cost %	Energy %
Electricity	1,508,712	kWh	$302,974	$0.24	5,148	100%	100%
Natural Gas	#N/A	Therm	$0	#N/A	#N/A	0%	#N/A
Water	#N/A	Gallons	$0	#N/A	#N/A	0%	#N/A
Annual Sum			$302,974		5,148		
Per Floor Area			$1.89		0.032		
Floor Area=		160,000	square feet		1 MMBTU =	1,000,000	Btu
Correctional Power Factor =		0.8			1 kWh =	3412	Btu
*From 2015 utility bills					1 Natural Gas Therm =	100,000	Btu

Electrical Usage

Electricity is supplied by Jamaica Public Service Company. The facility is served by two (2) active electrical meters. The facility annual electric consumption for year 2015 is approximately 1,508,712 kWh where the annual peak demand is 192kVa. As shown in the figure below, monthly electrical energy consumption stays relatively consistent with slight seasonable variation to reflect the typical weather pattern in Jamaica where the hottest months are from July to September. The small variance in electrical consumption between hotter months and other months is expected for a hospital that has comfort cooling. There is currently no renewable energy used on site at this time.

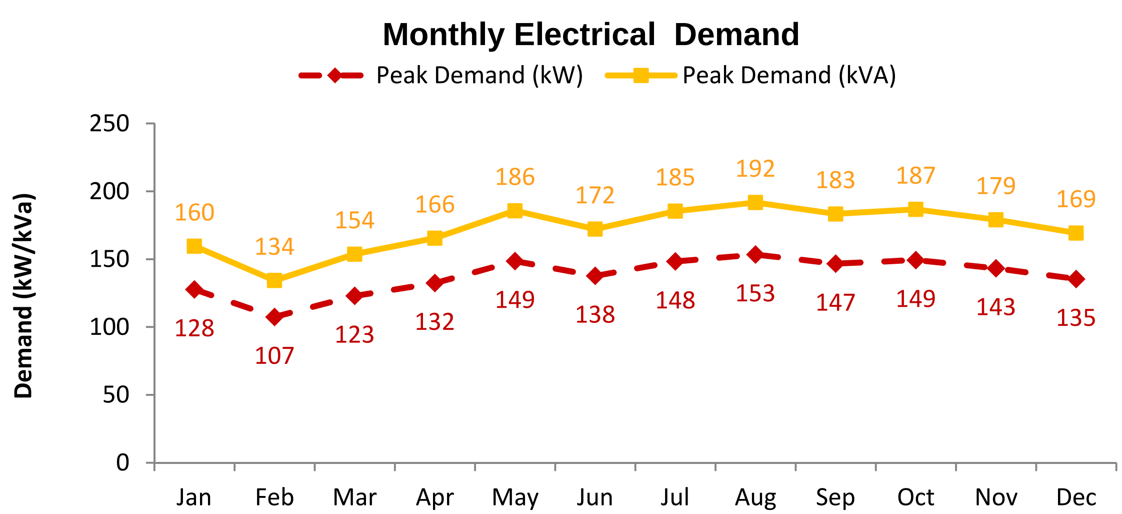


Year-by-year consumption trend shows that there was an increase in energy usage from 2013 to 2014 as shown in the figure below. On the other hand, there was a decrease from 2014 to 2015 that may be a result of space changes. The average utility rate from 2010 to 2015 is $0.24 USD per kWh. To account for the potential rate fluctuation in the future, this average utility rate is used to project energy saving costs.



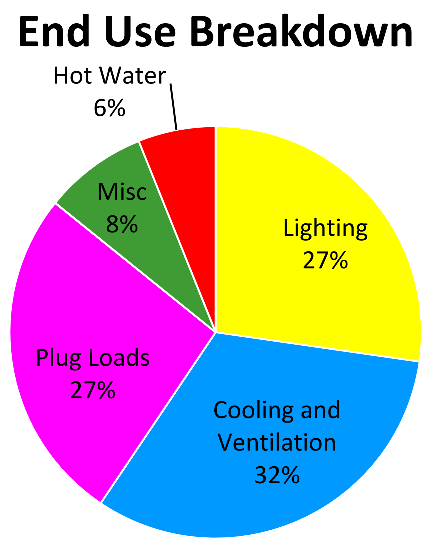
Electrical Demand

The figure below shows the Peak Demand in kVA (the demand charged by the utilities) and the Peak Demand in kW (actual demand of site). The Peak Demand in kW is estimated based on the power factor of 0.8, measured on site for year 2016, which is lower than U.S. standards of 0.9 or higher. The peak demand (in kVa) was not available. Hence, the estimated peak demand is shown below by taking the monthly electrical usage and dividing by the typical monthly operation hours. Typical causes of low power factor include lowly loaded induction motors and lack of capacitors in transformers.



Load Profile Evaluation

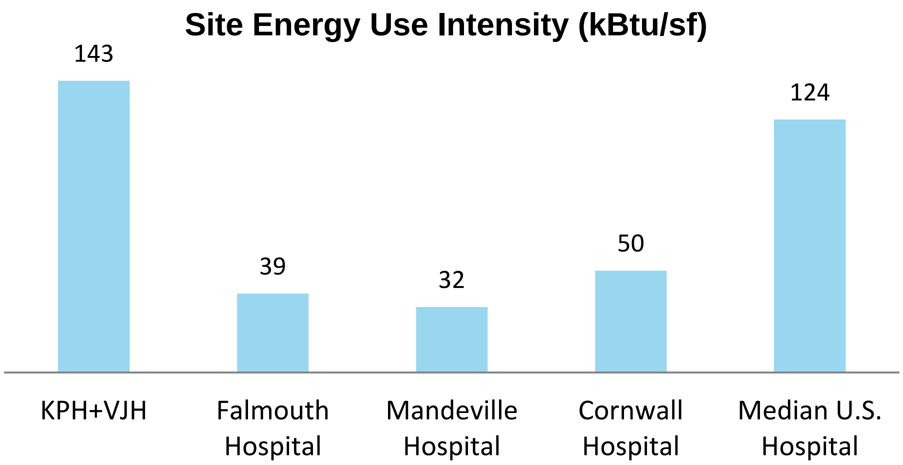
The building electrical use profile is divided into different end-use categories shown on the pie chart below. The annual end use breakdown will vary based on occupancy, operational changes, equipment maintenance, and occupant behavior. More accuracy can be garnered by adding sub-metering systems throughout the facility, which is recommended should a major electrical systems overhaul be undertaken.



Benchmarking

Energy use benchmarking is the process of comparing the energy use of a building with other similar structures. It is a critical evaluation for organizations with a large building portfolio to identify building performance and the factors that drive their energy use. The U.S. Department of Energy EnergySTAR program has developed an energy performance rating for commercial and institutional facilities.

The median hospital energy usage intensity (EUI) from EnergySTAR is 124 kBtu/sf annually. Mandeville hospital uses 32 kBtu/sf annually, which is approximately 74% below the median U.S. hospital. The site has a lower EUI in comparison to the median U.S. hospital EUI because the facility utilizes natural ventilation, has less intensive equipment, and does not have a heavy heating load.



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5.5 SAVINGS OPPORTUNITIES AND RECOMMENDATIONS

5.5.1 Building Envelope

Existing conditions

Site Context and Orientation

The campus is a combination of interconnected buildings of 1-3 floors in height of concrete construction, and is primarily a 24/7 facility. The campus is approximately 2015 feet above sea level on the top of a hill. The facility is designed with a Southwest-facing orientation, with administrative support buildings south in orientation.

General Building Description

The campus has progressively expanded over its 125+ year history, and thus construction methods and architecture varies. There is an atrium three stories high in the hospital's main building that acts as the central circulation point for the facility. On the ground floor there is an 8-foot wide open hallway that wraps around the perimeter of the main building. There are shaded walkways connecting each of the buildings.

Main Entrance

Extensive maintenance and repairs have been completed throughout, and a number of recent retrofits are evident.

Wall and Roof Elements

The typical exterior walls throughout the campus are concrete, have structural shading devices, and were designed for natural ventilation. This is preferable for energy efficient, resilient facilities. The material is extremely durable, fire-resistant, and able to withstand severe weather conditions. The mass of the concrete could insulate the interior and have the ability to limit air leakage, but limited areas of the hospital appear to be sealed. There is no insulation on the concrete walls. On the interior, wood-framed walls are commonly used to separate spaces.


Exterior Walkway

Rooftop Examples: Mix of metal and asphalt

Rooftops are mostly a combination of concrete construction with asphalt and metal roofing panels. Some of the flat roofs had membranes installed to limit leakage. The temperatures measured on each roof type varied greatly, with the asphalt reaching 128˚F, and the metal roofs at 140˚F. (The ambient temperature was recorded at 88˚F). Maintenance staff report that many roofs require some ongoing maintenance as leaking membranes are a regular occurrence. If a roof replacement is imminent, this is may be an opportunity to improve insulation and install daylighting at a low incremental cost.

The building structure is classified as 'moderately leaky' as there is an average level of leakage evident through unsealed windows, doors and envelope. Air sealing the building envelope is one of the most critical features of an energy efficiency building. Detected leaky areas need to be sealed in order to mitigate infiltration as well as potential leakage of the cool, conditioned air supply in places where there is an AC system installed. Freshly cooled air immediately escapes the room via the adjacent open window, which results in a room that remains hot even while the air conditioner is running full bore, burning energy, and decreasing the equipment's useful life.

Windows and Openings

The windows for the buildings are a mixture of glass tilt-out and awning type. The eastern windows have permanent awning shading that has a horizontal projection of 1 foot. There is a 2-foot roof overhang. No other shading devices were observed on site.

Exterior doors are uninsulated, and there are no vestibules used for entrances.

Air sealing the building envelope is one of the most critical features of an energy efficient building. The escape of freshly cooled air via open windows or doors results in a room that remains hot even while the air conditioner is running under full load, burning energy, and decreasing the equipment's useful life. Detected leaky areas need to be sealed in order to mitigate infiltration as well as potential leakage of the cool, conditioned air supply in places where there is an AC system installed.

Typical Windows

Most of the hallways are open-air and unconditioned, and multiple courtyards allow for natural lighting to reach most areas of the buildings. Natural light and ventilation is important to both human health and staff productivity. Replacing large artificial lighting and conditioning systems with access to natural elements has proved to be beneficial for the health, productivity, and safety of building occupants, as well as economically beneficial from use reduction. Natural light helps maintain good health and can alieve some medical ailments. The pleasant environment created by natural light also decreases stress levels for patients and staff.

Recommendations

DNV GL suggests the following measures:

1. **Automatic door closers**

   Doors were found to be open or improperly sealed, limiting the effectiveness of the cooling systems. The most cost effective strategy to automatically close the door is using a surface-mounted regular arm door closer attached behind the door frame where a spring mechanism is used to close the door. This ensures pressurization and limits infiltration, reducing the cooling power requirement.

2. **Air Seals on Doors / Windows**

   Improperly sealed doors and windows often are a significant source for leakage of conditioned air, causing excess energy use. A 0.125-inch gap around a typical entryway door is the equivalent of drilling a 5.5-inch-diameter hole through an outside wall. A weather seal system includes weather stripping, which covers the sides and top of the door, and a sweep, which fills the space between the threshold and the door bottom. Foam, felt, plastic, or tubular silicone weather stripping products are designed for this purpose.

Table 43. Envelope Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Air Seals on Doors	Saving is based on improved R-value.	703	$740	4.5 years
Automatic Door Closers	Saving is based on infiltration due to temperature difference.	11,027	$2,980	1.1 years

5.5.2 Mechanical and Electrical Systems

Existing conditions

Mandeville hospital's mechanical system is a combination of mini-split air conditioning units and a central cooling system. A new central chiller was installed in 2012 to support the large AHUs distributed throughout the facility. Mini-splits are used to supplement this cooling.

There are three Trane air-cooled scroll packaged chillers (80 ton) on site, although one was out of commission at the time of the site visit. The chillers were supplying chilled water at 44F and returning at 49F. There are three constant volume, 5 HP chilled water supply pumps (one per chiller). There are 13 air handling units (AHUs) throughout the facility that are scheduled to be replaced. The typical AHU has a 7.5HP CV fan.

Chilled Water System
<u>Components</u>

- 3 x Air Cooled Chillers (Trane CGAM 80 Ton)
- 3 x CV Supply Pumps (10HP)
- 13 x AHUs (7.5 HP)
- 1 x External Compressor

There are approximately 69 mini-split AC installed in wards, offices, and treatment rooms. There are a variety of manufacturers and unit capacities. Most of the units use basic remote-control systems with no temporal programming capabilities. Many of the condensing units have not been installed with manufacturer recommended spacing, limiting their effectiveness.

These systems require a significant amount of committed time for maintenance staff, and a substantial number of the units were out of service. It was repeatedly observed that staff were requesting repairs to their cooling systems throughout the walkthrough.

Mini-Split AC Units

A central steam plant is in place with two boilers, with its distribution network supporting the laundry and sterilization facilities. Surgical and delivery facilities require large amounts of sterile equipment, and use steam autoclaves fed by the facilities' boiler system. The live steam injected into the pressure chamber is held for a period of time to ensure sterilization, with fifteen to twenty loads sterilized per day.

Steam System
2 x Boilers
3 x Autoclaves
2 x Washer-Extractors
Steam Irons

There are four hood exhaust fans (ranging from 2.5-5 HP CV) in the kitchen operated continuously from 7am – 8pm daily. No make-up air is provided to the kitchen spaces.

Four Kitchen Exhaust Fans (CV)

Two backup generators (632kW) were installed for the hospital in 2002. They are completely automatic, and together they are able to power the whole hospital in case of power outage.

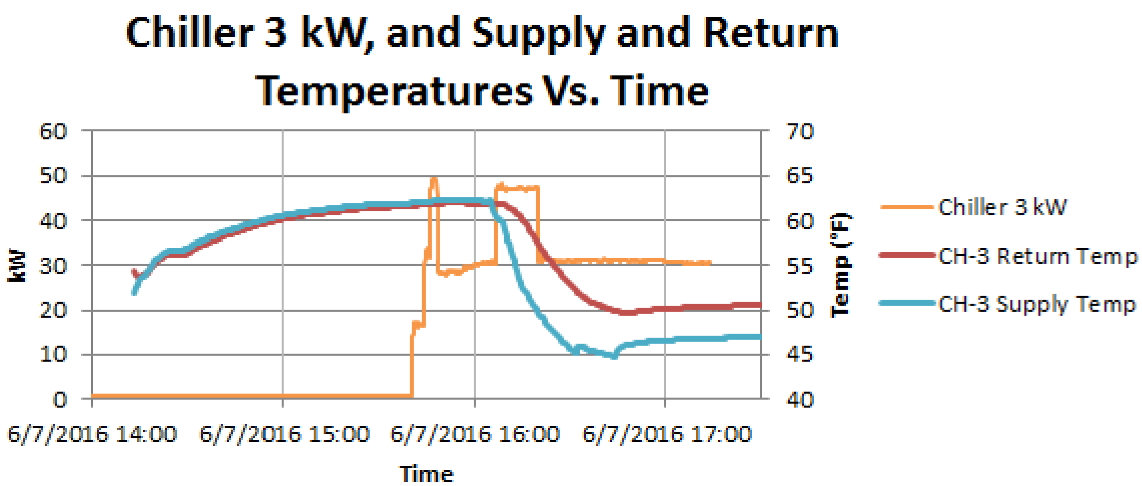
Backup Generators (Diesel)

Monitoring Data

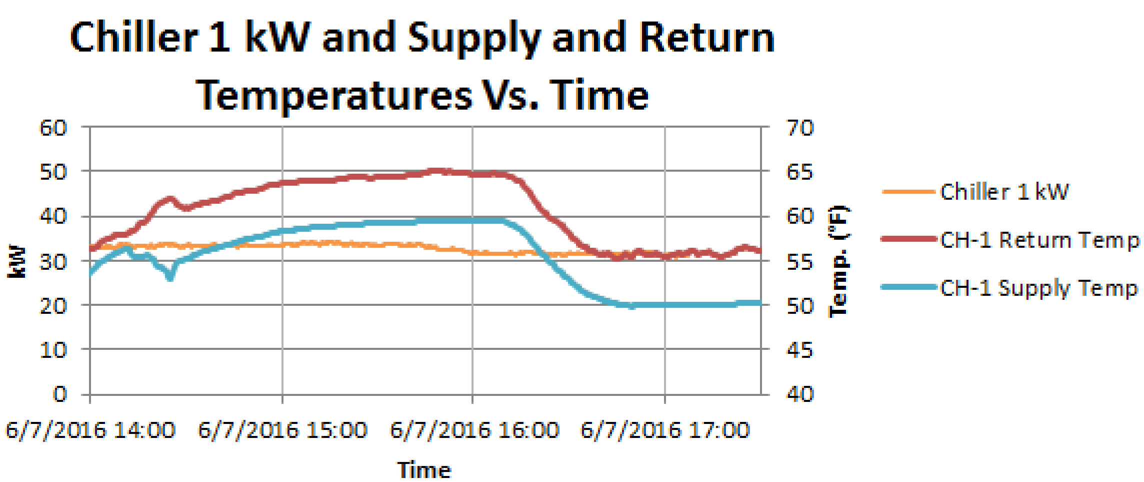
Air-cooled Chiller

There are (3) 80-ton air cooled chillers at Mandeville hospital which are estimated to be three years old (2013 vintage). One of the three chillers was a back-up chiller, and the other two chillers were on. Power loggers and temperature loggers on the supply and return pipes were installed on Chiller 1 and Chiller 3 for serval hours during the site visit. The chart below shows the results of that metering period.

The chart below shows that Chiller 3 was off for the first hour and a half of logging, producing no temperature differential between the supply and return piping. The chiller turned on around 3:45 PM, and the temperature differential between the supply and return lines of about 5° Fahrenheit became apparent shortly afterwards.



The chart below shows that Chiller 1 was on and running at 30 kW for the entire three and a half hour monitoring period, and it shows how the chilled water supply temperature drops from 60°F to 50°F around the same time that Chiller 3 (above) comes on.



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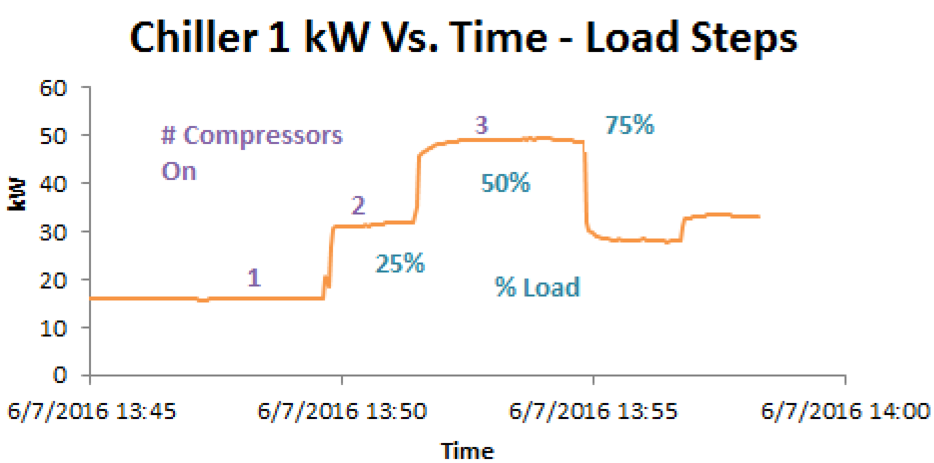
The return temperature stays consistent at about 5 degrees above the supply temperature. This 5 degree delta T is low compared to most chilled water plant designs with 10 degree delta T, and there are actions that can be taken to address it on the system side to improve performance. Improving low delta-t syndrome can save considerable energy, by limiting the amount of time that more compressors than necessary on this chiller have to be running simultaneously to maintain load. Low delta-t syndrome can be caused by dirty or improperly sized coils, or by malfunctioning control valves.

The chart below shows a close up of the measured Chiller 1 kW, and demonstrates the chiller's kW draw as three of the four total compressors come on one by one. During the day that chiller 1 and chiller 3 were logged, most of the time each chiller was on was running at 50% load, with 2 of the 4 compressors on. They were drawing about 30 kW at this load, and producing an estimated 29 tons of cooling capacity each at this kW draw.



Results:

	Nominal Tonnage	Hours/Year	Average kW	Annual kWh	Annual Operating Cost
Current Energy Use (3) 80 Ton Air Cooled Chillers	3 x (80)	1)8760 2)4380 3)0	1) 30 2) 30 3)0	394,200	$98,550

Recommendations

DNV GL suggests the following measures:

3. **Replace split systems with high efficiency, inverter-driven units**

It is recommended that a high-efficiency inverter system should replace the older split systems as they are approaching their end of useful life. Maintenance cost of the higher efficiency units should be similar to a Direct Expansion (DX) unitary system where consistent preventive maintenance to change filters and clean coil are recommended.

4. **Proper spacing behind condensing units**

Outdoor condensing units appear to be installed without proper clearance requirements behind units. Clearance behind air-cooled condensing units is critical for both space comfort and cooling system efficiency because the air used to reject heat is pulled from behind the condensing units. Current spacing between walls and condensing units hinders airflow, resulting in reduced cooling capacity and reduced coefficient of performance (COP.)

It is recommended that the contractor measure current condensing unit spacing and increase spacing to one inch greater than manufacturers minimum clearance requirements in order to ensure condensing units are meeting design requirements. In the event that the air conditioning system is being replaced, ensure new condensing units are installed per the manufacturer's specifications.

5. **VFD Installation on Kitchen Fans**

A Variable Frequency Drive (VFD) is a controller that provides adjustable speeds for an electric AC motor by varying the voltage and frequency. Adding the VFD on exhaust fan will vary fan speed to vary as needed when there is smoke or fumes from the kitchen to meet the required ventilation rates.

Installing a demand control controlled ventilation system to operate the exhaust fan is recommended. This system would include the VFD to control the exhaust fan motor, a digital controller, temperature probe, and smoke probe in the cooking hood to control the exhaust fan. Existing exhaust fan motor may need to be replaced with inverter duty motor.

6. **VFD Installation on Chiller Pumps and Fans**

The existing constant flow pumping system for the chilled water loop provides constant flow to meet the supply temperature set point regardless of the demand. Variable flow primary pumping systems save energy during part load operation because water flow is reduced and less pump energy is required. Moreover, with reduced water flow, less compressor energy is required to meet the cooling demand.

Installation of VFD on supply and return fans is recommended. Typically to control the fan speed, additional sensors are installed along the duct and calibrated to adjust the fan speed depend on the air flow demand. Alternatively, the fan speed can be pre-programmed to meet air flow requirement in cooling or heating modes for smaller units. A control interface board that matches fan speed to each equipment air flow requirement is required unless the control of the VFD is integrated and controlled by the Building Automation System.

This recommendation involves installing a variable frequency drive (VFD) on the pump and a differential pressure sensor with a VFD controller unless it is integrated with a Building Automation System.

Table 44. Mechanical System Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Replace split systems with high efficiency, inverter-driven units	Saving is based on the increased in unit efficiency.	60,119	$37,037	2.6 years
Proper Spacing between Split Units	Estimated savings are based on an estimate in increased efficiency.	18,582	$6,260	1.4 years
VFD Installation on Kitchen Fans	Savings are based on the reduced power demand at lower fan speeds.	48,864	$15,516	1.3 years
VFD Installation on Chiller Pumps	Savings are based on the reduced power demand at lower pump speeds.	36,752	$13,192	1.5 years

5.5.3 Lighting

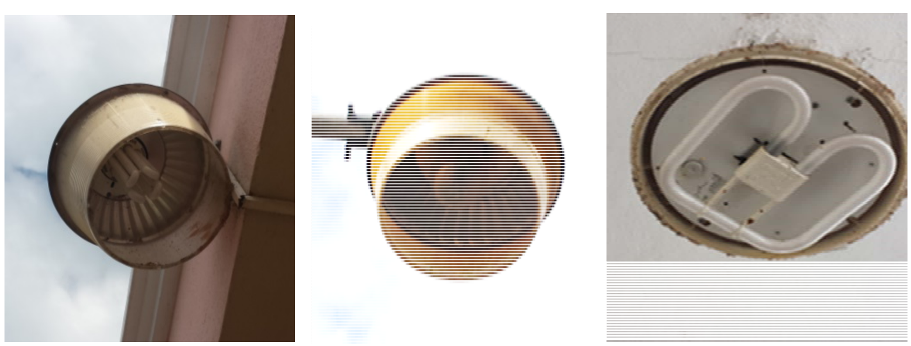
Existing conditions

The typical interior lighting configuration in Mandeville Hospital is a manual-switch controlled set of T8 or T12 linear fluorescent fixtures (4ft). It was also observed that often the lamps were with no reflectors or diffusers or left off due to sufficient natural lighting.

Typical Interior Fixtures

Most spaces in the building are not adequately lit with an illuminance range of 10 footcandles (FC) for the patient and administration areas. In the operating rooms and the examination areas an illuminance of 22 FC was recorded however; these spaces were not occupied at the time so not all fixtures were turned on. The Illuminating Engineering Society of North America (IESNA) Lighting Handbook Reference & Application recommends an illuminance of 28 FC for general ward lighting, 46 FC for simple examination areas and 93 FC for examination and treatment.

Exterior lighting is a mixture of pole and wall-mounted fixtures, with fluorescent tubes, CFLs, mercury vapor and metal halide lamps. These lamps were in various levels of repair. There were two different exterior lighting circuits for the hospital. One circuit served the lighting by the exterior roadway that looped around the property, the other was for lighting the areas around the building entrances and pathways. The fixtures were a combination of incandescent bulbs and fluorescent tubes.



Typical Exterior Fixtures

Recommendations

DNV GL suggests the following measures:

20. Full LED retrofit

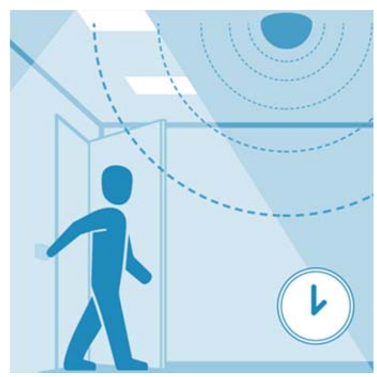
LED retrofits are one of the most beneficial and cost effective energy savings practices available. A typical 2-lamp T12 linear fluorescent bulb with magnetic ballast uses up to 94 Watts. An equivalent LED tube fixture (no ballast needed) can produce the same lighting levels with a single tube is rated at only 18W.

LED fixtures provide equivalent lighting levels and better light quality in comparison to fluorescent fixtures while achieving 30%+ in energy savings. The average life of LED tube lamps is typically 5 times as long as a fluorescent light, resulting in higher net present value long-term. There is also no longer a need to replace ballasts, further reducing maintenance and materials costs.

Many LEDs support lighting control capabilities such as full dimming and directional illuminance that allow custom adjustments to achieve preferred visual comforts and ensure adequate distributed light levels exactly where it is needed. Unlike fluorescents, LEDs contain no mercury, making them safe for the environment and resulting less additional recycling cost.

It is recommended to replace all existing fluorescent fixtures to dimmable LED fixtures with an LED lighting retrofit kit. Alternatively, simply installing LED tubes with a ballast bypass into the existing fixture can be more cost-effective with a simple wiring change. T12 fixtures already have a non-shunted rapid start lamp holder, and T8 fixtures need a replacement lamp holder for use with the LED tube.

7. Lighting controls



A recommended improvement is to install occupancy sensors to lighting for timed shutoff in non-continuously occupied areas.

Due to the prevalence of natural light, should LED's be installed, daylighting photocells can be tied into the lighting controls. These controls measure the ambient light levels to appropriately match the artificial lighting with the natural light present in the space. This "daylight harvesting" technique provides energy savings, allows for the automatic control of lights, and has the additional benefit of providing appropriate comfort and task lighting for patients and doctors alike.

Utilizing an Integrated Room Control (IRC) combines these technologies, and meets ASHRAE 90.1 requirements of lighting by combining receptacle control, occupancy sensing, space control, lighting control, and automatic shutoff.

Table 45. Lighting Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Payback**
Fluorescent to LED Fixture Retrofit	Savings are derived from the lower power requirement (wattage per fixture) of LED fixtures.	278,493	$31,297	< 1 Year
Occupancy Sensor for Interior Lights	Savings are derived from the discounted diversity factor when occupancy sensor is installed.	10,181	$6,395	2.7 years

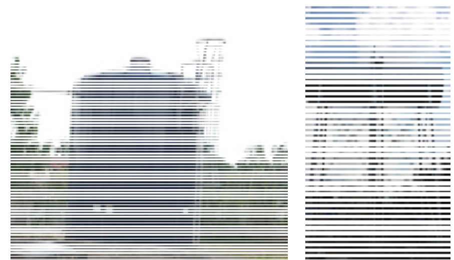
5.5.4 Water Consumption

Existing conditions

The city of Mandeville has a public water supply, however the region is often isolated due to reliance on long stretches of unreliable pipeline integrity and operational pumps required to reach the elevation. To ensure enough emergency water is available, an underground water storage tank (130k gallons) is in place for municipally supplied water, and an aboveground tank for rainwater collection (31k gallons) is on the roof. The above ground tank is filled to capacity every month.

Medical facility and laboratory water use typically ranges from 250 to 800 gallons per bed due to a number of medical water-using processes:

- sterilizers and central sterile operations
- water-cooled laboratory and therapeutic equipment
- equipment scrubbers
- X-ray equipment and film developers
- water-treatment systems for kidney dialysis and laboratory water
- vacuum systems
- medical air and compressor equipment
- therapeutic baths and treatment.



Rainwater Collection System

The primary use of hot water in the facility is limited to the main Kitchen. The kitchen is able to provide 3 meals per day for all patients. Hot water is provided through gas stoves. There is a solar hot water system installed on the roof; however it has never been activated.

There are additional solar thermal panels distributed over the rooftop, none of which are active. There are approximately 50 panels in total (4’x10’), and two sets of insulated storage tanks.

Inactive Kitchen Solar Thermal Systems

Recommendations

DNV GL suggests the following measures:

21. Activate Solar Thermal Systems

Hospitals have a high hot water load due to a number of medical water using processes. Significant reduction in fossil energy consumption can occur if a solar thermal system is installed to meet the hospital's hot water demand. The hospital's hot water consumption was unable to be obtained and therefore calculations on the solar thermal savings could not be performed at this time. It is recommended that the sizing of the solar thermal system is conducted once realistic data on hot water usage in the facility is obtained.

5.5.5 Process Systems

Existing conditions

Plug loads refer to energy used by equipment that is plugged into an outlet. The plug load in the hospital consists of medical equipment, computers, monitors, printers, task lighting, and specialty equipment. There are not any plug load control strategies evident on site. Low cost plug load control strategies are available which use manual controls or automatic sensors/timers to ensure the building isn't operating when vacant, and using energy-efficient equipment.

The hospital employs multiple high-energy process systems for medical uses. Medical equipment requires reliable compressor and vacuum systems for highly sensitive applications. The compressor system was noted to activate approximately every minute during the site visit, indicating a potential leak in the system.

The facility team was not able to provide an inventory of process and medical equipment that summarized the high equipment loads in the hospital. A summary of observations is included below.

Compressed Gasses and Vacuum Systems

Table 46. Process System Load Inventory		
Area	Equipment	Quantity
Central Systems	Vacuum System	1
	Medical Air System	1
	Water Pumps	4
Kitchen	Ovens (Gas)	2
	Stoves (Gas)	2
	Ranges (Gas)	2
	Refrigerated cold room	4
	Freezer	2
Laundry	Dryers	3
	Compressors	2

Recommendations

DNV GL suggests the following measures:

22. Compressed Air System Investigation

Compressed Air leaks cause a fluctuating air pressure which stresses both the system and tools, increased run frequency and time of compressor package, increased maintenance, and decreased service life. It is recommended to perform a Leak Detection investigation and repair leaks.

Air leakage in compressed air system is a significant waste of energy that often contribute up to 20-30% of excess system usage. Leakage induces to additional pressure drop in the system, leading the compressor to work harder and causing fluctuating air pressure that stresses the system and tools. Subsequently, overworking the compressor than it needs to can force short cycling, ultimately increasing maintenance and shortening the equipment's useful life. The most common areas where leakage occurs are typically in joints, connections, pressure regulators, open condensate traps, shut off valves, and thread sealants.

Efforts to detect leakage through an ultrasonic acoustic detector on a periodic basis through preventive maintenance program is recommended. Since air leaks are not always visible, recognizing high frequency hissing sounds associated with air leaks is a recommended training for dedicated maintenance staffs. Depend where the leakage occurs, fixing leaks can be as simple as tightening a connection to replacing a faulty component.

Post-adjustment, it is likely that the compressor controls will need to be adjusted to match repaired system demand such that the air pressure of the system be reduced to the lowest practical range that is needed on the demand side in order to reduce the leakage rates and alleviate unnecessary stress for the system.

8. Plug Load Efficiency

Plug load is an unregulated demand in terms of building energy code requirements. A plug load reduction program is to reduce energy use during non-business hours, as certain equipment acts as a parasitic energy load, and creates waste. A key step in any plug load reduction program is to reduce energy use during non-business hours, as it is generally wasted. In the case of receptacle load for a hospital, there are many areas such as the administration, outpatient offices and nurses stations where computers are left unoccupied for long periods of time. Employing power strips that can be switched off in times of no usage could reduce the 'standby mode' energy consumption.

In the case of computer labs, a timer or manual on/off vacancy control device could ensure all machines power down when not needed. For individual devices, a primary/secondary power strip can be used which uses a load sensing device to disable power to some outlets when select outlets are not being used. A primary load, such as a computer, would operate independently, and when turned on would cause the device to activate secondary outlet loads, such as a monitor.

Using an Advanced Power Strip (APS) in these areas will save energy by controlling the power supplied to plug-in devices during unoccupied periods. A variety of APS technologies exist on the market that vary in complexity, control strategies, data collection abilities, and costs. Even the simplest power strips can be switched off in times of no usage could reduce the 'standby mode' energy consumption.

One key step in reducing receptacle energy use is to create procurement policy programs (refer to ENERGY STAR® for guidance). Policies must be improved as needed to stay current with technologies.

There should be ENERGY STAR® appliances installed for kitchen and breakrooms to further reduce electrical consumption in these spaces.

Table 47. Process System Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Compressed Air Leakage Investigation	Estimated savings derived from reducing the operating pressure.	29,872	$6,152	< 1 Year

5.5.6 Smart Building Controls

Existing conditions

There are no existing lighting controls installed currently in the hospital but the building could definitely benefit from motion sensor controls for most transition and sporadically occupied spaces in the building such as corridors, storage rooms, conference rooms, nurse and staff rooms, examination/treatment rooms, medical and restrooms.

Recommendations

DNV GL suggests the following measures:

23. Chiller Controls

Chillers uses substantial amount of energy because it is responsible for the cooling of the entire facility where hydronic coils are used. The chiller systems are outdated, and have an insufficient level of controls installed. The chillers run at a constant temperature output, and do not appear to have been integrated with the appropriate level of controls for the range of zones that they control.

Centralized chiller controls not only establish a greater level of control over the equipment, but they enable the ability to implement multiple low-cost control strategies and to provide an interface to enable easy troubleshooting or maintenance long term. Energy efficiency strategies such as chiller lockout, chiller supply temperature reset, optimal start/stop, and scheduling can better serve the variable load in the building and provide up to 5 to 10% of facility total electrical consumption.

Table 48. Advanced Chiller Control Benefits

Benefits	Description
Scheduling	An optimized daily on/off period can be set to better match the operational peak load of the building.
Lockouts	Restricted use dependent on specified conditions, such as outdoor temperature, calendar date, etc.
Resets	Ensure equipment operates at the minimum needed capacity by automatically resetting operation to match weather conditions.
Diagnostics	Data monitoring of temps, flows, pressures, and actuator positions identifies if equipment is operating incorrectly or inefficiently.

9. BAS Upgrade

A Building Automation System (BAS) is an autonomous control system for the entire facility, including lighting, mechanical equipment, security, irrigation, and other systems. Historically, the mechanical system is the primary integrated to BAS due to its complexity and high saving returns. Hence, integration of the mechanical system as well as lighting system into the BAS is recommended.

The main advantage of BAS is the supervision and controls across all mechanical equipment to work cohesively and maintain the building climate within a specified range. Moreover, a building controlled by BAS is often referred to as "smart building" where there has been proven reduction in building energy and maintenance cost compared to a non-controlled building. Vital functions such as statuses, alarms, tuning the control loops, scheduling, and lockout provide a critical tool for faster responding to issues. Furthermore, low-cost to no-cost energy savings strategy such as simply changing a set point, tailoring the equipment schedule to match occupancy, and removing a temporary manual override are just a few common strategies that will lead up to 20% or more of energy savings.

Table 49. Smart Building Controls Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Cost (USD)**	**Payback (Yrs)**
BAS Upgrades	Saving is based on an estimate of percent better.	17,954	$50,000	11.8
Chiller Controls	Saving is based on various chiller control strategies based on outside air.	44,303	$30,000	2.9

5.5.7 Renewable Energy Generation

Existing Conditions

There are currently no active renewable energy systems in place on the campus. There are a large number of flat, concrete roofs with very little shading, and peak energy use is during daytime hours, which are ideal for solar and hot water generation.

Recommendations

24. Solar Photovoltaic System

A solar analysis was performed for Mandeville Hospital to illustrate the potential solar opportunity at the site.

The following assumptions were made regarding roof areas:

- 80% of flat roof area was assumed to be solar ready (20% unavailable for mechanical equipment, structural and misc. equipment on roof)
- 75% of pitched roof area was assumed to be solar ready (25% unavailable for mechanical equipment, structural and misc. equipment on roof)

Table 50. System Installation Criteria	
Module Type	Crystalline Silicon
Array Type	Fixed (open rack)
System Losses (%)	14
Tilt (deg)	20
Azimuth (deg)	Varies with roof orientation
Roof Area Availability	80% (flat roof) 75% (pitched roof)

The analysis was performed using National Renewable Energy Laboratory (NREL)'s PVWatts® Calculator. This is a web application that estimates the electricity production of a grid-connected roof based on square footage available. The location of the hospital site, basic design parameters such as azimuth of roof and tilt of panel and system economics were inputs for the tool. A cost per watt of $3 (NREL,2015) was used for the capital cost of PV installation. A utility cost of $0.25/kWh was used as an average utility rate of electricity for the Jamaican region.

As of 2015, JPS no longer allows for a net billing or net metering strategy for commercial facilities. This drastically affects the amount of solar photovoltaics that can cost effectively be installed on a building. Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation, we have assumed significant energy savings based on the report's other energy efficiency recommendations.

- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.

- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 51. Mandeville Hospital Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings	Simple Payback	ROI
Net Zero Energy	600 kW	$1,799,798	949,093 kWh	$224,158	8.0 years	12.5%
Maximize Onsite Opportunity	722 kW	$2,165,100	1,141,729 kWh	$269,655	8.0 years	12.5%
Load Matched System	115 kW	$345,871	182,389 kWh	$43,077	8.0 years	12.5%

The following map shows the roof areas considered in the solar analysis and the table shows the results of the solar feasibility study conducted for the site.

Table 52. Mandeville Hospital Renewable Potential							
Area	**Azimuth**	**Collector Area (square meters)**	**Collector Area (square feet)**	**KWdc**	**Capital Cost (USD)**	**Annual Energy Generation (kWh)**	**Annual Cost Savings**
A	180	841	9,052	126.1	$ 378,300	211,999	$ 53,000
B	180	1095	11,786	164.3	$ 492,900	276,221	$ 69,055
C1	180	79	850	11.8	$ 35,400	19,838	$ 4,960
C2	0	155	1,668	23.3	$ 69,900	31,511	$ 7,878
D1	180	103	1,109	15.5	$ 46,500	26,059	$ 6,515
D2	0	129	1,389	19.3	$ 57,900	26,101	$ 6,525
E	180	241	2,594	36.1	$ 108,300	60,691	$ 15,173
F1	45	203	2,185	30.4	$ 91,200	43,108	$ 10,777
F2	225	203	2,185	30.4	$ 91,200	49,664	$ 12,416
G	180	145	1,561	21.8	$ 65,400	36,650	$ 9,163
H1	225	98	1,055	14.8	$ 44,400	24,178	$ 6,045
H2	45	98	1,055	14.8	$ 44,400	20,987	$ 5,247
H3	135	51	549	7.7	$ 23,100	12,665	$ 3,166
I	180	603	6,491	90.4	$ 271,200	151,980	$ 37,995
J1	180	128	1,378	19.2	$ 57,600	32,279	$ 8,070
J2	0	128	1,378	19.2	$ 57,600	25,966	$ 6,492
K1	180	45	484	6.8	$ 20,400	11,432	$ 2,858
K2	0	45	484	6.8	$ 20,400	9,196	$ 2,299
K3	180	55	592	8.3	$ 24,900	13,954	$ 3,489
K4	0	55	592	8.3	$ 24,900	11,225	$ 2,806
K5	0	45	484	6.8	$ 20,400	9,196	$ 2,299
K6	225	29	312	4.3	$ 12,900	7,025	$ 1,756
K7	45	29	312	4.3	$ 12,900	6,098	$ 1,525
K8	225	47	506	7.1	$ 21,300	11,599	$ 2,900
K9	45	47	506	7.1	$ 21,300	10,068	$ 2,517
K10	225	56	603	8.4	$ 25,200	13,723	$ 3,431
K11	45	56	603	8.4	$ 25,200	11,912	$ 2,978
TOTAL		4,809	51,764	721.7	$2,165,100	1,165,325	$275,228

Disclaimer: The production estimates that PVWatts® calculates do not account for many factors that are important in the design of a photovoltaic system. These calculations should not be used to help design a system, rather seek a qualified professional to make final design decisions using more detailed engineering design and financial analysis tools. (NREL, 2015.)

5.5.8 Training

Building automation allows us to turn old facilities into smart buildings. However, the smartest control system within a building is the brain of the people who use it daily. Training of facilities staff as well as nurses, doctors, janitors and administrative staff enables the energy efficiency measures implemented within the building to work correctly. Training can help us ensure that unnecessary lights are off, thermostats are set correctly, and the right people are notified in the event of system failure.

Recommendations

25. Maintenance Staff – 2-day post-retrofit initial training

When the project is complete, it is important that members of the maintenance staff are fully trained on any new building systems. Without this key final project close-out item, energy efficiency measures are destined to fail. This circumstance has been noted during our visits to some facilities in Jamaica.

We recommend the maintenance staff is trained by the contractor team after initial installation of all energy efficiency measures to ensure that the staff knows the operational requirements of all new or upgraded equipment. This should be written into the energy efficiency implementation contract.

Training shall include preventative maintenance training such as: recommended filter replacement cycle, oil change cycles, refrigerant testing, valve testing, cleaning of solar panels, and other preventative items specific to each energy efficiency measure.

26. Facility Mangers – Annual Energy Workshop with other Hospitals FMs

As facility managers test and implement new energy efficiency measures and training, it is important to share lessons learned among other hospital facility managers in the country. This provides an excellent opportunity for cross-learning and collaboration on a variety of issues. The annual workshop will enable a project that was successful at one hospital to be implemented by staff at other hospitals. We recommend holding the annual energy workshop in a rotating hospital in a major city each year. Meeting location should be determined based on whichever hospital has most recently received energy upgrades.

27. All Staff – Quarterly Energy Awareness Training

Facility managers are not the only occupants who determine building energy use. Any building occupant armed with knowledge about energy efficiency can help reduce on-site energy usage. Closing doors to air conditioned spaces, turning off lights, properly setting thermostats, and turning equipment off when not in use is the job of the building occupant and is critical to minimizing energy use. Karl Heusner Memorial Hospital in Belize has shown a successful. We recommend the facility staff provide a quarterly energy awareness training to all staff to teach doctors, nurses, and other employees how equipment works and how to minimize energy use in their daily lives. This will have the added benefit of helping them to save energy use at home, reducing their monthly costs as well as their carbon foot print.

5.6 RECOMMENDATION SUMMARY

Mandeville Regional Hospital provides an excellent opportunity for energy savings and associated carbon reduction. These savings will result in a decrease in oil dependence for the island of Jamaica, a decrease in the annual energy bill for the Government of Jamaica, and will help increase in-country capacity for energy efficiency implementation. The table below outlines the energy efficiency recommendations for the project. We recommend that the Government of Jamaica take the following steps:

13. Perform an Investment Grade Audit of the facility to provide more in-depth analysis of building energy use as well as more accuracy for energy savings of each energy efficiency measure
14. Determine applicable funding and scope for the project
15. Draft Request for Proposal for energy efficiency implementation
16. Engage an Energy Services Company (ESCO) to install energy efficiency measures and distributed renewable energy

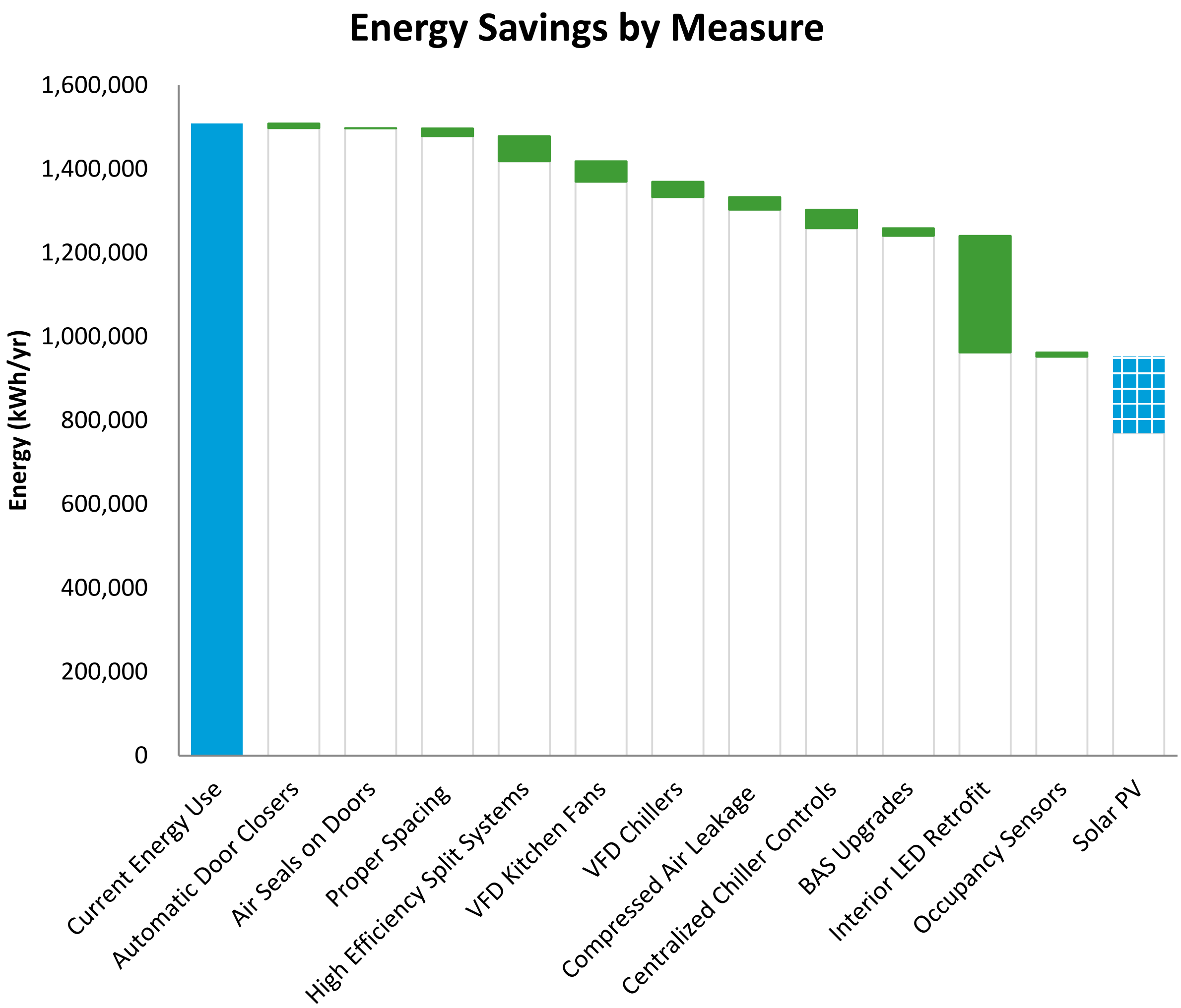
Based on the technical assessment performed, the following energy efficiency opportunities exist at the hospital.

Table 53. Mandeville Hospital Key Recommendations Overview

Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Automatic Door Closers	11,027	$2,604	$2,980	87.4%	1.1
Air Seals on Doors	703	$166	$740	22.4%	4.5
Proper Spacing between Split Units	18,582	$4,389	$6,260	70.1%	1.4
Replace split systems with high efficiency, inverter-driven units	60,119	$14,199	$37,037	38.3%	2.6
VFD Installation on Kitchen Fans	48,864	$11,541	$15,516	74.4%	1.3
VFD Installation on Chiller Pumps	36,752	$8,680	$13,192	65.8%	1.5
Compressed Air Leakage	29,872	$7,055	$6,152	114.7%	< 1
Centralized Chiller Controls	44,303	$10,464	$30,000	34.9%	2.9
BAS Upgrades	17,954	$4,240	$50,000	8.5%	11.8
Fluorescent to LED Fixture Retrofit	278,493	$65,775	$31,297	210.2%	< 1
Occupancy Sensor for Interior Lights	10,181	$2,405	$6,395	37.6%	2.7
Exterior Light Retrofit to LED	22,531	$5,321	$880	604.7%	< 1
Solar PV	182,389	$43,077	$345,871	12.5%	8.0

Total Savings (Recommended Measures)	761,770	$179,916	$546,321	32.9%	3.0
Total Savings (Without Renewable)	579,381	$136,839	$200,449	68.3%	1.5

Savings of non-renewable EEMs	38%
Annual GHG Savings (metric tons CO2)	485
15 year GHG Reduction (metric tons CO2)	7,279



Renewable Energy Recommendations

Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 54. Mandeville Hospital Solar Renewable Options						
Solar Option	**System Size**	**Capital Cost (USD)**	**Annual Energy Generation**	**Annual Cost Savings**	**Simple Payback**	**ROI**
Net Zero Energy	600 kW	$1,799,798	949,093 kWh	$224,158	8 years	12.5%
Maximize Onsite Opportunity	722 kW	$2,165,100	1,141,729 kWh	$269,655	8 years	12.5%
Load Matched System	115 kW	$345,871	182,389 kWh	$43,077	8 years	12.5%

6 MARCUS GARVEY HIGH SCHOOL

An Investment Grade Audit (IGA) was performed by DNV GL Energy Engineers of government buildings in Jamaica. The site visit of Marcus Garvey High School was used to gather information and compile energy efficiency investment recommendations. The nature of the deep energy retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation. The team included the facility managers, Ministry of Science, Energy and Technology (MSET), representatives from the utility Petroleum Corporation of Jamaica (PCJ), and the Ministry in charge of managing the building.

The project is commissioned by the IDB and the goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. GoJ facilities use 12% of electricity consumed in Jamaica. Of that GoJ usage, 14.5% powers healthcare and educational facilities. The facilities visited in April represent a quarter of energy use of those sectors. The expected results of the project are:

- Reduced electricity consumption within government facilities
- Decreased oil imports through improved EE
- Reduced GHG emissions which can contribute to Jamaica's INDC commitment
- An increased capacity to promote and supervise electricity planning in Jamaica

Utility analysis shows the campus energy consumption has been decreasing annually. Nevertheless, the campus's Energy Usage Intensity (EUI) is substantially lower than the median U.S.school. Opportunities to lower energy consumption as well as improve occupant comfort, are identified as Energy Efficiency Measures (EEMs), and summarized in Table 1. Additionally, the renewable energy analysis indicates potential electric generation, implying that there is a large potential for the facility to achieve net zero.

6.1 Site Visit Summary

On June 6, 2016 DNV GL led the team technical visit of Marcus Garvey Technical High School. The weather during the visit was heavy rains and 88˚F. It was attended by representatives from MSET, PCJ, Inter-American Development Bank (IDB), and Academy Operations and Maintenance staff.

An Investment Grade Audit was conducted with appropriate personnel familiar with the physical condition and day-to-day operation of the facility and equipment. Through the facility profile established during the kickoff meeting, the following systems were identified for special consideration:

- Lighting systems
- Mini-split air conditioning systems
- Kitchen equipment
- Rainwater collection and distribution
- Roof system (for Solar PV potential)
- Other process equipment
- HVAC Scheduling

The following staff attended the site visit:

Table 55. Marcus Garvey Site Visit Attendee List			
Dates: 6/6/2016			
Name	**Organization**	**Phone**	**Email**
Andre Russell	Marcus Garvey		-
Shevon Sherwood	Marcus Garvey		-
Craig	PCJ		-
Kent Dahlquist	DNV GL	415-336-1490	kent.dahlquist@dnvgl.com
Joe St. John	DNV GL	646-428-5788	joseph.st.john@dnvgl.com

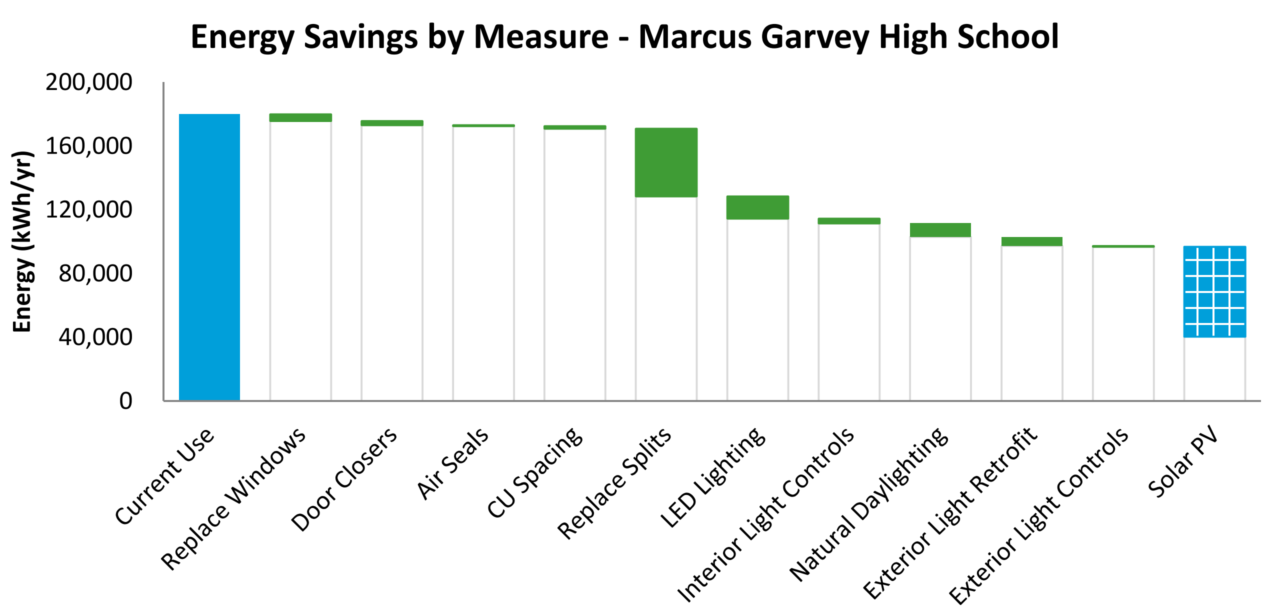
6.2 Key Recommendations

The following table outlines key recommendations for the project. Please note that the total recommended measures include solar photovoltaics (PV).

Table 56. Marcus Garvey Key Recommendations Overview

Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Window Replacement with Insulated Glazing	4,275	$1,058	$7,085	15%	6.7
Automatic Door Closers	2,200	$544	$3,922	14%	7.2
Air Seals on Doors/Windows	593	$147	$600	24%	4.1
Proper spacing behind condensing units	1,347	$333	$1,459	23%	4.4
Replace split systems with high efficiency, inverter-driven units	36,129	$8,941	$38,530	23%	4.3
Fluorescent to LED Fixture Retrofit	27,148	$6,719	$11,301	59%	1.7
Occupancy Sensor for Interior Lights	4,892	$1,211	$5,620	22%	4.6
Installment of Solar Tubes	7,907	$1,957	$23,333	8%	11.9
Exterior Light Retrofit to LED	3,574	$885	$2,041	43%	2.3
Exterior Lighting Timer Control	1,289	$319	$500	64%	1.6
Solar PV	56,347	$13,945	$106,853	13%	7.7
Total Recommended Savings	145,701	$36,058	$201,245	18%	5.6
Total Savings (Without Renewable)	89,353	$22,113	$94,497	23%	4.3

Savings of non-renewable EEMs	50%
Annual GHG Savings (metric tons CO2)	93
15 year GHG Reduction (metric tons CO2)	1,392

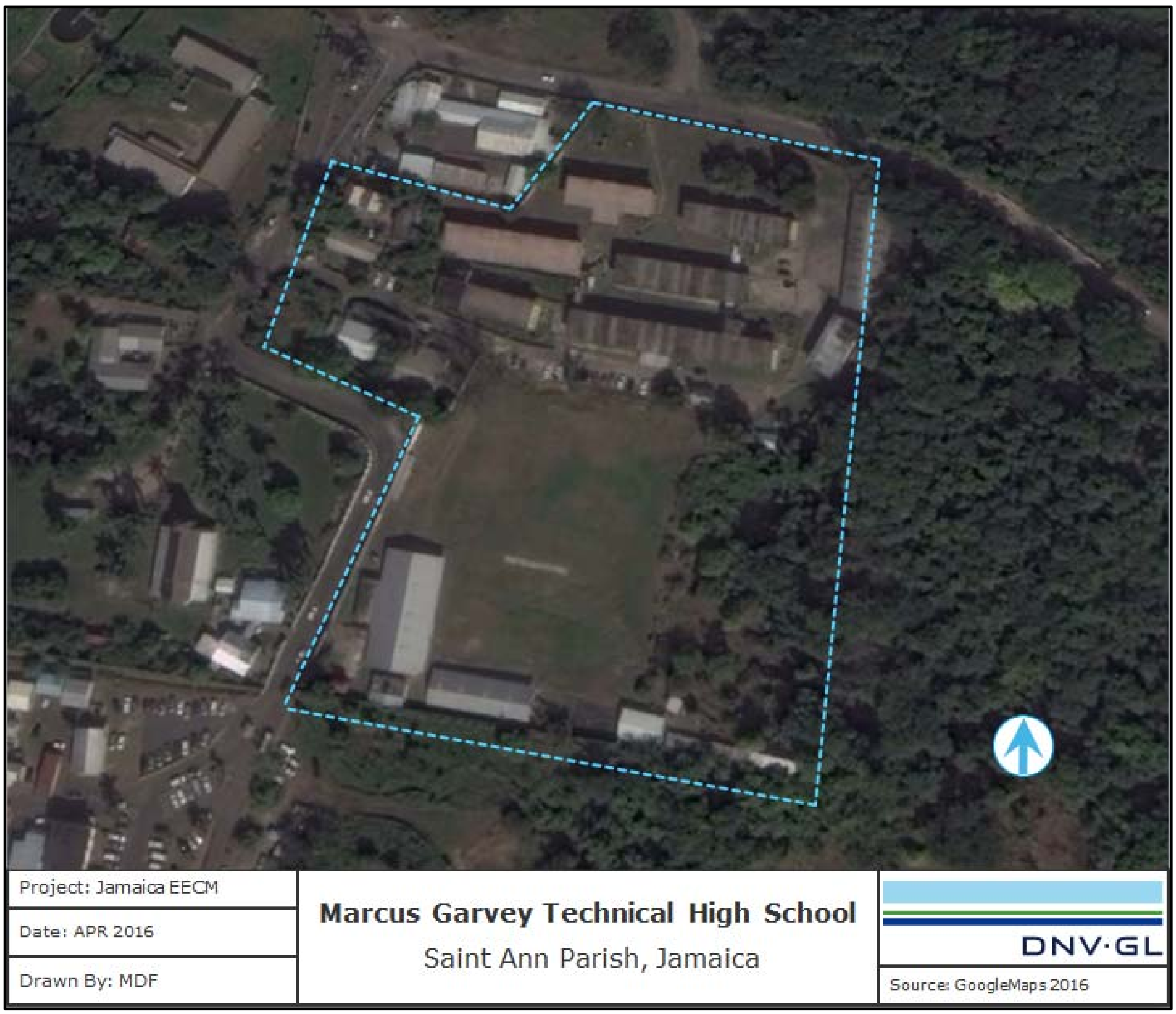


6.3 FACILITY OVERVIEW

Marcus Garvey Technical High School is located in Saint Ann Parish, and serves 1,100 students from grade nine to eleven in a three-year program in technical and vocational curriculums. Its 12-building campus has shops dedicated to metalwork, wood working and culinary arts, and an agriculture and farming center in addition to a number of computer rooms. The facility is open for both full day schooling, as well as night school for community education.

The energy supply to the building is measured by two electricity meters. Additionally Liquefied Petroleum Gas (LPG) is delivered for the kitchen operations.

Water is supplied through the National Water Commission (NWC), and there no rainwater collection or pumping system in place. The school staff is committed to responsible energy use, and has initiated staff and student "green-teams" to generate savings ideas. Service contractors are used for all non-routine maintenance, including split system repairs.



Campus Aerial View

6.4 UTILITY ANALYSIS

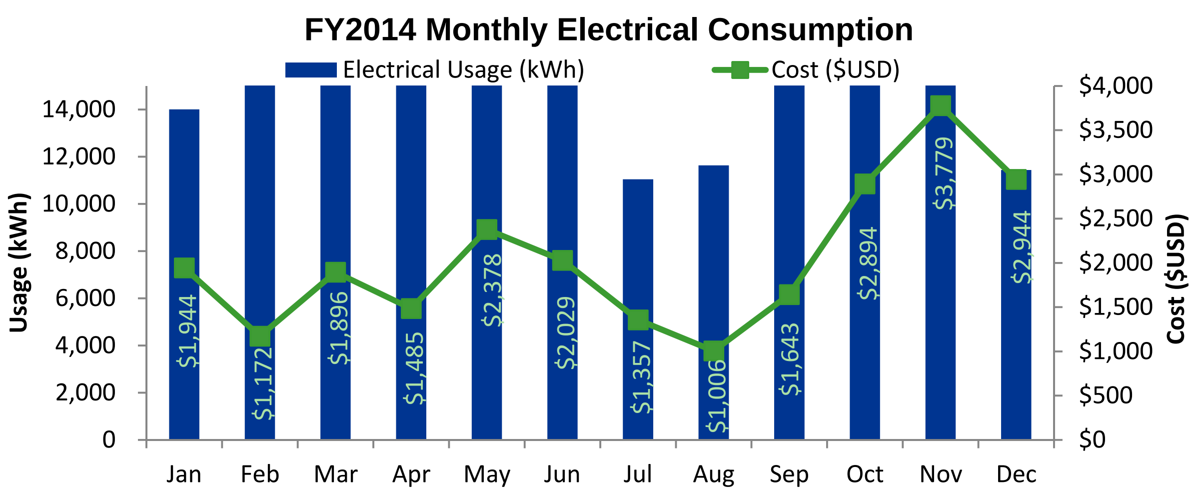
Utility data was evaluated for 2011 through 2015. Based on the provided information, electricity is the primary fuel used with diesel fuel only utilized for the emergency generator. Water utility and other fuel types were requested but were not made available for data analysis. The data for 2015 is unexpectedly low compared to the previous four years, as such 2014 data has been used for baseline comparison in this report. The table below summarizes the annual utility profile.

Annual Utility Profile Summary							
Utility	Usage*	Unit	Cost*	Unit Cost	Energy (MMBTU)	Cost %	Energy %
Electricity	179,925	kWh	$24,527	$0.25	614	100%	100%
Natural Gas	#N/A	Therm	#N/A	#N/A	#N/A	#N/A	#N/A
Water	#N/A	Gallons	#N/A	#N/A	#N/A	#N/A	#N/A
Annual Sum			$24,527		614		
Per Floor Area			$0.37		0.0092		
Floor Area=		67,000	square feet		1 MMBTU =	1,000,000	Btu
Correction Factor =		0.67			1 kWh =	3412	Btu
*From 2015 utility bills					1 Natural Gas Therm =	100,000	Btu

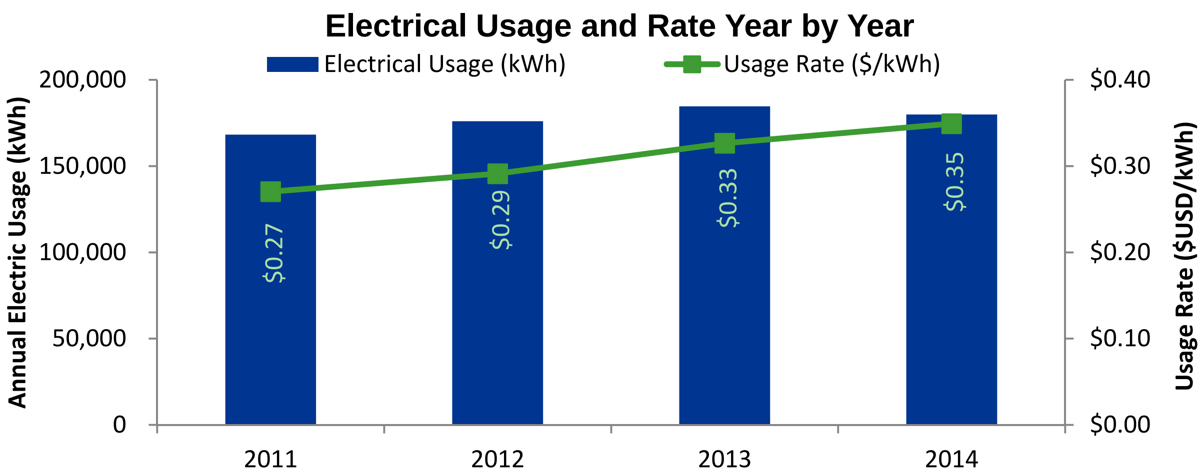
6.4.1 Electricity

Electrical Usage

Electricity is supplied by Jamaica Public Service Company. The facility is served by three (3) meters. The facility annual assumption for year 2014 is approximately 179,925 kWh where the annual peak demand is approximately 89 kVa. As shown in the figure below, monthly electrical energy consumption stays relatively consistent with slight seasonable variation to reflect the typical weather pattern in Jamaica where the hottest months are from July to September. The unusual variance in July may be due to the lower occupancy. There is currently no active renewable energy used on site at this time.

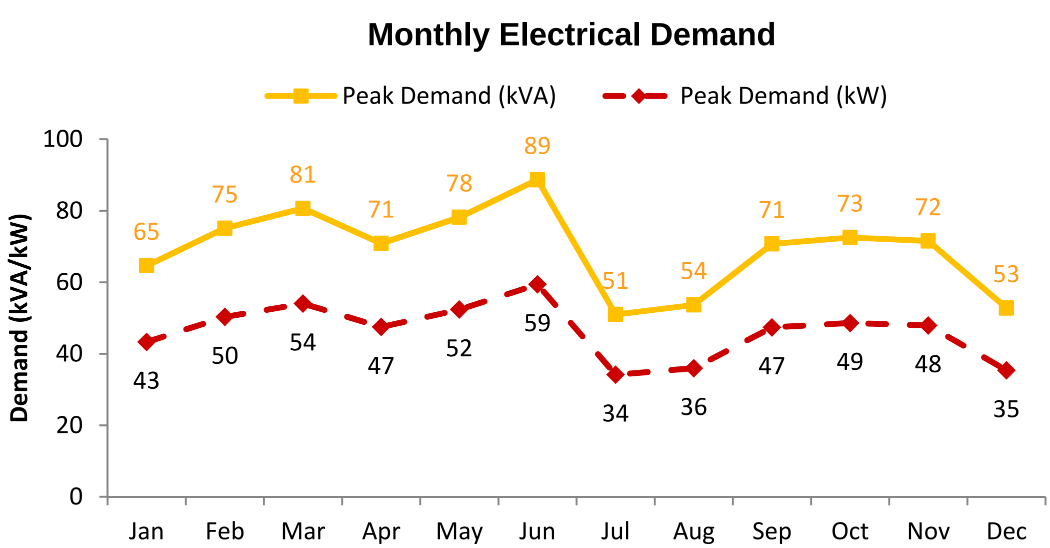


Year by year consumption trend shows that there was an increase in energy usage from 2011 to 2014 as shown in the figure below. The average utility rate from 2011 to 2014 is $0.30 USD per kWh. To account for the potential rate fluctuation in the future, this average utility rate is used to project energy saving costs.



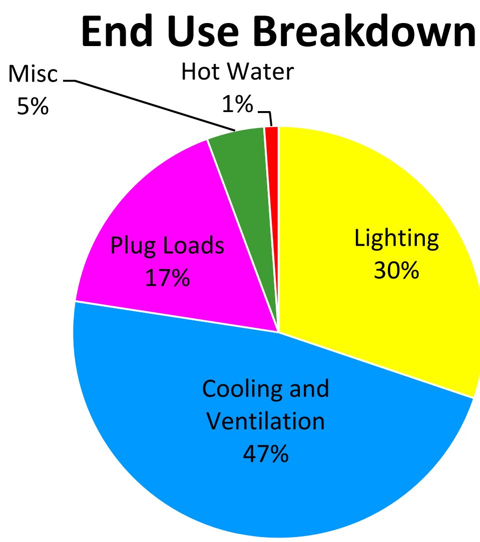
Electrical Demand

The figure below shows the Peak Demand in kVA (the demand charged by the utilities) and the Peak Demand in kW (actual demand of site). The power demand data were not provided and were estimated based on the facility operational hours. The Peak Demand in kW is estimated based on the power factor of 0.67, measured on site for year 2016, which is lower than U.S. standards of 0.9 or higher. Typical causes of low power factor include lowly loaded induction motors and lack of capacitors in transformer.



Load Profile Evaluation

The building electrical use profile is divided into different end-use categories shown on the pie chart below. The annual end use breakdown will vary based on occupancy, operational changes, equipment maintenance, and occupant behavior. More accuracy can be garnered by adding sub-metering systems throughout the facility, which is recommended should a major electrical systems overhaul be undertaken.



6.5 Site Visit Equipment Counts

6.5.1 Summary of Lighting Count

The table below summarizes the lighting equipment inventory identified at Marcus Garvey High School during the site visit which took place on 6/6/2016. A more detailed inventory by specific location may be found in the appendix. Please note that during the site visit, there were a number of areas where the existing fixtures were either not illuminated, or they were currently lacking bulbs. Operating hour estimates are based on staff interviews.

Table 57. Summary of Lighting Counts

Existing Fixture Description	Fixture Wattage	Fixture Quantity
25 W CFL	25	1
60 W Incandescent	60	1
14 Watt CFL	14	46
1-lamp 4' LED	18	14
1-Lamp 4' T12 w/ mag	43	6
1-Lamp 4' T8 w/mag	32	8
1-Lamp 5' T12 w/mag	63	97
1-Lamp 5' T8 w/mag	55	139
1-Lamp 5' T8/T12	59	27
200 Watt Metal Halide	220	15
2-Lamp 2' LED	18	1
2-Lamp 2' T12	51	2
2-Lamp 2' T8	33	1
2-lamp 4' LED	36	11
2-Lamp 4' T12 w/mag	72	95
2-Lamp 4' T8	52	29
2-Lamp 5' T12 w/mag	128	79
2-Lamp 5' T8 w/ mag	112	19
4' LED Tube	18	6
5' LED Tube	23	14
50 Watt Metal Halide	72	1
Total		**612**

6.5.2 Ductless Mini-Split Unit Counts Summary

The table below summarizes the air conditioner equipment inventory identified at Marcus Garvey High School during the site visit which took place on 6/6/2016. A more detailed inventory by specific location may be found in the appendix. The baseline efficiency was estimated from several nameplate photos of the existing equipment's EER rating at 95°F, and adjusted to Jamaica's average ambient outdoor temperature of 83°F. The operating hour estimates are based on interviews with the school's maintenance staff who led us to each of the buildings during the site visit.

Table 58. Summary of Mini Split Units Count

Size (Btu)	Size (tons)	Total Unit Quantity
8000	0.67	5
18000	1.50	8
24000	2.00	2
36000	3.00	4
Total/Average	**1.65**	**19**

6.6 SAVINGS OPPORTUNITIES AND RECOMMENDATIONS

6.6.1 Building Envelope

Existing conditions

Site Context and Orientation

Marcus Garvey Technical High School is located in Saint Ann Parish, located only 400 meters from the coastline. The school is in a contained campus format, consisting of 12 main school buildings and a large schoolyard. The orientation of these buildings is either North or South facing, with long East-West courtyards between. The majority of the campus is in direct sunlight and receives no shading from any source.

General Building Description

The classroom buildings and all offices are all similarly constructed 2 story concrete facilities. All corridors are exterior covered walkways, with the balconies serving as shading devices for the buildings.

Wall and Roof Elements

The main campus is made up of primarily two-story block construction with flat poured-in-place concrete roofs. There is also a large "cafetorium" with a vaulted ceiling and a corrugated metal roof. No envelope elements are insulated. This method of concrete construction provides benefit to thermal comfort, energy efficiency, and resilient facilities. The material is extremely durable, fire-resistant, and able to withstand severe weather conditions. The mass of the concrete both insulates the interior, and limits air leakage, which typically accounts for a large percentage of energy loss in alternative material construction.

Windows and Openings

The campus has exterior circulation, which allows for classrooms to incorporate operable windows, as displayed below. Curtains are used to limit direct sunlight.

Example Window Units

The buildings incorporate both glass louver windows and open cell Concrete Masonry Unit (CMU) that allows for outdoor air circulation. The school however has been modified to meet modern educational requirements by supplying a number of computer rooms for the students, which require air-conditioned space to avoid overheating, and acrylic panels have been attached to the walls to limit air infiltration in all conditioned rooms.

The buildings all have high levels of air leakage, with infiltration evident through unsealed windows and doors. This leakage results in a room that remains hot even while the air conditioner is running at full load, burning energy, and decreasing the equipment's useful life. Air sealing the building envelope is one of the most critical features of an energy efficient building. Room sealing will mitigate infiltration as well as reduce potential leakage of the cool, conditioned air supply in places where there is an AC system installed.

Recommendations

DNV GL suggests the following measures:

28. Window replacements with insulated glazing

The school has been modified from its original building design to meet modern educational requirements by supplying a number of computer rooms for the students, which require an air-conditioned space to avoid overheating. These rooms have been sealed using single-pane 0.25-inch acrylic (i.e. Plexiglass), which has a typical U-Value (the heat transfer coefficient; the lower this value, the less energy is conducted through the material) of approximately 0.96 Btu/hr-sq ft °F.

Installing a double-glazed window will have insulating air- or gas-filled spaces between each pane will improve the U-Value. A double-glazed, low-emittance glass with gas between the panes has a U-factor of about .32, effectively tripling the current thermal resistance. More importantly, double-glazed windows with proper mounting prevents infiltration and limits air leakage when the air conditioners are active, reducing the cooling power requirement.

Where open-cell CMU is used structurally and replacement is infeasible, a supporting frame should be installed around the opening and the insulated window set within the frame and create a continuous airtight seal between the existing block, the frame material and the new window with appropriate adhesive and sealing compounds applied.

29. Automatic door closers and door sealing

Doors were found to be open or improperly sealed, limiting the effectiveness of the cooling systems. The most cost effective strategy to automatically close the door is using a surface-mounted regular arm door closer attached to the door frame where a spring mechanism is used to close the door. This ensures pressurization and limits infiltration, reducing the cooling power requirement.

Improperly sealed doors often are a significant source for leakage of conditioned air, causing excess energy use. A 0.125-inch gap around a typical entryway door is the equivalent of drilling a 5.5-inch-diameter hole through an outside wall. A weather seal system includes weather stripping, which covers the sides and top of the door, and a sweep, which fills the space between the threshold and the door bottom. Foam, felt, plastic, or tubular silicone weather stripping products are designed for this purpose.

Table 59. Envelope Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Window Replacement with Insulated Glazing	Saving calculation from infiltration derives from the improved R-value.	4,275	$7,085	6.7 years
Air Seals on Doors/Windows	Saving is based on improved R-value.	593	$701	4.8 years
Automatic Door Closers	Saving is based on reduction of infiltration due to temperature difference.	2,585	$3,922	6.1 years

6.6.2 Electrical and Mechanical Systems

Existing conditions

The school was designed to have open air ventilation, however modern educational computers and equipment requires air conditioning to avoid overheating. Mini-split AC units have been installed (approximately 24) in classrooms, offices, and in all computer rooms. There are a variety of manufacturers and unit capacities ranging from 2-5 kW rated input. All of the systems used basic remote-control systems with no programming capabilities.

There is a large exhaust hood in the home-economics classroom, and one in the main kitchen.

Condensing Unit Layout

Recommendations

DNV GL suggests the following measures:

30. Proper spacing behind condensing units

Outdoor condensing units appear to be installed without proper clearance requirements behind units. Clearance behind air-cooled condensing units is critical for both space comfort and cooling system efficiency because the air used to reject heat is pulled from behind the condensing units. Current spacing between walls and condensing units hinders airflow, resulting in reduced cooling capacity and reduced coefficient of performance (COP.)

It is recommended that the contractor measure current condensing unit spacing and increase spacing to one inch greater than manufacturers minimum clearance requirements in order to ensure condensing units are meeting design requirements. In the event that the air conditioning system is being replaced, ensure new condensing units are installed per the manufacturer’s specifications.

31. Replace split systems with high efficiency, inverter-driven units

It is recommended that a high-efficiency inverter system should replace the existing split systems as they are approaching their end of useful life. Maintenance cost of the VRF system should be similar to a

Direct Expansion (DX) unitary system where consistent preventive maintenance to change filters and clean coil are recommended.

In addition, it is recommended that programmable setback thermostats be required accompanying the newly installed units to better manage the classrooms according to scheduling.

32. Programmable Controls or Timers

We recommend that programmable setback thermostats or equipment timers be installed where possible to better manage the classrooms according to scheduling, and restrict access to facility personnel to avoid overuse. None of the currently installed units appeared to have anything by temperature controls and restricted run timers. Behavioral changes are effective at energy savings, but automatic controls present a more reliable option. Savings vary with operation and behavior of thermostats and therefore cannot be quantified at this time.

Table 60. Electrical and Mechanical Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Replace split systems with high efficiency, inverter-driven units	Saving is based on the improved unit efficiency.	36,129	$38,530	9.0 years
Proper spacing behind condensing units	Saving is based on the improved unit efficiency.	1,347	$1,459	4.4 years

6.6.3 Lighting

Existing conditions

The typical interior lighting configuration in Marcus Garvey is a manual-switch controlled set of T12 linear fluorescent fixtures. High occupancy areas and computer rooms have begun to switch to linear LED lamps, with about 50% completed. In classrooms, it was observed that often the lamps were often left off due to sufficient natural lighting.

Exterior lighting is primarily provided by metal-halide bulbs; however, there is a limited number of high-wattage CFLs.


Typical interior and exterior lighting

Recommendations

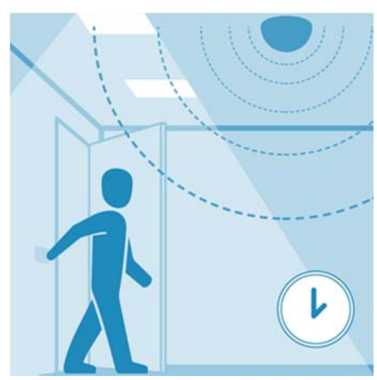
DNV GL suggests the following measures:

33. Full LED retrofit

LED retrofits are one of the most beneficial and cost effective energy savings practices available. A typical 2-lamp T12 linear fluorescent bulb with a magnetic ballast uses up to 94 W. An equivalent LED tube fixture (no ballast needed) can produce the same lighting levels with a single tube is rated at only 18 W.

Alternatively, simply installing LED tubes with a ballast bypass into the existing fixture can be more cost-effective with a simple wiring change. T12 fixtures already have a non-shunted rapid start lamp holder, and T8 fixtures need a replacement lamp holder for use with the LED tube.

34. Lighting controls



The school has proactively instituted "Green Teams" to shut off lights and HVAC systems when not in use. A recommended improvement is to install occupancy sensors to lighting for timed shutoff.

Due to the prevalence of natural light, if LEDs are installed, daylighting photocells can be tied into the lighting controls. These controls measure the ambient light levels to appropriately match the artificial lighting with the natural light present in the space. This "daylight harvesting" technique provides energy savings, allows for the automatic control of lights, and has the additional benefit of providing appropriate task lighting for the students.

Utilizing an integrated room control (IRC) system combines these technologies and meets ASHRAE 90.1 requirements of lighting by combining receptacle control, occupancy sensing, space control, lighting control, and automatic shutoff.

35. Natural lighting

While most of the facilities have concrete roofs and are often used for night classes, the large cafeteria has a large corrugated metal roof, and is used primarily during daylight hours. This is a prime location for installation of a natural daylighting system. The two preferred options available are the installation of translucent roof paneling or solar tube daylighting.

Translucent paneling has been used elsewhere on the campus, and can provide a soft natural light to substitute for artificial lighting. Panels can be made of various colors depending on the lighting levels needed for the space.

Solar tube daylighting systems use a rooftop dome capture system and a diffuser on the internal ceiling to distribute a dispersed light. These units require limited structural changes to the roof, and the smaller shape of the rooftop system limits the debris buildup that is common on translucent paneling.

Table 61. Lighting Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Fluorescent to LED Fixture Retrofit	Saving is based on the lower power requirement (wattage per fixture) of LED fixtures.	27,148	$11,301	1.7 years
Installment of Solar Tubes	Saving is derived from the reduced hours annually from utilizing daylighting instead of the existing light fixtures throughout the year.	7,907	$23,333	11.9 years
Occupancy Sensor for Interior Lights	Saving is based on the discounted diversity factor when occupancy sensor is installed.	4,892	$5,620	4.6 years
Exterior Light Retrofit to LED	Savings are derived from the lower power requirement (wattage per fixture) of LED fixtures.	3,574	$2,041	2.3 years
Exterior Lighting Timer Control	Savings are derived from the reduced hours from manual lighting scheduling to automatic control.	1,289	$500	1.6 years

6.6.4 Water Consumption

Existing conditions

The primary use of water in the facility is limited to the home economics classroom and the main kitchen. The home economics classroom is on the top floor of a concrete-roof building, and the kitchen has a corrugated roof. Both buildings are in direct sunlight.

Recommendations

DNV GL suggests the following measures for future considerations:

36. Rainwater catchment system

The typical site weather pattern reveals that precipitation occurs for approximately 25% of the year, presenting an opportunity to collect the water independently on site. There are several methods to collect rain water such as rooftop capture to rain barrels, collection from fog through nets, or using a reservoir. It is recommended that rain barrels be used to collect the rainwater from gutters and the roofs where the first flush occurs for the first 2 inches of rainwater. Typically, rainwater is used for irrigation and toilet flushing. However, we recommend additional proper filtration and treatment system is added to make the water potable and meet drinking water standards.

The total roof area for Marcus Garvey is approximately 43,500 ft^2. The average maximum rainfall volume from roof capture is estimated to 2.54 million gallons per year. Utilizing rainwater would significantly reduce the site water demand from the municipal supply and induce to substantial pump energy savings. In case of dry seasons where water resources are scarce and in case of natural disaster that hinder the municipal supply pipeline, the site would have the rain catchment system to provide some water resource.

37. Solar thermal water heaters

For the home economics classroom application, a direct heating, passive set might be appropriate. The higher demand in the kitchen might necessitate a storage tank with a backup heater (preferably solar powered as well).

Significant reduction in fossil energy consumption can occur if a solar thermal system is installed to meet the school's hot water demand. The school's hot water consumption was unable to be obtained and therefore calculations on the solar thermal savings could not be performed at this time. It is recommended that the sizing of the solar thermal system is conducted once realistic data on hot water usage in the facility is obtained.

. A typical solar water heating system consists of solar collectors, piping, and insulated water storage tanks. Heat is generated from incoming solar radiation energy transferred to water or glycol circulating through the panel and back to a storage tank. The heated fluid is either directly used, or a heat exchanger is used with potable water. The fluid can either be actively pumped, or use gravity and a density/pressure differential in a passive flow.


Glazed Flat Plate Collector with Storage


Evacuated Tube Collector with Storage

6.6.5 Process Systems

Existing conditions

Process energy encompasses energy consumed other than conditioning spaces and maintaining comfort for the occupants of a building, known as "plug load" since it refers to energy used by equipment that is plugged into an outlet. The plug load in the school consists of desktop computers, monitors, printers, and any task lighting in the classrooms and office areas, as well as microwaves and refrigerators in staff areas for individual use. Equipment that goes into standby mode and certain UPS devices with a cooling fan are still drawing power.

There are not any plug load control strategies evident on site. Low cost plug load control strategies are available which use manual controls or automatic sensors/timers to ensure the building isn't operating when vacant, and using energy-efficient equipment.

Table 62. Potential Plug Load Reduction Targets

Equipment Type	Typical Wattage	Number of Units
Laptop Computer	90 W	29
Desktop Computer	240 W	135
Monitors	25W	176
UPS	Variable	22

The vocational training at the school requires a variety of equipment with discrete high energy use, such as equipment in the woodworking (saws, drills, lathes), metalworking (welders and soldering irons), culinary (electric ovens and microwaves), and garments shops (irons and sewing machines).

Recommendations

DNV GL suggests the following measure:

38. Plug Load Efficiency

Plug load is an unregulated demand in terms of building energy code requirements. A plug load reduction program is to reduce energy use during non-business hours, as certain equipment acts as a parasitic energy load, and creates waste. In the case of receptacle load for a school, there are many areas such as the administration, offices, and computer labs where equipment are left unoccupied for long periods of time.

In the case of computer labs, a timer or manual on/off vacancy control device could ensure all machines power down when not needed. For individual devices, a primary/secondary power strip can be used which uses a load sensing device to disable power to some outlets when select outlets are not being used. A primary load, such as a computer, would operate independently, and when turned on would cause the device to activate secondary outlet loads, such as a monitor.

Using an advanced power strip (APS) in these areas will save energy by controlling the power supplied to plug-in devices during unoccupied periods. A variety of APS technologies exist on the market that vary in complexity, control strategies, data collection abilities, and costs. Even the simplest power strips can be switched off in times of no usage could reduce the 'standby mode' energy consumption.

One key step in reducing receptacle energy use is to create procurement policy programs (refer to ENERGY STAR® for guidance). Policies must be improved as needed to stay current with technologies. There should be ENERGY STAR® appliances installed for kitchen and breakrooms to further reduce electrical consumption in these spaces.

6.6.6 Smart Building Controls

Existing conditions

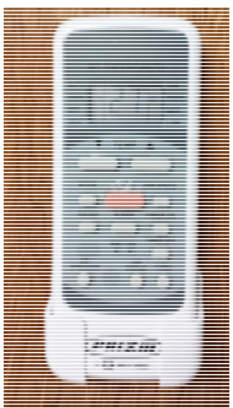
There are currently no controls available for any of the buildings on the campus. Each room's lighting and HVAC systems are controlled by manual switches or remote controls. While behavioral changes can be beneficial to improving the energy efficiency of a building, properly programmed and maintained automated control systems are more reliable.

Recommendations

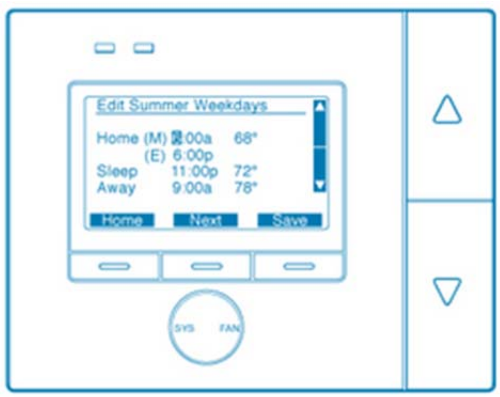
DNV GL suggests the following measures:

39. Programmable thermostats and lighting controls

Referenced in previous sections, programmable thermostats and lighting controls allow the facility managers to more accurately manage energy use throughout the facility, and to be more informed on any activity deviations. Energy savings will vary based on behavior and cannot be quantified at this time.



Typical Split-System Remote Control



Typical Programmable Panel

40. Submetering

There are multiple buildings on this campus that are used on inconsistent schedules and with dissimilar equipment. In addition, the buildings are often leased out for training sessions. While there are no direct savings associated with metering, the availability of submeters empowers the facility manager to review trends and consumption, and react to deviations.

The installation of submeters would allow the facility managers to track the energy use of the individual activities more closely and to bill facility rentals more accurately. Similarly to the programmable controls measure, the energy savings as a result of submetering will depend on the system setup and ongoing monitoring. A quantifiable number cannot be recommended at this time.

6.6.7 Renewable Energy Generation

Existing conditions

There are currently no renewable energy systems in place on the campus. There are a large number of flat, concrete roofs with very little shading, and peak energy use is during daytime hours.

Recommendations

DNV GL suggests the following measures:

3. Solar Photovoltaic System

A solar analysis was performed for Marcus Garvey High School to illustrate the potential solar opportunity at the site. The following assumptions were made regarding roof areas:

- 80% of flat roof area was assumed to be solar ready (20% unavailable for mechanical equipment, structural and misc. equipment on roof)
- 75% of pitched roof area was assumed to be solar ready (25% unavailable for mechanical equipment, structural and misc. equipment on roof)

Table 63. System Installation Criteria	
Module Type	Crystalline Silicon
Array Type	Fixed (open rack)
System Losses (%)	14
Tilt (deg)	20
Azimuth (deg)	Varies with roof orientation
Roof Area Availability	80% (flat roof) 75% (pitched roof)

The analysis was performed using National Renewable Energy Laboratory (NREL)'s PVWatts® Calculator. This is a web application that estimates the electricity production of a grid-connected roof based on square footage available. The location of the school site, basic design parameters such as azimuth of roof and tilt of panel and system economics were inputs for the tool. A cost per watt of $3**Invalid source specified.** was used for the capital cost of PV installation. A utility cost of $0.25/kWh was used as an average utility rate of electricity for the Jamaican region.

As of 2015, JPS no longer allows for a net billing or net metering strategy for commercial facilities. This drastically affects the amount of solar photovoltaics that can cost effectively be installed on a building. Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a

given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 64. Marcus Garvey High School Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings	Simple Payback	ROI
Net Zero Energy	62 kW	$184,524	97,306 kWh	$24,082	7.7 years	13.1%
Maximize Onsite Opportunity	520 kW	$1,559,100	822,165 kWh	$203,472	7.7 years	13.1%
Load Matched System	36 kW	$106,853	56,347 kWh	$13,945	7.7 years	13.1%

The following map shows the roof areas considered in the solar analysis and the table shows the results of the solar feasibility study conducted for the site.

Map of Potential Solar Array Opportunities on Site

Table 65. Marcus Garvey Renewable Potential							
Area	**Azimuth**	**Collector Area (square meters)**	**Collector Area (square feet)**	**KWdc**	**Capital Cost (USD)**	**Annual Energy Generation (kWh)**	**Annual Cost Savings**
A	180	273	2,939	41	$123,000	68,929	$20,876
B	180	362	3,897	54.4	$163,200	91,457	$27,699
C	180	462	4,973	69.2	$207,600	116,339	$35,235
D	180	375	4,036	56.3	$168,900	94,651	$28,666
E	180	254	2,734	38.1	$114,300	64,054	$19,399
F	180	545	5,866	81.7	$245,100	137,354	$41,599
G1	270	187	2,013	28	$84,000	42,733	$12,942
G2	90	188	2,024	28.2	$84,600	43,479	$13,168
H1	270	228	2,454	34.2	$102,600	52,195	$15,808
H2	90	264	2,842	39.6	$118,800	61,056	$18,491
I1	180	123	1,324	18.4	$55,200	30,934	$9,369
I2	0	126	1,356	18.9	$56,700	25,560	$7,741
J1	180	39	420	5.9	$17,700	9,919	$3,004
J2	0	39	420	5.8	$17,400	7,844	$2,376
TOTAL		**3,465**	**37,297**	**519.7**	$1,559,100	**846,504**	**$256,373**

6.6.8 Training

Building automation allows us to turn old facilities into smart buildings. However, the smartest control system within a building is the brain of the people who use it daily. Training of facilities staff as well as teachers, students, janitors and administrative staff enables the energy efficiency measures implemented within the building to work correctly. Training can help us ensure that unnecessary lights are off, thermostats are set correctly, and the right people are notified in the event of system failure.

Recommendations

DNV GL suggests the following measures:

41. Maintenance Staff – 1-day post-retrofit initial training

When the project is complete, it is important that members of the maintenance staff are fully trained on any new building systems. Without this key final project close-out item, energy efficiency measures are destined to fail. This circumstance has been noted during our visits to some facilities in Jamaica.

We recommend the maintenance staff is trained by the contractor team after initial installation of all energy efficiency measures to ensure that the staff knows the operational requirements of all new or upgraded equipment. This should be written into the energy efficiency implementation contract.

Training shall include preventative maintenance training such as: recommended filter replacement cycle, oil change cycles, refrigerant testing, valve testing, cleaning of solar panels, and other preventative items specific to each energy efficiency measure.

42. Facility Mangers – Annual Energy Workshop with other School FMs

As facility managers test and implement new energy efficiency measures and training, it is important to share lessons learned among other school facility managers in the country. This provides an excellent opportunity for cross-learning and collaboration on a variety of issues. The annual workshop will enable a project that was successful at one school to be implemented by staff at other schools. We recommend holding the annual energy workshop in a rotating school in a major city each year. Meeting location should be determined based on whichever school has most recently received energy upgrades.

43. Annual Energy Awareness Assembly

Facility managers are not the only occupants who determine building energy use. Any building occupant armed with knowledge about energy efficiency can help reduce on-site energy usage. Closing doors to air conditioned spaces, turning off lights, properly setting thermostats, and turning equipment off when not in use is the job of the building occupant and is critical to minimizing energy use. We recommend the facility staff provide an annual energy awareness assembly to all students and staff to teach them how equipment works and how to minimize energy use in their daily lives. This will have the added benefit of helping them to save energy use at home, reducing their monthly costs as well as their carbon footprint. The assembly will be most interesting to students, as the youth are naturally drawn to environmental issues and this serves as a way to help inspire the future leaders and innovators of Jamaica.

6.7 RECOMMENDATION SUMMARY

Marcus Garvey Technical High School provides an excellent opportunity for energy savings and associated carbon reduction. These savings will result in a decrease in oil dependence for the island of Jamaica, a decrease in the annual energy bill for the GoJ, and will help increase in-country capacity for energy efficiency implementation. The table below outlines the energy efficiency recommendations for the project. We recommend that the GoJ take the following steps:

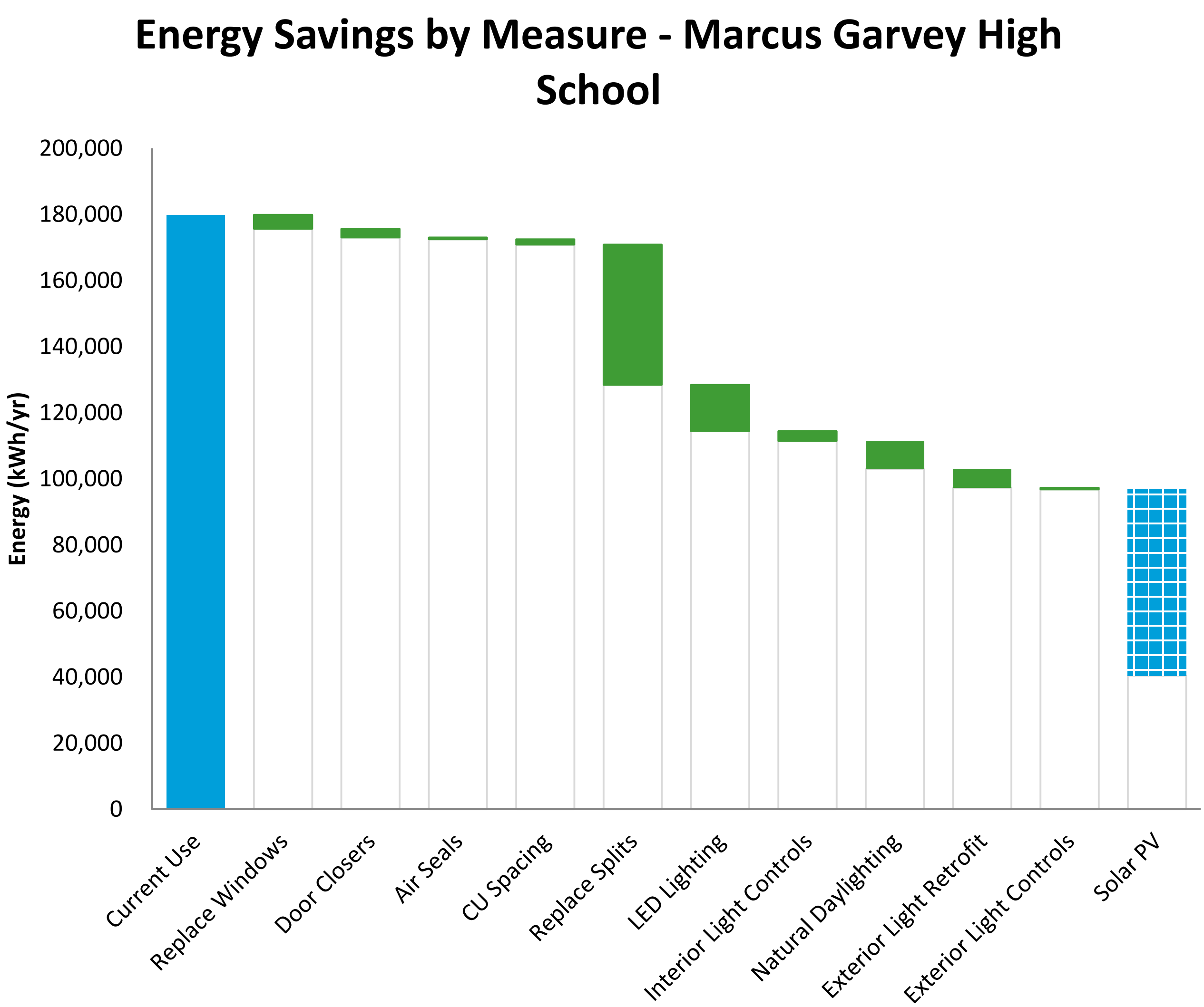
17. Perform an Investment Grade Audit of the facility to provide more in-depth analysis of building energy use as well as more accuracy for energy savings of each energy efficiency measure
18. Determine applicable funding and scope for the project
19. Draft Request for Proposal for energy efficiency implementation
20. Engage an Energy Services Company (ESCO) to install energy efficiency measures and distributed renewable energy

Based on the technical assessment performed, the following energy efficiency opportunities exist at the school.

Table 66. Marcus Garvey Key Recommendations Overview

Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Window Replacement with Insulated Glazing	4,275	$1,058	$7,085	15%	6.7
Automatic Door Closers	2,200	$544	$3,922	14%	7.2
Air Seals on Doors/Windows	593	$147	$600	24%	4.1
Proper spacing behind condensing units	1,347	$333	$1,459	23%	4.4
Replace split systems with high efficiency, inverter-driven units	36,129	$8,941	$38,530	23%	4.3
Fluorescent to LED Fixture Retrofit	27,148	$6,719	$11,301	59%	1.7
Occupancy Sensor for Interior Lights	4,892	$1,211	$5,620	22%	4.6
Installment of Solar Tubes	7,907	$1,957	$23,333	8%	11.9
Exterior Light Retrofit to LED	3,574	$885	$2,041	43%	2.3
Exterior Lighting Timer Control	1,289	$319	$500	64%	1.6
Solar PV	56,347	$13,945	$106,853	13%	7.7
Total Recommended Savings	145,701	$36,058	$201,245	18%	5.6
Total Savings (Without Renewable)	89,353	$22,113	$94,497	23%	4.3

Savings of non-renewable EEMs	50%
Annual GHG Savings (metric tons CO2)	93
15 year GHG Reduction (metric tons CO2)	1,392



Renewable Energy Recommendations

Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy photovoltaic array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 67. Marcus Garvey High School Solar Renewable Options						
Solar Option	**System Size**	**Capital Cost (USD)**	**Annual Energy Generation**	**Annual Cost Savings**	**Simple Payback**	**ROI**
Net Zero Energy	62 kW	$184,524	97,306 kWh	$24,082	7.7 years	13.1%
Maximize Onsite Opportunity	520 kW	$1,559,100	822,165 kWh	$203,472	7.7 years	13.1%
Load Matched System	36 kW	$106,853	56,347 kWh	$13,945	7.7 years	13.1%

7 EBONY HEART TRUST ACADEMY

DNV GL energy engineers performed an investment-grade audit of government buildings in Jamaica. This report provides the results of a full-day site visit of the Ebony HEART Trust Academy to gather information and compile energy efficiency investment recommendations. The nature of the deep energy-retrofit approach necessitates that the billing history and equipment inventories are provided for evaluation. The audit team included the facility managers, Ministry of Science, Energy, and Technology (MSET), representatives from the utility Petroleum Corporation of Jamaica (PCJ), and Academy operations and maintenance staff.

The goal of this work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. The project is commissioned by the Inter-American Development Bank (IDB and the goal of the work is to provide a path to widespread energy savings across municipal and federal buildings throughout Jamaica. The expected results of the project are:

- Reduced electricity consumption within government facilities
- Decreased oil imports through improved energy efficiency
- Reduced greenhouse gas (GHG) emissions that can contribute to Jamaica's INDC commitment
- An increased capacity to promote and supervise electricity planning in Jamaica

Utility analysis shows the campus energy consumption has been decreasing annually. Opportunities to further lower energy consumption through energy efficiency measures (EEMs) are summarized in **Error! Reference source not found.**. Additionally, the renewable energy analysis indicates potential electric generation that would provide large savings, implying that there is significant potential for the facility to achieve net zero energy.

7.1 Site visit summary

On June 2, 2016 DNV GL kicked off the team technical visit of Ebony Park Academy. The weather during the visit was light rain and 84°F. It was attended by representatives from MSET, PCJ, IDB, and Academy operations and maintenance staff.

An Investment Grade Audit was conducted with appropriate personnel familiar with the physical condition and day-to-day operation of the facility and equipment. Through the facility profile established during the kickoff meeting, the following systems were identified for special consideration:

- Lighting systems
- Mini-split air conditioning systems
- Agro-processing operations
- Rainwater collection and distribution
- Animal waste-to-energy potential
- Roof system for solar photovoltaic (PV) potential
- HVAC scheduling

7.2 Key recommendations

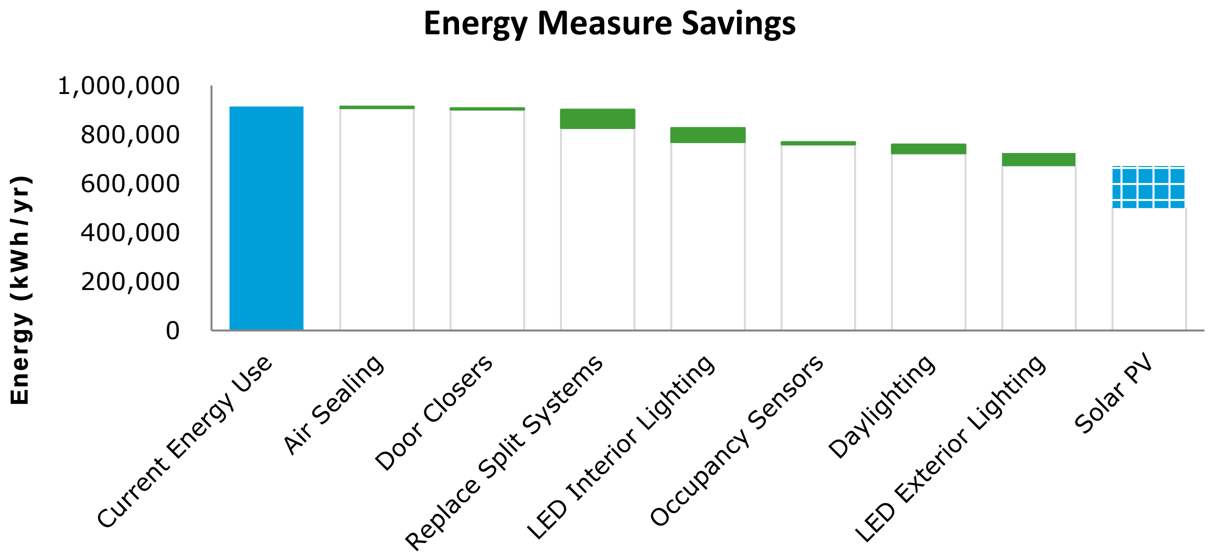
The following table outlines key recommendations for the project.

Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Air Seals on Doors and Windows	6,186	$2,003	$12,936	15%	6.5
Automatic Door Closers	6,400	$2,072	$12,000	17%	5.8
Replace Split Systems with High Efficiency, Inverter-Driven Units	74,717	$24,195	$55,860	43%	2.3
Fluorescent to LED Fixture Retrofit	57,651	$18,669	$15,134	123%	0.8
Occupancy Sensor for Interior Lights	9,662	$3,129	$7,300	43%	2.3
Installment of Solar Tubes	36,169	$11,712	$67,925	17%	5.8
Exterior Light Retrofit to LED	52,523	$13,131	$32,135	41%	2.4
Solar PV	168,170	$54,458	$318,906	17%	5.9
Total Recommendation Savings	411,477	$129,369	$562,195	23%	4.3
Total Savings (Without Renewable)	243,308	$74,912	$243,290	31%	3.2

Table 68. Ebony HEART Trust Academy Key Recommendations Overview

Savings of non-renewable EEMs	27%
Annual GHG Savings (metric tons CO2)	262
15 year GHG Reduction (metric tons CO2)	3,932

The figure below shows the current energy use and the energy savings by measure. Replacing HVAC split systems saves the most energy, followed by LED interior lighting, LED exterior lighting, and daylighting.

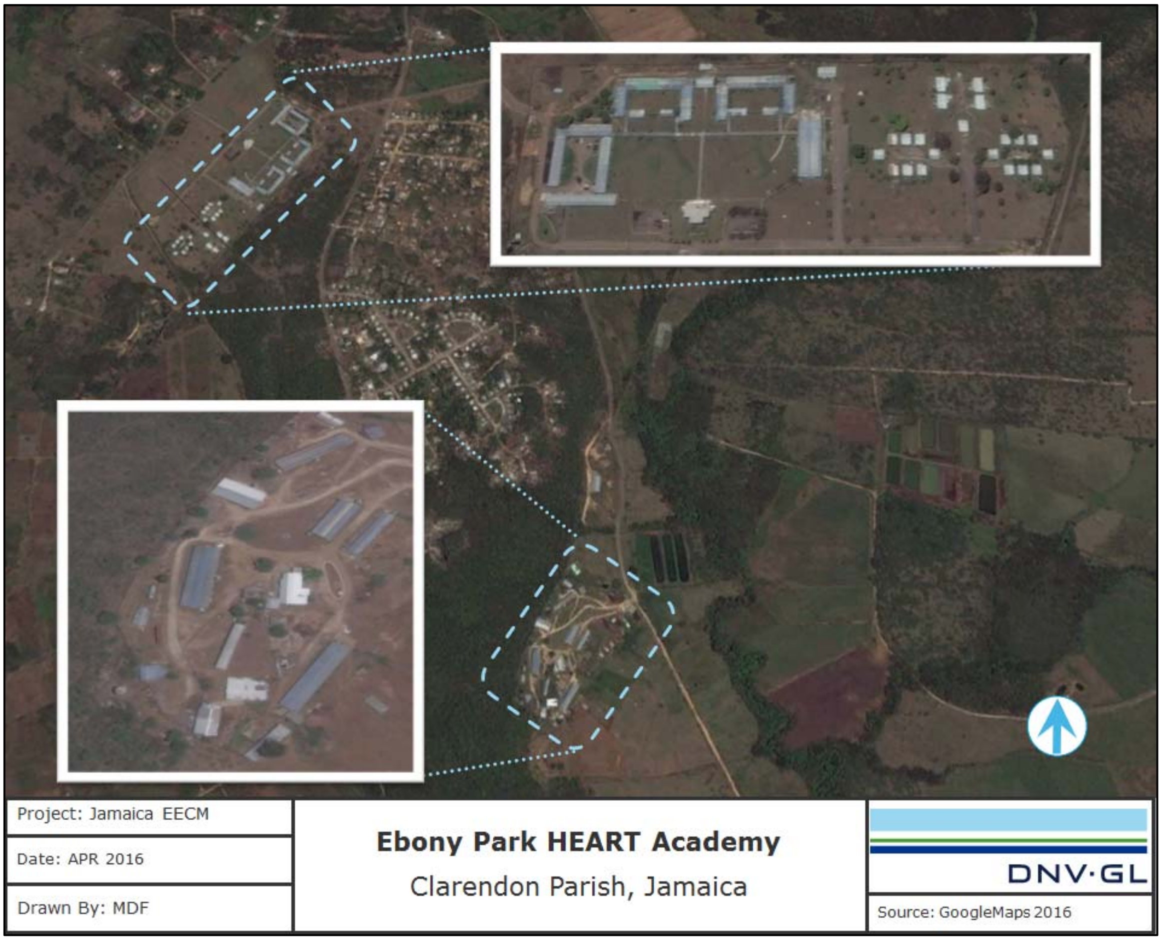


7.3 FACILITY OVERVIEW

Ebony Park HEART Academy is located centrally in the Clarendon Parish. The organization's mission is to create a workforce trained and certified to international standards and to stimulate employment-creating investments needed to generate economic growth and job creation. Facilities support both full- and part-time programs, and its facilities and staff are actively engaged in partnership with trade groups, churches, youth clubs, and other stakeholders. This location is the largest of 26 HEART academies in Jamaica.

The site is a 500 acre (200 hectare) property, including a fully functional farm with both arable land and livestock pastures. There is a 25,000 poultry house, a slaughterhouse, horticulture and dairy operations facilities, functional agro-processing operations, science laboratories, and classroom space.

Water is supplied through the National Water Commission, and there no rainwater collection or pumping system in place. The institution has a maintenance team complete with plumbers, electricians, and multi-skilled technicians. Contractors are used for all non-routine maintenance utilizing one year service contracts with three preventative maintenance visits per year. Service contractors are used for all non-routine maintenance, including split-system repairs.



7.4 UTILITY ANALYSIS

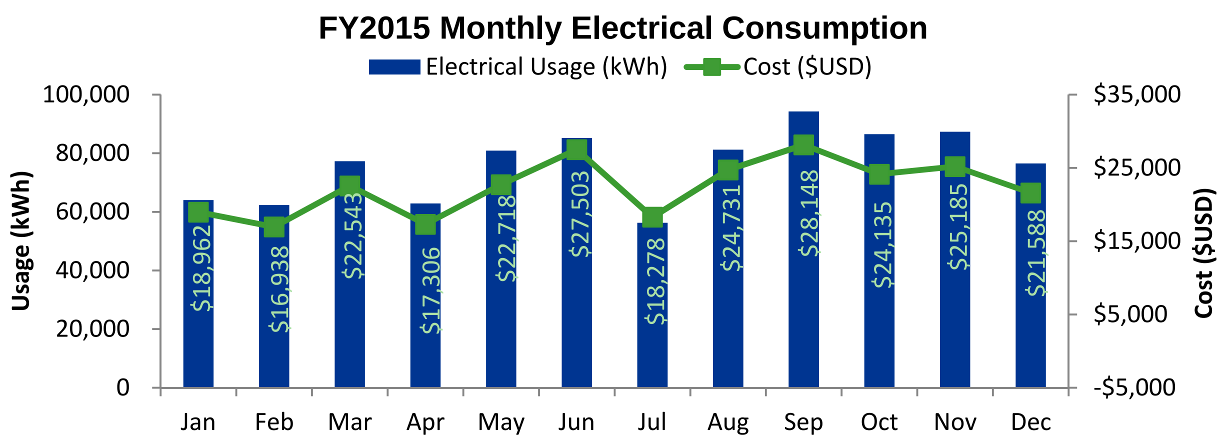
Utility data were evaluated for 2013 through 2015. Based on the provided information, electricity is the primary fuel used, with diesel fuel only utilized for the emergency generator. Water utility and other fuel types were requested but were not made available for data analysis. The table below summarizes the annual utility profile.

Annual Utility Profile Summary							
Utility	Usage*	Unit	Cost*	Unit Cost	Energy (MMBTU)	Cost %	Energy %
Electricity	914,666	kWh	$268,034	$0.32	3,121	100%	100%
Natural Gas	#N/A	Therm	#N/A	#N/A	#N/A	#N/A	#N/A
Water	#N/A	Gallons	#N/A	#N/A	#N/A	#N/A	#N/A
Annual Sum			$268,034		3,121		
Per Floor Area			$4.47		0.05		
Floor Area=		60,000 sf			1 MMBTU =	1,000,000 Btu	
Correction Power Factor =		0.67			1 kWh =	3412 Btu	
*From 2015 utility bills					1 Natural Gas Therm =	100,000 Btu	

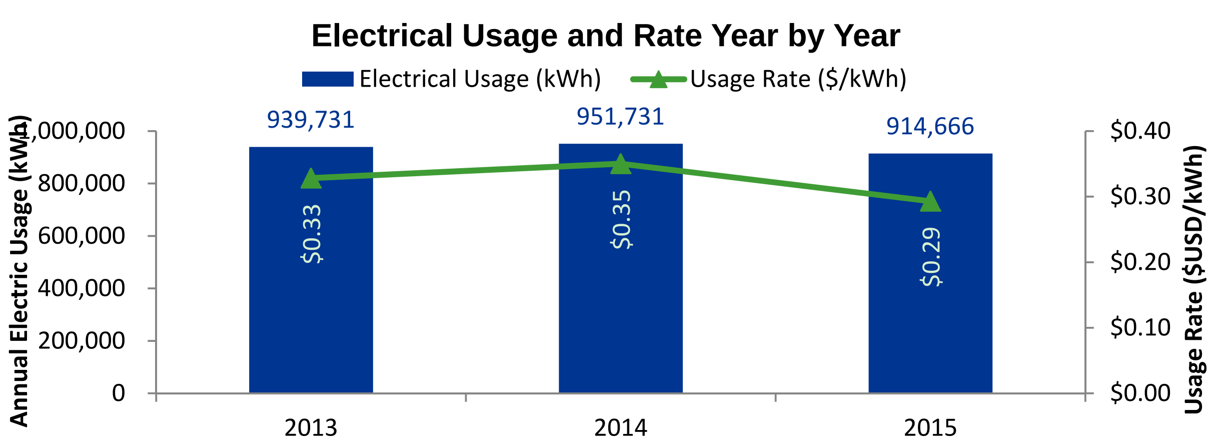
7.4.1 Electricity

Electrical usage

Electricity is supplied by Jamaica Public Service Company. The main campus facility is served by 3 meters. The facility annual assumption for year 2015 is approximately 914,666 kWh where the annual peak demand is approximately 320 kvar (this is volt ampere reative power, and is the demand value charged by the utility). As shown in the figure below, monthly electrical energy consumption stays relatively consistent with slight seasonable variation to reflect the typical weather pattern in Jamaica where the hottest months are from July to September. The unusual variance in July may be due to the lower occupancy. There is currently no active renewable energy used on site at this time.

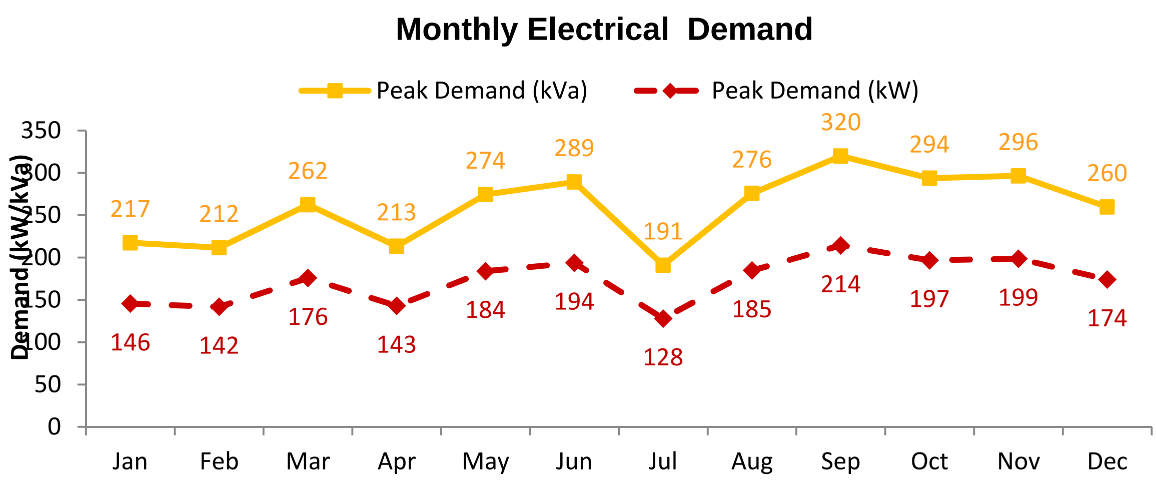


Year by year consumption trend shows that there was an increase in energy usage from 2013 to 2014 as shown in the figure below. On the other hand, there was a decrease from 2014 to 2015 that may be a result of previous efforts to implement energy efficiency measures. The average utility rate from 2013 to 2015 was $0.32 USD per kWh. To account for the potential rate fluctuation in the future, this average utility rate is used to project energy saving costs.



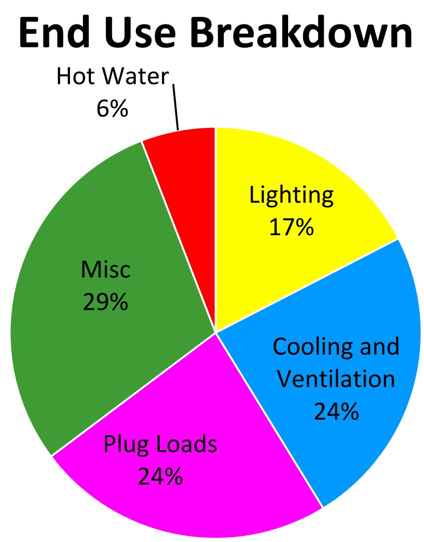
Electrical demand

The figure below shows the peak demand in kvar and the peak demand in kW (actual demand of site). The power demand data were not provided and were estimated based on the facility operational hours. The peak demand in kW is estimated based on the power factor of 0.67 measured on site for year 2016, which is lower than US standards of 0.9 or higher. Typical causes of low power factor include lowly loaded induction motors and lack of capacitors in transformer.



Load profile evaluation

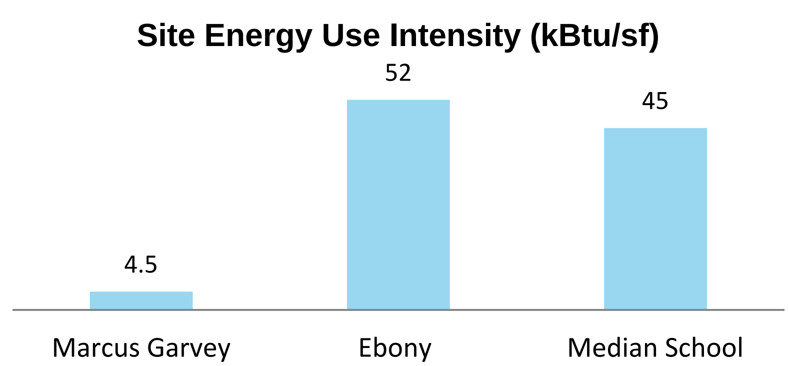
The building electrical use profile is divided into different end-use categories shown on the pie chart below. The annual end use breakdown will vary based on occupancy, operational changes, equipment maintenance, and occupant behavior. More accuracy can be garnered by adding sub-metering systems throughout the facility, which is recommended should a major electrical systems overhaul be undertaken.



Benchmarking

Energy use benchmarking is the process of comparing the energy use of a building with other similar structures. It is a critical evaluation for organizations with a large building portfolio to identify building performance and the factors that drive their energy use. The US Department of Energy has developed an energy performance rating for commercial and institutional facilities called ENERGY STAR®.

The median school energy-usage intensity (EUI) estimated by ENERGY STAR is 45 kBtu/ft^2 annually. Ebony Heart Academy utilizes 52 kBtu/ft^2 annually, which is approximately 15.5% below the median for US schools. The site has a higher EUI in compared with the median for US schools likely due to longer operation hours.



7.5 EQUIPMENT INVENTORY

7.5.1 Walk-in coolers and freezers

The existing walk-in coolers and freezers at Ebony Park seem to be at or past their rated useful life. The staff indicated that the refrigeration equipment has been having trouble maintaining temperatures, and that maintenance has been required more and more lately. Power measurements were not taken during the site visit, but the visual inspection of the existing units indicate considerable wear and tear, suggesting that new, more efficient units would be beneficial both in terms of both better food storage, as well as a reduction in energy consumption.

Table 69. Cooler and Freezer Summary

Location	Description	Age in Years	Temp (F)	Approx. Dimensions	Est. kW	Hours/ Year	Estimated kWh/Year	20% Savings
Canteen	Walk-In Freezer	>10	28	8' x 10'	6.5	6,570	42,705	8,541
Canteen	Walk-in Cooler	>10	52	8' x 10'	2.5	5,840	14,600	2,920
Kitchen Training Area	Walk-In Freezer	>10	28	8' x 10'	6.5	6,570	42,705	8,541
Kitchen Training Area	Walk-in Cooler	>10	52	8' x 10'	2.5	5,840	14,600	2,920
Slaughterhouse /Packing	Walk-In Freezer	>10	28	8' x 10'	6.5	6,570	42,705	8,541
Slaughterhouse /Packing	Walk-In Freezer	>10	28	8' x 10'	6.5	6,570	42,705	8,541
Slaughterhouse /Packing	Walk-in Cooler	>10	52	8' x 10'	2.5	5,840	14,600	2,920
Total Usage (kWh/yr)							214,620	42,924
Total Cost ($USD)							$53,655	$10,731

7.6 SAVINGS OPPORTUNITIES AND RECOMMENDATIONS

7.6.1 Building envelope

Existing conditions

Site Context and Orientation

Ebony Park Academy is located in Clarendon Parish in the farmlands of south-central Jamaica. There are three main components to the academy: a main campus, a set of dormitories, and an agriculture center complete with extensive farmland. The entire site is a 500 acre (200 hectare) property, including a fully functional farm with both arable land and livestock pastures. The orientation of these buildings varies with no intentional sun-related alignment. The campus is in direct sunlight and receives no shading from any source.

General Building Description

The main campus has 11 buildings of block construction with corrugated roofs, and the agriculture center has 22 buildings and warehouses. All corridors are exterior covered walkways, with overhands serving as shading devices for the buildings.

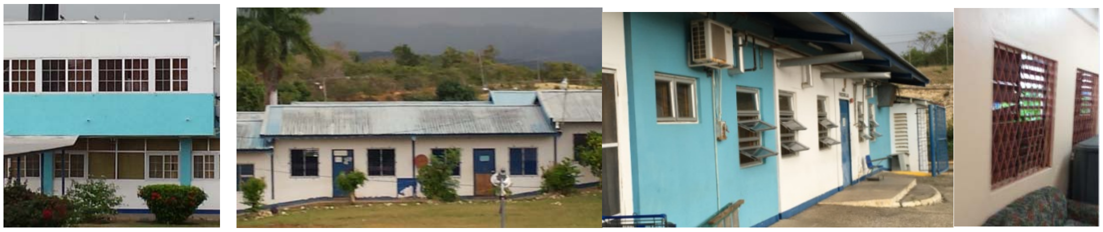
Wall and Roof Elements

Exterior and interior walls are typically uninsulated concrete, and building roofs were either bare corrugated metal or included a ceiling when the room was conditioned. A limited number of buildings included a poured-in-place concrete ceiling.

Example Roofs

Windows and Openings

The campus has exterior circulation, which allows for classrooms to incorporate operable windows, as displayed below. Curtains are used to limit direct sunlight. The buildings incorporate a number of different window treatments, including fixed glazing, glass panels, and metal louvers. The administration building has been renovated to meet modern educational requirements with computer rooms for the students, which require a conditioned space to avoid overheating.



Example Window Units

The buildings all have high levels of air leakage (with the exception of the renovated administration building), with infiltration evident through unsealed windows and doors. This leakage results in a room that remains hot even while the air conditioner is running at full load, burning energy, and decreasing the equipment's useful life. Air sealing the building envelope is one of the most critical features of an energy efficient building. Room sealing will mitigate infiltration as well as reduce potential leakage of the cool, conditioned air supply in places where there is an AC system installed.

The administration building is unique on the campus with fully concrete construction, completely retrofitted windows, and the entirety of the building conditioned using multiple mini-split systems.

Recommendations

DNV GL suggests the following measures:

1. Automatic door closers and envelope sealing

Doors were found to be open or improperly sealed, limiting the effectiveness of the cooling systems. The most cost-effective strategy to automatically close the door is using a surface-mounted regular arm door closer attached to the door frame where a spring mechanism is used to close the door. This ensures pressurization and limits infiltration, reducing the cooling power requirement.

Improperly sealed doors often are a significant source for leakage of conditioned air, causing excess energy use. A 0.125-inch gap around a typical entryway door is the equivalent of drilling a 5.5-inch-diameter hole through an outside wall. A weather seal system includes weather stripping, which covers the sides and top of the door, and a sweep, which fills the space between the threshold and the door bottom. Foam, felt, plastic, or tubular silicone weather stripping products are designed for this purpose.

Table 70. Envelope Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Air Seals on Doors and Windows	Saving is based on improved R-value.	6,186	$12,936	6.5 years
Automatic Door Closers	Saving is based on reduction of infiltration due to temperature difference.	11,645	$12,000	3.2 years

7.6.2 Electrical and mechanical systems

Existing conditions

Rooms that require conditioning, such as classrooms, offices, and in all computer rooms, use mini-split AC units. There are a variety of manufacturers and unit capacities ranging from 2 kW–4 kW rated input, and approximately 54 units in total. All of the systems used basic remote-control systems with no temporal programming capabilities.

Split System Typical Layout

A large steam boiler system (23,350 W) is set up for the agro-processing operations.

Steam System

A set of walk-in storage refrigerator and freezer are used for processing materials and products. There are 2 additional walk-in refrigerators and 1 freezer in the agricultural center. There are medium-sized exhaust hoods in the kitchen/packaging classroom that are used.

Kitchen Environmental Equipment

Recommendations

DNV GL suggests the following measures:

1. **Proper spacing behind condensing units**

   Outdoor condensing units appear to be installed without proper clearance requirements behind units. Clearance behind air-cooled condensing units is critical for both space comfort and cooling system efficiency because the air used to reject heat is pulled from behind the condensing units. Current spacing between walls and condensing units hinders airflow, resulting in reduced cooling capacity and reduced coefficient of performance.

   It is recommended that the contractor measure current condensing unit spacing and increase spacing to one inch greater than manufacturers minimum clearance requirements in order to ensure condensing units are meeting design requirements. In the event that the air conditioning system is being replaced, ensure new condensing units are installed per the manufacturer's specifications.

2. **Replace split systems with high efficiency, inverter-driven units**

   It is recommended that a high-efficiency inverter system should replace the existing split systems as they are approaching their end of useful life. Maintenance cost of the VRF system should be similar to a direct-expansion unitary system where consistent preventive maintenance to change filters and clean coil are recommended.

   Each individual unit can be controlled by a programmable thermostat, or a centralized control option would enable facility management to monitor and control the entire system from a single location.

3. **Programmable Controls or Timers**

   It is recommend that programmable setback thermostats or equipment timers be installed where possible to better manage the classrooms according to scheduling, and restrict access to facility personnel to avoid overuse. None of the currently installed units appeared to have anything by temperature controls and restricted run timers. Behavioral changes are effective at energy savings, but automatic controls present a more reliable option.

Table 71. Mechanical System Savings Recommendation Summary

Measure Name	Calculation Method	Annual Savings (kWh)	Estimated Cost (USD)	Simple Payback
Replace Split Systems with High Efficiency, Inverter-Driven Units	Saving is based on the improved unit efficiency.	74,717	$55,860	2.3 years

7.6.3 Lighting

Existing conditions

The typical interior lighting configuration in Ebony Park Academy is a manual-switch controlled set of T12 and T8 linear fluorescent fixtures. In classrooms, it was observed that often the lamps were often left off due to sufficient natural lighting. A lighting retrofit has been completed in the main administration building to switch to linear LED lamps.

Exterior lighting is primarily provided by fluorescent bulbs down exterior walkways, however there are a limited number of high-wattage CFLs.


Typical interior and exterior lighting

Recommendations

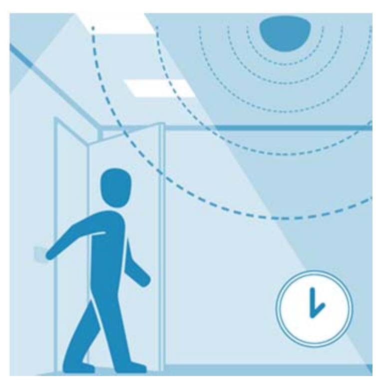
DNV GL suggests the following measures:

1. **Full LED retrofit**

   LED retrofits are one of the most beneficial and cost-effective energy savings practices available. A typical 2-lamp T12 linear fluorescent bulb with a magnetic ballast uses up to 94 W. An equivalent LED tube fixture (no ballast needed) can produce the same lighting levels with a single tube is rated at only 18 W.

   Alternatively, simply installing LED tubes with a ballast bypass into the existing fixture can be more cost-effective with a simple wiring change. T12 fixtures already have a non-shunted rapid start lamp holder, and T8 fixtures need a replacement lamp holder for use with the LED tube.

2. **Lighting controls**

   The school has proactively instituted "Green Teams" to shut off lights and HVAC systems when not in use. A recommended improvement is to install occupancy sensors to lighting for timed shutoff.

   Due to the prevalence of natural light, if LEDs are installed, daylighting photocells can be tied into the lighting controls. These controls measure the ambient light levels to appropriately match the artificial lighting with the natural light present in the space. This "daylight harvesting" technique provides energy savings, allows for the automatic control of lights, and has the additional benefit of providing appropriate task lighting for the students.

Utilizing an integrated room control (IRC) system combines these technologies and meets ASHRAE 90.1 requirements of lighting by combining receptacle control, occupancy sensing, space control, lighting control, and automatic shutoff.

3. Natural lighting

While most of the facilities have concrete roofs and are often used for night classes, the large cafeteria has a large corrugated metal roof, and is used primarily during daylight hours. This is a prime location for installation of a natural daylighting system. The two preferred options available are the installation of translucent roof paneling or solar tube daylighting.

Translucent paneling has been used elsewhere on the campus, and can provide a soft natural light to substitute for artificial lighting. Panels can be made of various colors depending on the lighting levels needed for the space.

Example of Skylights and Solatubes

Solar tube daylighting systems use a rooftop dome capture system and a diffuser on the internal ceiling to distribute a dispersed light. These units require limited structural changes to the roof, and the smaller shape of the rooftop system limits the debris buildup that is common on translucent paneling.

Table 72. Lighting Savings Recommendation Summary				
Measure Name	**Calculation Method**	**Annual Savings (kWh)**	**Estimated Cost (USD)**	**Simple Payback**
Fluorescent to LED Fixture Retrofit	Saving is based on the lower power requirement (wattage per fixture) of LED fixtures.	57,651	$15,134	< 1 year
Installment of Solar Tubes	Saving is derived from the reduced hours annually from utilizing daylighting instead of the existing light fixtures throughout the year.	36,169	$67,925	5.8 years
Occupancy Sensor for Interior Lights	Saving is based on the discounted diversity factor when occupancy sensor is installed.	9,662	$7,300	2.3 years
Exterior Light Retrofit to LED	Saving is from the lower power requirement (wattage per fixture) of LED fixtures.	52,523	$32,135	1.9 years
Exterior Lighting Timer Control	Savings is based on the reduced hours from manual lighting scheduling to automatic control.	7,398	$9,565	4.0 years

7.6.4 Water consumption

Existing conditions

The primary use of water in the facility is limited to the agro-processing lab, which currently has a solar thermal system on the roof, and uses large steamers connected to the boiler.

Recommendations

These systems appear to designed and utilized in line with their intended application and efficiency.

7.6.5 Smart building controls

Existing conditions

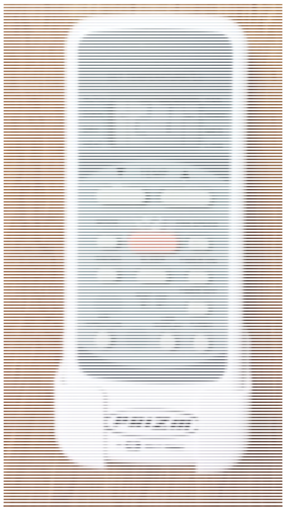
There are currently no controls available for any of the buildings on the campus. Each room's lighting and HVAC systems are controlled by manual switches or remote controls. While behavioral changes can be beneficial to improving the energy efficiency of a building, properly programmed and maintained automated control systems are more reliable.

Recommendations

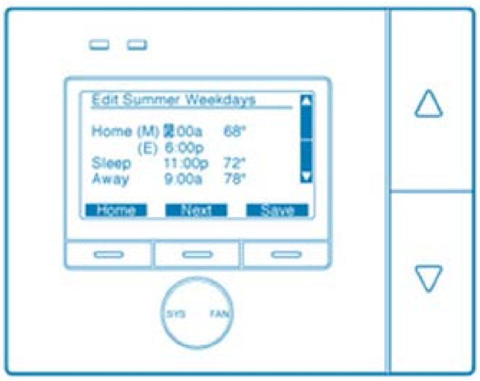
DNV GL suggests the following measures:

4. Programmable thermostats and lighting controls

Referenced in previous sections, programmable thermostats and lighting controls allow the facility managers to more accurately manage energy use throughout the facility, and to be more informed on any activity deviations.



Typical Split-System Remote Control



Typical Programmable Panel

5. Submetering

There are multiple buildings on this campus that are used on inconsistent schedules and with dissimilar equipment. In addition, the buildings are often leased out for training sessions. While there are no direct savings associated with metering, the availability of submeters empowers the facility manager to review trends and consumption, and react to deviations. The installation of submeters would allow the facility managers to track the energy use of the individual activities more closely and to bill facility rentals more accurately.

7.6.6 Renewable energy generation

Existing conditions

There are two rooftop solar thermal systems above the agro-processing lab. There are currently no solar PV systems in place on the campus. There are a large number of wide, low-slope roofs with very little shading, and peak energy use is during daytime hours, which is ideal for solar energy and hot water generation.

Recommendations

DNV GL suggests the following measures:

6. Solar Photovoltaic System

A solar analysis was performed to illustrate the potential solar opportunity at the site. The following assumptions were made regarding roof areas:

- 80% of flat roof area was assumed to be solar ready (20% unavailable for mechanical equipment, structural, and miscellaneous equipment on roof)
- 75% of pitched roof area was assumed to be solar ready (25% unavailable for mechanical equipment, structural, and miscellaneous equipment on roof)

Table 73. System Installation Criteria

Module Type	Crystalline Silicon
Array Type	Fixed (open rack)
System Losses (%)	14
Tilt (degree)	20
Azimuth (degree)	Varies with roof orientation
Roof Area Availability	80% (flat roof) 75% (pitched roof)

The analysis was performed using National Renewable Energy Laboratory (NREL)'s PVWatts® Calculator. This is an online application that estimates the electricity production of a grid-connected roof based on square footage available. The location of the school site, basic design parameters such as azimuth of roof and tilt of panel and system economics were inputs for the tool. A cost of $3/W (NREL 2015) was used for the capital cost of PV installation. A utility cost of $0.25/kWh was used as an average utility rate of electricity for the Jamaican region.

As of 2015, Jamaica Public Service company no longer allows for a net billing or net metering strategy for commercial facilities. This drastically affects the amount of solar PV that can be cost-effectively installed on a building. Since there is uncertainty around the future of net billing on the island, we provide three scenarios for the site:

- Net Zero Energy: A net zero energy PV array will produce enough energy to offset the annual demands of the facility. For this calculation we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- Maximize On-site Opportunity: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- Load Matched: In order to avoid net billing issues, the load matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 74. Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings (USD)	Simple Payback	ROI
Net Zero Energy	424 kW	$1,273,119	671,358 kWh	$217,403	5.9 years	17.1%
Maximize Onsite Opportunity	775 kW	$2,323,800	1,225,417 kWh	$396,821	5.9 years	17.1%
Load Matched System	106 kW	$318,906	168,170 kWh	$54,458	5.9 years	17.1%

The following map shows the roof areas considered in the solar analysis and the table shows the results of the solar feasibility study conducted for the site.

Table 75. Renewable Solar PV Potential

Area	Azimuth	Collector Area (square meters)	Collector Area (square feet)	KWdc	Capital Cost (USD)	Annual Energy Generation (kWh)	Annual Cost Savings
A1	225	285	3,068	42.8	$128,400	69,921	$17,480
A2	45	285	3,068	42.8	$128,400	60,692	$15,173
B1	225	112	1,206	16.9	$50,700	27,609	$6,902
B2	45	112	1,206	16.9	$50,700	23,965	$5,991
B3	135	226	2,433	33.9	$101,700	55,757	$13,939
B4	315	226	2,433	33.9	$101,700	47,668	$11,917
C1	225	143	1,539	21.4	$64,200	34,961	$8,740
C2	45	143	1,539	21.4	$64,200	30,346	$7,587
C3	135	167	1,798	25.1	$75,300	41,284	$10,321
C4	315	167	1,798	25.1	$75,300	35,294	$8,824
C5	225	139	1,496	20.9	$62,700	34,144	$8,536
C6	45	139	1,496	20.9	$62,700	29,637	$7,409
D1	225	230	2,476	34.5	$103,500	56,362	$14,091
D2	45	230	2,476	34.5	$103,500	48,922	$12,231
D3	135	163	1,755	24.4	$73,200	40,132	$10,033
D4	315	163	1,755	24.4	$73,200	34,310	$8,578
D5	225	230	2,476	34.5	$103,500	56,362	$14,091
D6	45	230	2,476	34.5	$103,500	48,922	$12,231
E1	135	296	3,186	44.4	$133,200	73,027	$18,257
E2	315	296	3,186	44.4	$133,200	62,432	$15,608
F1	225	23	248	3.1	$9,300	5,064	$1,266
F2	45	23	248	3.1	$9,300	4,396	$1,099
F3	225	23	248	3.1	$9,300	5,064	$1,266
F4	45	23	248	3.1	$9,300	4,396	$1,099
F5	225	23	248	3.1	$9,300	5,064	$1,266
F6	45	23	248	3.1	$9,300	4,396	$1,099
F7	225	23	248	3.1	$9,300	5,064	$1,266
F8	45	23	248	3.1	$9,300	4,396	$1,099
F9	225	23	248	3.1	$9,300	5,064	$1,266
F10	45	23	248	3.1	$9,300	4,396	$1,099
F11	225	23	248	3.1	$9,300	5,064	$1,266
F12	45	23	248	3.1	$9,300	4,396	$1,099
F13	225	23	248	3.1	$9,300	5,064	$1,266
F14	45	23	248	3.1	$9,300	4,396	$1,099
G1	225	76	818	11.4	$34,200	18,624	$4,656
G2	225	76	818	11.4	$34,200	18,624	$4,656
H1	225	38	409	5.7	$17,100	9,312	$2,328

H2	45	38	409	5.7	$17,100	8,083	$2,021
H3	225	38	409	5.7	$17,100	9,312	$2,328
H4	45	38	409	5.7	$17,100	8,083	$2,021
I1	225	36	388	5.4	$16,200	8,822	$2,206
I2	45	36	388	5.4	$16,200	7,657	$1,914
I3	225	36	388	5.4	$16,200	8,822	$2,206
I4	45	36	388	5.4	$16,200	7,657	$1,914
I5	225	36	388	5.4	$16,200	8,822	$2,206
I6	45	36	388	5.4	$16,200	7,657	$1,914
I7	225	36	388	5.4	$16,200	8,822	$2,206
I8	45	36	388	5.4	$16,200	7,657	$1,914
I9	225	36	388	5.4	$16,200	8,822	$2,206
I10	45	36	388	5.4	$16,200	7,657	$1,914
TOTAL		5,196	55,929	775	2,323,800	1,184,279	296,070

Disclaimer: The production estimates that PVWatts® calculates do not account for many factors that are important in the design of a PV system. These calculations should not be used to help design a system, rather seek a qualified professional to make final design decisions using more detailed engineering design and financial analysis tools. (NREL 2015)

7.6.7 Process systems

Existing conditions

Process energy encompasses energy consumed other than conditioning spaces and maintaining comfort for the occupants of a building, known as "plug load" since it refers to energy used by equipment that is plugged into an outlet. The plug load in the school consists of desktop computers, monitors, printers, and any task lighting in the classrooms and office areas, as well as microwaves and refrigerators in staff areas for individual use. Equipment that goes into standby mode and certain UPS devices with a cooling fan are still drawing power.

There are not any plug load control strategies evident on site. Low-cost plug-load control strategies are available which use manual controls or automatic sensors/timers to ensure the building isn't operating when vacant, and using energy-efficient equipment.

The vocational training at the school requires a variety of equipment with discrete high energy use, such as equipment in the agro-processing lab and training kitchen. The following table is a sample of the high-energy equipment at the school.

Table 76. Potential Plug Load Reduction Targets

Equipment Type	Typical Wattage	Number of Units
Computers	250W	60
Monitors	25W	60
Residential Refrigerators	1200 watt-hours /day*	3
Commercial Refrigerators	212-570W	3
Industrial Washer (40lb)	1500W	2
Industrial Dryer	4600W	1
Blister Packaging Machine (Koch 350027)	1500W	1
Meat Grinders	2500W	3
Walk-in Refrigerators	Varies	2
Walk-in Freezer		1

Recommendations

DNV GL suggests the following measures:

1. **Plug-Load Efficiency**

   Plug load is an unregulated demand in terms of building energy code requirements. A plug-load reduction program is to reduce energy use during non-business hours, as certain equipment acts as a parasitic energy load, and creates waste. In the case of receptacle load for a school, there are many areas such as the administration, offices, and computer labs where equipment are left unoccupied for long periods of time.

In the case of computer labs, a timer or manual on/off vacancy control device could ensure all machines power down when not needed. For individual devices, a primary/secondary power strip can be used which uses a load sensing device to disable power to some outlets when select outlets are not being used. A primary load, such as a computer, would operate independently, and when turned on would cause the device to activate secondary outlet loads, such as a monitor.

Using advanced power strips (APS) in these areas will save energy by controlling the power supplied to plug-in devices during unoccupied periods. A variety of APS technologies exist on the market that vary in complexity, control strategies, data collection abilities, and costs. Even the simplest power strips can be switched off in times of no usage could reduce the ‘standby mode’ energy consumption.

One key step in reducing receptacle energy use is to create procurement policy programs (refer to ENERGY STAR for guidance). Policies must be improved as needed to stay current with technologies. There should be ENERGY STAR appliances installed for kitchen and break rooms to further reduce electrical consumption in these spaces.

7.6.8 Training

Existing conditions

The school administration has taken an active role in reducing energy requirements for the campus. While building automation makes it possible to turn old facilities into smart buildings, the smartest control system within a building is the brain of the people who use it daily. The staff is interested and invested in improvement both academic and economic performance of the school.

Training of facilities staff as well as teachers, students, janitors, and administrative staff enables the energy efficiency measures implemented within the building to work correctly. Training can help us ensure that unnecessary lights are off, thermostats are set correctly, and the right people are notified in the event of system failure.

Recommendations

DNV GL suggests the following measures:

7. Maintenance Staff – 1-day, Post-retrofit Initial Training

When the project is complete, it is important that members of the maintenance staff are fully trained on any new building systems. Without this key final project close-out item, energy efficiency measures are destined to fail. This circumstance has been noted during our visits to some facilities in Jamaica.

We recommend the maintenance staff is trained by the contractor team after initial installation of all energy efficiency measures to ensure that the staff knows the operational requirements of all new or upgraded equipment. This should be written into the energy efficiency implementation contract.

Training should include preventative maintenance training such as recommended filter replacement cycle, oil change cycles, refrigerant testing, valve testing, cleaning of solar panels, and other preventative items specific to each energy efficiency measure.

8. Facility Managers – Annual Energy Workshop with other School Facility Managers

As facility managers test and implement new energy efficiency measures and training, it is important to share lessons learned among other school facility managers in the country. This provides an excellent opportunity for cross-learning and collaboration on a variety of issues. An annual workshop will enable a project that was successful at one school to be implemented by staff at other schools. We recommend holding the annual energy workshop in a rotating school in a major city each year. Meeting location should be determined based on whichever school has most recently received energy upgrades.

9. Annual Energy Awareness Assembly

Facility managers are not the only occupants who determine building energy use. Any building occupant armed with knowledge about energy efficiency can help reduce on-site energy usage. Closing doors to air conditioned spaces, turning off lights, properly setting thermostats, and turning equipment off when not in use is the job of the building occupant and is critical to minimizing energy use. We recommend the facility staff provide an annual energy awareness assembly to all students and staff to teach them how equipment works and how to minimize energy use in their daily lives. This will have the added benefit of helping them to save energy use at home, reducing their monthly costs as well as their carbon footprint. The assembly will be most interesting to students, as the youth are naturally drawn to environmental issues and this serves as a way to help inspire the future leaders and innovators of Jamaica.

10. Student training

Ebony Park Academy provides vocational training to the local populace, and its programs could be augmented by directed support to energy efficient technologies and practices that could be imparted on the students. The recommended equipment and tools to help identify, analyze, and implement energy savings opportunities have a high probability of programmatic use. Training could be offered through classroom-based events on the newly installed technology should each energy system be made accessible for educational purposes.

7.7 RECOMMENDATION SUMMARY

Ebony Park Academy provides an excellent opportunity for energy savings and associated carbon reduction. These savings will result in a decrease in oil dependence for the island of Jamaica, a decrease in the annual energy bill for the GoJ, and will help increase in-country capacity for energy efficiency implementation. The table below outlines the energy efficiency recommendations for the project. We recommend that the GoJ take the following steps:

21. Perform an Investment Grade Audit of the facility to provide more in-depth analysis of building energy use as well as more accuracy for energy savings of each energy efficiency measure
22. Determine applicable funding and scope for the project
23. Draft Request for Proposal for energy efficiency implementation
24. Engage an Energy Services Company (ESCO) to install energy efficiency measures and distributed renewable energy

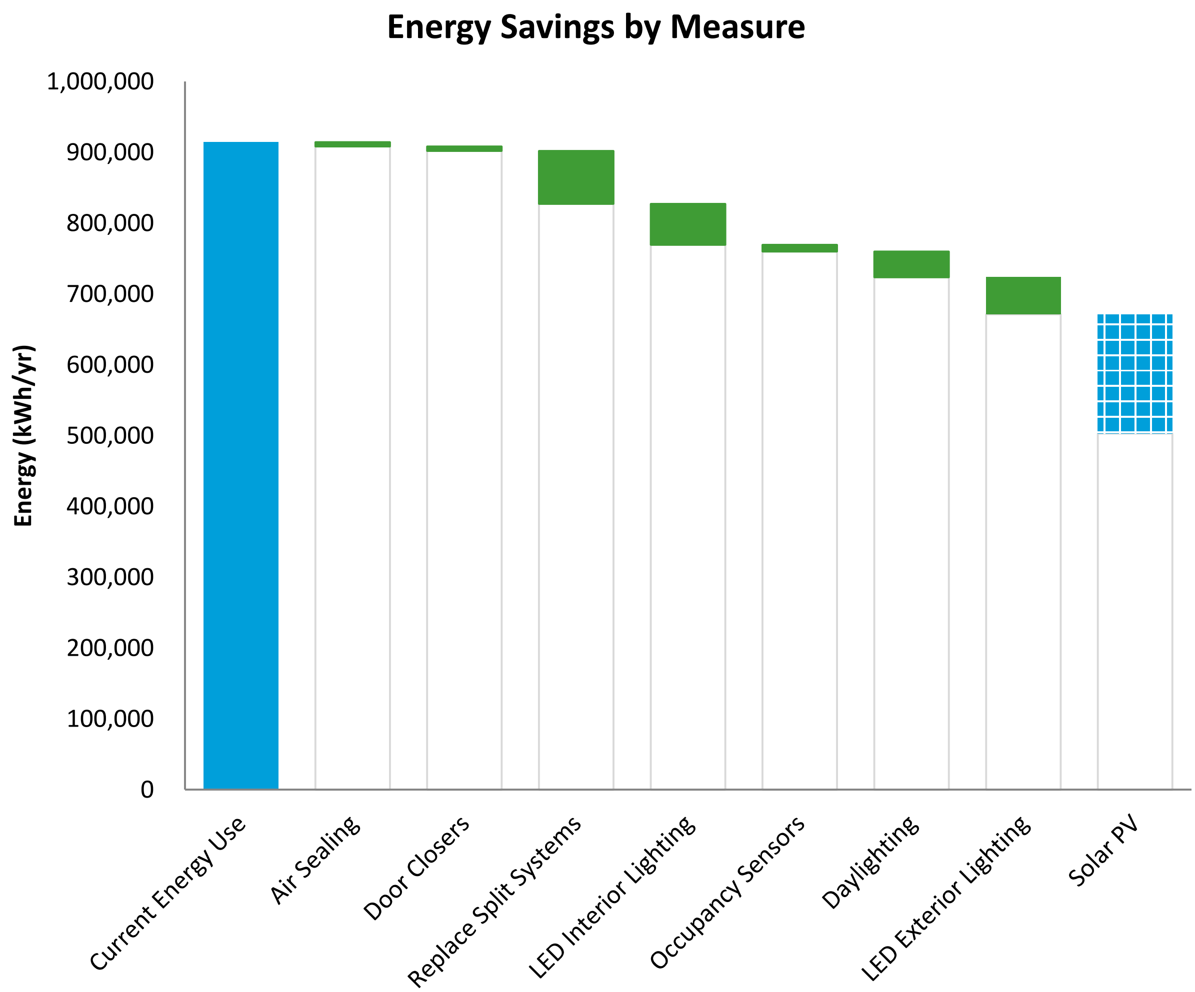
Based on the technical assessment performed, the following energy efficiency opportunities exist at the school:

Table 77. Ebony HEART Trust Academy Key Recommendations Overview

Measure Description	Savings		Payback		
	Electricity Savings (kWh)	Total Cost Savings ($ USD)	Measure Cost ($ USD)	ROI	Simple Payback (yr)
Air Seals on Doors and Windows	6,186	$2,003	$12,936	15%	6.5
Automatic Door Closers	6,400	$2,072	$12,000	17%	5.8
Replace Split Systems with High Efficiency, Inverter-Driven Units	74,717	$24,195	$55,860	43%	2.3
Fluorescent to LED Fixture Retrofit	57,651	$18,669	$15,134	123%	< 1
Occupancy Sensor for Interior Lights	9,662	$3,129	$7,300	43%	2.3
Installment of Solar Tubes	36,169	$11,712	$67,925	17%	5.8
Exterior Light Retrofit to LED	52,523	$13,131	$32,135	41%	2.4
Solar PV	168,170	$54,458	$318,906	17%	5.9
Total Recommendation Savings	411,477	$129,369	$562,195	23%	4.3

Total Savings (Without Renewable)	243,308	$74,912	$243,290	31%	3.2

Savings of non-renewable EEMs	27%
Annual GHG Savings (metric tons CO2)	262
15 year GHG Reduction (metric tons CO2)	3,932



Renewable Energy Recommendations

Since there is uncertainty around the future of net billing on the island, three scenarios are provided for the site:

- **Net Zero Energy:** A net zero energy PV array will produce enough energy to offset the annual demands of the facility. For this calculation, we have assumed significant energy savings based on the report's other energy efficiency recommendations.
- **Maximize On-site Opportunity**: This option assumes all available roof area, parking lot, and ground-mounted opportunities are utilized. It represents the maximum amount of solar available on the site.
- **Load Matched**: In order to avoid net billing issues, the load-matched options ensures that the building will always use all the solar energy it produces and will not overproduce to the utility at a given time. The potential system size is substantially lower than other options, but is feasible today, regardless of current legislative barriers to distributed renewable energy.

The table below represents the options outlined above.

Table 78. Solar Renewable Options

Solar Option	System Size	Capital Cost (USD)	Annual Energy Generation	Annual Cost Savings (USD)	Simple Payback	ROI
Net Zero Energy	424 kW	$1,273,119	671,358 kWh	$217,403	5.9 years	17.1%
Maximize Onsite Opportunity	775 kW	$2,323,800	1,225,417 kWh	$396,821	5.9 years	17.1%
Load Matched System	106 kW	$318,906	168,170 kWh	$54,458	5.9 years	17.1%

8 APPENDIX A – UTILITY BILLS

8.1 KPH Utility Bills

Month-Year	Usage (kWh)	Demand (kVA)	Cost (J)	Cost (USD)
Jan-13	570,360	1531.04	J$ 17,065,996.23	$139,885
Feb-13	502,382	1497.6	J$ 15,606,165.52	$127,919
Mar-13	561,568	1534.4	J$ 19,326,213.59	$158,412
Apr-13	546,415	1509.2	J$ 17,727,218.22	$145,305
May-13	594,192	1246.9	J$ 19,025,270.76	$155,945
Jun-13	667,252	1641.5	J$ 19,203,215.59	$157,403
Jul-13	660,903	1655.5	J$ 20,546,452.46	$168,414
Aug-13	629,965	1644	J$ 18,904,466.12	$154,955
Sep-13	624,748	1654	J$ 20,596,350.58	$168,823
Oct-13	609,504	1616	J$ 20,935,593.39	$171,603
Nov-13	575,661	1570	J$ 18,965,395.14	$155,454
Dec-13	550,934	1535	J$ 18,528,693.05	$151,875
Jan-14	511,126	1424.8	J$ 17,416,133.15	$142,755
Feb-14	489,146	1455	J$ 16,123,856.29	$132,163
Mar-14	535,762	1419	J$ 19,424,942.57	$159,221
Apr-14	519,362	1504	J$ 16,858,563.64	$138,185
May-14	536,170	1398	J$ 19,107,446.21	$156,618
Jun-14	563,322	1542	J$ 18,828,671.44	$154,333
Jul-14	613,136	1603	J$ 21,578,339.81	$176,872
Aug-14	590,391	1568	J$ 19,907,003.08	$163,172
Sep-14	573,897	1533	J$ 19,930,637.26	$163,366
Oct-14	564,920	1487.2	J$ 19,532,091.02	$160,099
Nov-14	538,714	1456	J$ 16,890,675.59	$138,448
Dec-14	485,324	1348	J$ 14,905,436.64	$122,176
Jan-15	514,187	1324	J$ 14,081,075.51	$115,419
Feb-15	463,046	1433	J$ 11,516,667.73	$94,399
Mar-15	552,802	1482	J$ 14,800,248.34	$121,314
Apr-15	515,147	1414.4	J$ 12,595,336.72	$103,240
May-15	568,820	1443	J$ 14,189,376.10	$116,306
Jun-15	585,562	1501	J$ 17,724,066.21	$145,279
Jul-15	583,986	1538	J$ 17,980,294.66	$147,379
Aug-15	601,466	1494	J$ 16,804,035.79	$137,738

Sep-15	562,846	1466	J$ 15,443,785.53	$126,588
Oct-15	586,649	1477	J$ 14,629,564.63	$119,914
Nov-15	560,709	1477	J$ 14,724,734.98	$120,695
Dec-15	532,526	1477	J$ 13,737,433.07	$112,602
Jan-16	530,826	1478	J$ 13,023,800.57	$106,752
Feb-16	467,198	1479	J$ 941,261.30	$7,715
Mar-16	511,922	1345	J$ 11,608,831.96	$95,154
Apr-16	536,644	1441	J$ 11,348,691.62	$93,022

8.2 Cornwall Regional Hospital Utility Bills

Time	YEAR	kWh	kVA	Cost
Jan-11	2011	311,371	N/A	J$ 7,151,474
Feb-11	2011	287,748	N/A	J$ 6,744,741
Mar-11	2011	316,541	N/A	J$ 8,321,394
Apr-11	2011	331,366	N/A	J$ 8,468,247
May-11	2011	358,222	N/A	J$ 9,639,320
Jun-11	2011	364,810	N/A	J$ 10,335,887
Jul-11	2011	386,813	N/A	J$ 10,877,959
Aug-11	2011	380,837	N/A	J$ 10,049,271
Sep-11	2011	363,089	N/A	J$ 9,947,676
Oct-11	2011	361,670	N/A	J$ 10,033,911
Nov-11	2011	349,243	N/A	J$ 9,413,777
Dec-11	2011	314,431	N/A	J$ 8,769,085
Jan-12	2012	312,206	662	J$ 8,394,726
Feb-12	2012	305,856	698	J$ 8,836,979
Mar-12	2012	330,242	713	J$ 9,621,221
Apr-12	2012	325,987	691	J$ 9,369,376
May-12	2012	367,358	806	J$ 10,998,442
Jun-12	2012	380,686	799	J$ 10,519,363
Jul-12	2012	372,521	806	J$ 9,820,763
Aug-12	2012	372,096	785	J$ 8,470,421
Sep-12	2012	369,338	778	J$ 10,304,270
Oct-12	2012	355,882	756	J$ 10,626,601
Nov-12	2012	334,166	720	J$ 10,002,578
Dec-12	2012	332,215	713	J$ 9,986,087
Jan-13	2013	335,894	713	J$ 9,597,061
Feb-13	2013	300,701	670	J$ 8,848,730
Mar-13	2013	326,160	662	J$ 10,710,105
Apr-13	2013	342,252	734	J$ 10,571,631
May-13	2013	359,590	763	J$ 11,315,055
Jun-13	2013	380,686	799	J$ 10,519,363
Jul-13	2013	383,335	799	J$ 11,438,092
Aug-13	2013	379,102	792	J$ 10,821,961
Sep-13	2013	366,350	785	J$ 11,534,927
Oct-13	2013	382,068	785	J$ 12,514,198
Nov-13	2013	372,888	785	J$ 11,671,229
Dec-13	2013	351,698	727	J$ 11,207,109
Jan-14	2014	346,176	713	J$ 11,160,151
Feb-14	2014	320,954	713	J$ 9,954,550
Mar-14	2014	356,328	763	J$ 12,366,250
Apr-14	2014	360,670	763	J$ 10,985,176
May-14	2014	366,264	770	J$ 12,471,463

Jun-14	2014	350,647	778	J$ 11,151,194
Jul-14	2014	382,961	792	J$ 12,851,927
Aug-14	2014	419,083	828	J$ 13,316,221
Sep-14	2014	368,539	806	J$ 12,207,639
Oct-14	2014	376,805	806	J$ 12,428,569
Nov-14	2014	361,807	785	J$ 10,754,062
Dec-14	2014	331,754	713	J$ 9,593,822
Jan-15	2015	341,287	720	J$ 8,831,610
Feb-15	2015	300,672	698	J$ 6,858,545
Mar-15	2015	355,622	828	J$ 9,028,381
Apr-15	2015	352,750	922	J$ 8,248,229
May-15	2015	394,610	1,008	J$ 9,530,016
Jun-15	2015	389,398	1,015	J$ 11,431,058
Jul-15	2015	425,664	1,037	J$ 12,523,493
Aug-15	2015	428,364	1,066	J$ 11,557,583
Sep-15	2015	420,509	1,080	J$ 11,077,380
Oct-15	2015	410,702	1,022	J$ 9,794,288
Nov-15	2015	386,100	994	J$ 9,678,089
Dec-15	2015	370,094	986	J$ 9,065,895
Jan-16	2016	360,526	922	J$ 8,308,140
Feb-16	2016	354,557	1,015	J$ 7,910,645
Mar-16	2016	424,238	1,094	J$ 9,252,796
Apr-16	2016	438,710	1,116	J$ 8,658,226

8.3 Mandeville Hospital Utility Bills

Year	Month	Usage (kWh)	Cost ($J)	Cost ($USD)
2010	Jan	112,992	$J 2,686,738	$22,022
2010	Feb	104,628	$J 2,604,903	$21,352
2010	Mar	112,176	$J 2,659,924	$21,803
2010	Apr	105,768	$J 2,288,452	$18,758
2010	May	120,420	$J 2,636,581	$21,611
2010	Jun	116,532	$J 2,555,029	$20,943
2010	Jul	128,616	$J 2,752,111	$22,558
2010	Aug	108,660	$J 2,348,054	$19,246
2010	Sep	98,556	$J 2,193,702	$17,981
2010	Oct	88,512	$J 2,004,765	$16,432
2010	Nov	86,376	$J 2,010,468	$16,479
2010	Dec	76,488	$J 1,926,653	$15,792
2011	Jan	82,764	$J 2,059,197	$16,879
2011	Feb	75,780	$J 1,909,503	$15,652
2011	Mar	78,216	$J 2,188,895	$17,942
2011	Apr	81,156	$J 2,225,188	$18,239
2011	May	87,768	$J 2,514,904	$20,614
2011	Jun	85,044	$J 2,543,862	$20,851
2011	Jul	95,364	$J 2,838,082	$23,263
2011	Aug	101,808	$J 2,811,366	$23,044
2011	Sep	97,692	$J 2,838,301	$23,265
2011	Oct	98,196	$J 2,866,973	$23,500
2011	Nov	93,360	$J 2,629,539	$21,554
2011	Dec	66,132	$J 2,006,540	$16,447
2012	Jan	82,788	$J 2,369,733	$19,424
2012	Feb	79,824	$J 2,425,872	$19,884
2012	Mar	80,148	$J 2,452,415	$20,102
2012	Apr	84,300	$J 2,564,236	$21,018
2012	May	83,460	$J 2,619,631	$21,472
2012	Jun	87,216	$J 2,549,047	$20,894
2012	Jul	87,432	$J 2,435,381	$19,962
2012	Aug	84,300	$J 2,035,934	$16,688
2012	Sep	87,504	$J 2,569,505	$21,062
2012	Oct	82,356	$J 2,597,930	$21,295
2012	Nov	86,472	$J 2,713,973	$22,246
2012	Dec	37,920	$J 1,333,352	$10,929

2013	Jan	42,084	$J 2,295,533	$18,816
2013	Feb	77,032	$J 2,141,040	$17,550
2013	Mar	67,912	$J 2,761,228	$22,633
2013	Apr	83,364	$J 2,718,114	$22,280
2013	May	92,160	$J 3,046,685	$24,973
2013	Jun	84,148	$J 2,597,756	$21,293
2013	Jul	86,524	$J 2,707,276	$22,191
2013	Aug	90,708	$J 2,735,417	$22,421
2013	Sep	96,948	$J 3,211,476	$26,324
2013	Oct	93,668	$J 3,279,658	$26,882
2013	Nov	111,056	$J 3,802,288	$31,166
2013	Dec	121,576	$J 4,054,251	$33,232
2014	Jan	108,652	$J 3,752,323	$30,757
2014	Feb	101,532	$J 3,366,985	$27,598
2014	Mar	120,852	$J 4,450,359	$36,478
2014	Apr	115,176	$J 3,760,123	$30,821
2014	May	115,960	$J 4,134,136	$33,886
2014	Jun	129,520	$J 4,255,891	$34,884
2014	Jul	140,424	$J 4,888,522	$40,070
2014	Aug	137,552	$J 4,706,053	$38,574
2014	Sep	137,396	$J 4,739,553	$38,849
2014	Oct	130,248	$J 4,533,149	$37,157
2014	Nov	118,560	$J 3,736,856	$30,630
2014	Dec	114,540	$J 3,541,686	$29,030
2015	Jan	116,512	$J 3,246,940	$26,614
2015	Feb	98,056	$J 2,422,772	$19,859
2015	Mar	112,216	$J 2,991,958	$24,524
2015	Apr	120,820	$J 2,910,559	$23,857
2015	May	135,584	$J 3,319,661	$27,210
2015	Jun	125,688	$J 3,236,655	$26,530
2015	Jul	135,348	$J 3,535,938	$28,983
2015	Aug	140,012	$J 3,361,891	$27,556
2015	Sep	133,848	$J 3,162,084	$25,919
2015	Oct	136,296	$J 2,974,026	$24,377
2015	Nov	130,736	$J 3,001,093	$24,599
2015	Dec	123,596	$J 2,799,193	$22,944

8.4 Falmouth Hospital Utility Bills

Date	Usage (kWh)	Demand (kVA)	Cost ($J)	Cost ($USD)
2/9/2015	53,009	169	$J 1,502,193	$12,313
3/9/2015	46,705	169	$J 1,200,439	$9,840
4/9/2015	57,112	169	$J 1,550,563	$12,710
5/9/2015	56,337	169	$J 1,393,165	$11,419
6/9/2015	63,756	151	$J 1,565,230	$12,830
7/9/2015	62,641	146	$J 1,857,307	$15,224
8/9/2015	66,133	175	$J 1,926,316	$15,789
9/9/2015	69,625	205	$J 1,995,325	$16,355
10/9/2015	64,942	203	$J 1,834,900	$15,040
11/9/2015	55,641	164	$J 1,423,098	$11,665
12/9/2015	48,761	164	$J 1,340,186	$10,985
1/9/2016	59,137	164	$J 1,512,654	$12,399
2/9/2016	57,722	164	$J 1,411,686	$11,571
3/9/2016	50,742	163	$J 1,214,162	$9,952
4/9/2016	57,710	139	$J 1,290,201	$10,575

8.5 Marcus Garvey High School Utility Bills

Year	Month	kWh	Cost (J$)	Cost (USD)
2011	1	16,497	$J 484,908	$3,975
2011	2	15,187	$J 452,507	$3,709
2011	3	15,667	$J 512,791	$4,203
2011	4	14,621	$J 470,135	$3,854
2011	5	15,849	$J 531,432	$4,356
2011	6	14,172	$J 494,309	$4,052
2011	7	8,407	$J 293,814	$2,408
2011	8	8,473	$J 281,024	$2,303
2011	9	14,083	$J 484,783	$3,974
2011	10	16,937	$J 582,777	$4,777
2011	11	16,845	$J 564,685	$4,629
2011	12	11,469	$J 396,050	$3,246
2012	1	14,452	$J 484,734	$3,973
2012	2	15,184	$J 537,039	$4,402
2012	3	16,714	$J 597,661	$4,899
2012	4	13,426	$J 475,937	$3,901
2012	5	17,102	$J 624,886	$5,122
2012	6	15,753	$J 541,840	$4,441
2012	7	10,602	$J 351,835	$2,884
2012	8	9,388	$J 277,793	$2,277
2012	9	13,910	$J 482,625	$3,956
2012	10	15,804	$J 597,439	$4,897
2012	11	18,077	$J 679,586	$5,570
2012	12	15,589	$J 601,628	$4,931
2013	1	20,239	$J 757,016	$6,205
2013	2	12,348	$J 449,863	$3,687
2013	3	17,441	$J 723,758	$5,932
2013	4	15,208	$J 598,212	$4,903
2013	5	17,298	$J 689,024	$5,648
2013	6	16,033	$J 603,702	$4,948
2013	7	11,219	$J 437,982	$3,590
2013	8	10,803	$J 411,501	$3,373
2013	9	16,330	$J 667,429	$5,471
2013	10	17,442	$J 750,191	$6,149
2013	11	17,399	$J 717,616	$5,882
2013	12	12,841	$J 547,813	$4,490
2014	1	14,008	$J 595,498	$4,881
2014	2	16,271	$J 669,479	$5,488
2014	3	17,477	$J 787,942	$6,459

2014	4	15,358	$J 628,797	$5,154
2014	5	20,658	$J 928,591	$7,611
2014	6	15,492	$J 645,011	$5,287
2014	7	11,047	$J 488,228	$4,002
2014	8	11,632	$J 499,321	$4,093
2014	9	15,327	$J 668,883	$5,483
2014	10	15,717	$J 682,805	$5,597
2014	11	15,499	$J 619,809	$5,080
2014	12	11,439	$J 451,821	$3,703
2015	1	6,285	$J 237,174	$1,944
2015	2	3,987	$J 143,002	$1,172
2015	3	6,198	$J 231,309	$1,896
2015	4	5,194	$J 181,198	$1,485
2015	5	8,270	$J 290,120	$2,378
2015	6	6,795	$J 247,562	$2,029
2015	7	4,505	$J 165,577	$1,357
2015	8	3,539	$J 122,739	$1,006
2015	9	5,929	$J 200,401	$1,643
2015	10	11,561	$J 353,032	$2,894
2015	11	14,689	$J 460,992	$3,779
2015	12	11,627	$J 359,170	$2,944
2016	1	13,280	$J 393,540	$3,226
2016	2	12,365	$J 353,040	$2,894
2016	3	13,585	$J 386,732	$3,170
2016	4	13,883	$J 367,797	$3,015

8.6 Ebony Park Heart Trust Academy Utility Bills

Year	Month	Usage (kWh)	Cost (J$)	Cost ($USD)
2012	Jun	103,920	3,655,853	29,966
2012	Jul	93,186	3,220,763	26,400
2012	Aug	87,692	2,690,868	22,056
2012	Sep	96,270	3,500,915	28,696
2012	Oct	70,159	2,703,734	22,162
2012	Nov	62,735	2,459,705	20,162
2012	Dec	55,250	2,176,491	17,840
2013	Jan	84,697	3,117,732	25,555
2013	Feb	82,641	3,124,778	25,613
2013	Mar	66,661	2,842,408	23,298
2013	Apr	69,952	2,804,890	22,991
2013	May	103,955	4,192,128	34,362
2013	Jun	96,279	3,675,072	30,124
2013	Jul	91,987	3,571,454	29,274
2013	Aug	2,414	89,737	736
2013	Sep	90,034	3,591,533	29,439
2013	Oct	86,528	3,735,674	30,620
2013	Nov	83,631	3,478,383	28,511
2013	Dec	80,952	3,406,452	27,922
2014	Jan	73,205	3,112,119	25,509
2014	Feb	75,982	3,123,021	25,599
2014	Mar	83,780	3,800,072	31,148
2014	Apr	80,419	3,276,394	26,856
2014	May	82,085	3,675,693	30,129
2014	Jun	83,865	3,543,300	29,043
2014	Jul	87,295	3,900,202	31,969
2014	Aug	78,079	3,385,939	27,754
2014	Sep	80,705	3,527,886	28,917
2014	Oct	81,808	3,566,359	29,232
2014	Nov	77,399	3,117,198	25,551
2014	Dec	67,109	2,634,981	21,598
2015	Jan	64,026	2,313,345	18,962
2015	Feb	62,336	2,066,474	16,938
2015	Mar	77,305	2,750,266	22,543
2015	Apr	62,849	2,111,273	17,306
2015	May	80,862	2,771,635	22,718
2015	Jun	85,192	3,355,316	27,503
2015	Jul	56,247	2,229,879	18,278
2015	Aug	81,236	3,017,144	24,731
2015	Sep	94,236	3,434,104	28,148

2015	Oct	86,528	2,944,461	24,135
2015	Nov	87,321	3,072,543	25,185
2015	Dec	76,528	2,633,677	21,588
2016	Jan	79,692	2,637,891	21,622
2016	Feb	56,053	1,787,472	14,651
2016	Mar	85,263	2,721,525	22,308

9 APPENDIX B – EQUIPMENT SCHEDULES

9.1 KPH Equipment Inventory

Lighting Equipment Summary			
Approximate Fixture Quantity	Type	Watts Per Fixture	Total Watts
30	Compact Fluorescent	25	750
11	Incandescent Bulb	75	825
68	T-12, 2ft	30	2,040
3621	T-12, 4ft	47	168,377
1	T-12, 5ft	75	75
497	T-12, 6ft	85	42,245
94	T-8, 2ft	18	1,692
289	T-8, 4ft	36	10,404
2	T-8,5ft	58	116
43	T-8,6ft	70	3,010

Mechanical System Count		
Description	Size	Quantity
Air Cooled Chiller	Vary	2
Constant Volume Supply Pumps	15 HP	2
Air Handling Units	Vary	3
Kitchen Exhaust	Vary	2
Steam Boiler	10,461 MBH / 8,368 MBH	2

Split DX Unit Count In Measure		
Unit Size (Btu)	Unit Size (Tons)	Quantity
12,000	1	70
24,000	2	12
9,000	0.75	8
18,000	1.5	3
13,000	1.08	3

9.2 Cornwall Regional Hospital Equipment Inventory

Summary of Estimated Split DX Unit Counts		
Count	**Type**	**Approximate Size (Tons)**
96	Split	1
128	Split	1.5
96	Split	2

9.3 Mandeville Hospital Equipment Inventory

Summary of Lighting Equipment			
Approximate Quantity	Description	Watts per Fixture	Total Watts
345	4' Flourescent lamp double (T8)	72	24,840
505	4' Flourescent lamp trough (T8)	144	72,720
24	2' Flourescent lamp double (T8)	18	432
56	2' Flourescent lamp trough (T8)	72	4,032
9	4' Flourescent lamp double (T12)	72	648
60	bug head lamp	28	1,680
6	2' Flourescent lamp single (T8)	18	108
27	2' Flourescent lamp (single) (T8)	18	486
5	4' Flourescent lamp single(T8)	36	180
11	incandescent lamp	30	330
7	4' Flourescent lamp single (T8)	36	252
10	4' Flourescent lamp trough (T12)	178	1,780
10	2' Flourescent lamp double (T12)	89	890
6	2' Flourescent lamp single (T12)	89	534
30	4' Flourescent lamp tripple (T8)	108	3,240
15	2' Flourescent lamp tripple (T8)	54	810
6	2' Flourescent lamp (T8)	18	108

9.4 Falmouth Hospital Equipment Inventory

Summary of Lighting Count			
Approximate Fixture Count	Type	LPD (W/fixt)	Total Watts
30	CFL	25	750
29	Incandescent	75	2,175
101	T-12 2ft	20	2,020
304	T-12 4ft	40	12,160
1	T-12 6ft	85	85
106	T8 2ft	28	2,968
265	T8 4ft	36	9,540
12	PAR 38	75	900
29	HPS	100	2,900
6	MV	150	900

Summary of Mechanical Equipment		
Quantity	Type	Size (HP/Tons)
25	Split DX	1 – 3 Tons
2	RTUs w/ Supply & Return Fans	10 HP Supply / 7.5 HP Return
1	Air Compressor	Approx. 10 HP
4	Ducted Split System	25 Tons
1	Natural Gas Boiler	
1	Residential Water Heater	

9.5 Marcus Garvey High School Equipment Inventory

Lighting Inventory by Location

Building Name	Fixture Type	Fixture Quantity	Wattage	Occupied Hours/Year	% On When Occupied Estimated or Actual
Admin Block C	5' LED Tube	9	23	2,161	0.35
Admin Block C	2-Lamp 4' T8	8	52	2,161	1
Admin Block C	1-Lamp 5' T8/T12	9	59	2,161	0.35
Admin Block C	1-Lamp 5' T8/T12	9	59	2,161	0.35
Admin Block C	1-Lamp 5' T8/T12	6	59	2,161	0.35
Admin Block C	1-Lamp 5' T8/T12	3	59	2,161	0.35
Admin Block C	2-Lamp 4' T12 w/mag	1	72	2,161	1
Admin Block C	1-Lamp 5' T12 w/mag	1	63	2,161	1
Admin Block C	2-lamp 4' LED	1	36	2,161	1
Admin Block C	2-lamp 4' LED	1	36	2,161	1
Admin Block C	2-lamp 4' LED	1	36	2,161	1
Admin Block C	1-lamp 4' LED	1	18	2,161	1
Admin Block C	2-Lamp 2' LED	1	18	2,161	1
Admin Block C	1-Lamp 5' T8 w/mag.	1	55	2,161	1
Admin Block C	1-lamp 4' LED	8	18	2,161	0.8
Admin Block C	1-Lamp 4' T8 w/mag	7	32	2,161	0.8
Admin Block C	1-Lamp 5' T8 w/mag.	9	55	2,161	1
Admin Block C	2-Lamp 4' T12 w/mag	2	72	2,161	1
Admin Block C	2-Lamp 4' T12 w/mag	3	72	2,161	1
Admin Block C	14 Watt CFL	6	14	2,161	1
Science Block E	2-Lamp 4' T12 w/mag	12	72	2,283	0.35
Science Block E	2-Lamp 4' T12 w/mag	3	72	2,283	0.7
Science Block E	2-Lamp 4' T12 w/mag	15	72	2,283	0.35
Science Block E	2-Lamp 4' T12 w/mag	12	72	2,283	0.35
Science Block E	2-Lamp 4' T12 w/mag	3	72	2,283	1
Science Block E	2-Lamp 4' T12 w/mag	12	72	2,283	0.35
Block D	2-lamp 4' LED	2	36	1,917	0.35
Block D	2-Lamp 5' T12 w/mag	8	128	1,917	0.8
Block D	1-Lamp 5' T12 w/mag	8	63	1,917	1
Block D	1-Lamp 4' T12 w/ mag	1	43	1,917	1
Block D	2-Lamp 5' T12 w/mag	1	128	1,917	0.35
Block D	2-Lamp 5' T8 w/ mag	1	112	1,917	1
Block D	2-Lamp 5' T8 w/ mag	1	112	1,917	1
Block D	1-Lamp 5' T12 w/mag	6	63	1,917	0.35
Block D	1-Lamp 5' T12 w/mag	6	63	1,917	0.35
Block D	1-Lamp 5' T12 w/mag	6	63	1,917	0.35
Block D	1-Lamp 5' T12 w/mag	6	63	1,917	0.35

Building Name	Fixture Type	Fixture Quantity	Wattage	Occupied Hours/Year	% On When Occupied Estimated or Actual
Block D	1-Lamp 5' T12 w/mag	6	63	1,917	1
Block D	14 Watt CFL	8	14	1,917	1
Block D	50 Watt Metal Halide	1	72	1,917	1
Industrial Arts Block F	1-Lamp 5' T8 w/mag.	3	55	1,673	1
Industrial Arts Block F	1-Lamp 5' T8 w/mag.	2	55	1,673	1
Industrial Arts Block F	1-Lamp 5' T8 w/mag.	9	55	1,673	0.35
Industrial Arts Block F	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Industrial Arts Block F	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Industrial Arts Block F	1-Lamp 5' T12 w/mag	6	63	1,673	0.35
Industrial Arts Block F	1-lamp 4' LED	1	18	1,673	1
Industrial Arts Block F	1-Lamp 5' T12 w/mag	5	63	1,673	0.35
Industrial Arts Block F	2-Lamp 5' T8 w/ mag	4	112	1,673	0.35
Industrial Arts Block F	1-Lamp 5' T8 w/mag.	3	55	1,673	0.35
Industrial Arts Block F	1-lamp 4' LED	1	18	1,673	0.35
Industrial Arts Block F	1-Lamp 5' T12 w/mag	1	63	1,673	0.35
Industrial Arts Block F	1-Lamp 5' T8 w/mag.	5	55	1,673	0.35
Industrial Arts Block F	14 Watt CFL	4	14	1,673	1
Block B	1-Lamp 5' T8 w/mag.	1	55	1,673	1
Block B	2-Lamp 5' T8 w/ mag	2	112	1,673	0.1
Block B	1-Lamp 5' T12 w/mag	15	63	1,673	0.7
Block B	~25 W CFL	1	25	1,673	0.1
Block B	~60 W Inc	1	60	1,673	0.1
Block B	1-Lamp 5' T12 w/mag	2	63	1,673	0.35
Block B	1-Lamp 5' T12 w/mag	6	63	1,673	0.35
Block B	2-Lamp 5' T8 w/ mag	3	112	1,673	1
Block B	2-lamp 4' LED	6	36	1,673	0.35
Block B	2-Lamp 5' T8 w/ mag	6	112	1,673	0.35
Block B	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block B	1-lamp 4' LED	3	18	1,673	1
Block B	1-Lamp 5' T12 w/mag	6	63	1,673	0.35
Block B	2-Lamp 5' T12 w/mag	6	128	1,673	0.35
Block B	1-Lamp 5' T12 w/mag	6	63	1,673	0.35
Block B	2-Lamp 5' T12 w/mag	6	128	1,673	0.35
Block B	1-Lamp 5' T8 w/mag.	3	55	1,673	0.5
Block B	1-Lamp 5' T12 w/mag	2	63	1,673	0.5
Block B	1-Lamp 5' T8 w/mag.	3	55	1,673	0.5
Block B	2-Lamp 5' T8 w/ mag	1	112	1,673	0.5
Block B	1-Lamp 5' T8 w/mag.	5	55	1,673	0.35
Block B	1-Lamp 5' T12 w/mag	1	63	1,673	0.35
Block B	1-Lamp 5' T12 w/mag	2	63	1,673	1
Block B	2-Lamp 5' T8 w/ mag	1	112	1,673	1

Building Name	Fixture Type	Fixture Quantity	Wattage	Occupied Hours/Year	% On When Occupied Estimated or Actual
Block B	2-Lamp 2' T8	1	33	1,673	1
Block B	1-Lamp 5' T12 w/mag	6	63	1,673	0.35
Block B	14 Watt CFL	14	14	1,673	0.35
Block B	14 Watt CFL	14	14	1,673	0.35
Block B	2-Lamp 2' T12	2	51	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Block A	1-Lamp 5' T8 w/mag.	6	55	1,673	0.35
Exterior	200 Watt Metal Halide	15	220	4,380	1
Industrial Arts Block 2	2-Lamp 4' T8	1	52	1,673	0.6
Industrial Arts Block 2	2-Lamp 4' T12 w/mag	2	72	1,673	0.6
Industrial Arts Block 2	1-Lamp 4' T12 w/ mag	1	43	1,673	0.6
Industrial Arts Block 2	4' LED Tube	4	18	1,673	0.6
Industrial Arts Block 2	2-Lamp 4' T12 w/mag	1	72	1,673	0.6
Industrial Arts Block 2	4' LED Tube	2	18	1,673	0.6
Industrial Arts Block 2	5' LED Tube	5	23	1,673	0.6
Industrial Arts Block 2	1-Lamp 5' T8 w/mag.	1	55	1,673	0.6
Industrial Arts Block 2	1-Lamp 5' T8 w/mag.	1	55	1,673	0.6
Industrial Arts Block 2	1-Lamp 5' T8 w/mag.	1	55	1,673	0.6
Industrial Arts Block 2	2-Lamp 4' T12 w/mag	4	72	1,673	0.6
Industrial Arts Block 2	2-Lamp 4' T8	2	52	1,673	0.6
Industrial Arts Block 2	1-Lamp 4' T12 w/ mag	1	43	1,673	0.6
Industrial Arts Block 2	1-lamp 4' T8 w/mag	1	32	1,673	0.6
Music Room	2-Lamp 4' T12 w/mag	3	72	1,673	0.6
Music Room	2-Lamp 4' T8	2	52	1,673	0.6
Snack Shop 1	2-Lamp 4' T12 w/mag	3	72	1,673	0.6
Snack Shop 2	2-Lamp 4' T12 w/mag	3	72	1,673	0.6
Ag Classroom	2-Lamp 5' T12 w/mag	13	128	1,917	0.6
Canteen and Auditorium	2-Lamp 5' T12 w/mag	45	128	1,200	0.6
Canteen and Auditorium	2-Lamp 4' T12 w/mag	4	72	1,200	0.6
Canteen and Auditorium	1-Lamp 4' T12 w/ mag	3	43	1,200	0.6
Canteen and Auditorium	2-Lamp 4' T12 w/mag	12	72	1,200	0.6

Building Name	Fixture Type	Fixture Quantity	Wattage	Occupied Hours/Year	% On When Occupied Estimated or Actual
Classrooms - I	1-Lamp 5' T8 w/mag.	26	55	1,673	0.6
Cosmetology Teaching Area	2-Lamp 4' T8	8	52	1,673	0.6
Cosmetology Teaching Area	2-Lamp 4' T8	8	52	1,673	0.6
Total/Average		612		2,456	64%

Ductless Mini-Split Air Conditioner Inventory by Location

Building Name	Floor	Room Description	Quantity	Size	Hours/ Year
Admin Block C	2	Computer Lab	2	36,000	2,161
Admin Block C	2	Classroom/Computer Lab	2	24,000	2,161
Admin Block C	1	General Office	1	18,000	2,161
Admin Block C	1	Bursar's Office	1	18,000	2,161
Admin Block C	1	Principal's Office	1	18,000	2,161
Admin Block C	1	Bursar's Office 2	1	8,000	2,161
Admin Block C	1	E-Learning/ Computer Lab	3	8,000	2,161
Admin Block C	1	Typing Office	1	8,000	2,161
Block D	1	Literacy Center	1	18,000	1,917
Block D	2	Literacy Center 2	3	18,000	1,917
Industrial Arts Block F	1	CAD Computer Lab	1	36,000	1,673
Block B	2	Conference Room	1	36,000	1,673
Block B	1	Maintenance Area	1	18,000	1,673
Total / Average			**19**	**19,789**	**1,987**

9.6 Ebony Park Heart Trust Academy Equipment Inventory