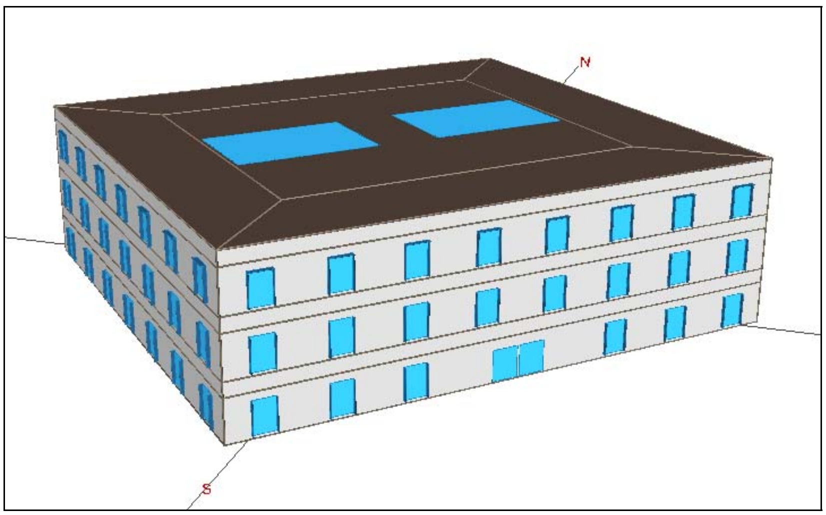
Energy Efficiency and Renewable Energy Site Assessment

Low Carbon Communities in the Caribbean Project



Ministry of Communications, Works, Transport & Public Utilities, Saint Lucia

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CONTACTS AND TEAM MEMBERS

National Renewable Energy Laboratory

Name: Adam Warren, PhD
Position: Regional Initiatives Section Supervisor
Office Phone: 303-275 4346
E-mail: adam.warren@nrel.gov

Name: Otto VanGeet, P.E.
Position: Senior Engineer
Office Phone: 303-384-7369
E-mail: otto.vangeet@nrel.gov

Name: Jesse Dean, CEM
Position: Building Engineer
Office Phone: 303-384-7539
E-mail: jesse.dean@nrel.gov

Organization of American States

Name: Kevin De Cuba
Position: LCCC Project Manager
Office Phone: (202) 458-6467
E-mail: kdecuba@oas.org

Name: Carolina Peña
Position: CSEP-RCU Manager
Office Phone: (758) 452-4330
E-mail: cpena@oas.org

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EXECUTIVE SUMMARY

The following report summarizes the results from an energy efficiency and renewable energy assessment of the Ministry of Communications, Works, Transport and Public Utilities office building in St. Lucia. A team led by the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) and comprised of energy assessment workshop trainees conducted the site assessment. During the site visit, the assessment team identified a total of 9 energy conservation measures.

The Ministry of Communications building is a three story office building with a square footage of approximately 39,996 ft^2 (3,716 m^2). The facility is an office building with a large open atrium in the middle of the facility and a number of offices that are open to the public.

The occupancy rate varies throughout the day. The facility is generally occupied Monday - Friday from 8:00 am to 4:30 pm. In addition to the standard operating hours there are a number of occupants who might work later than 4:30 pm on any given day.

The HVAC system consists of six series of packaged air conditioning units that utilize constant volume supply fans. The air cooled condensing units are located on the back of the facility and air handling units are located in mechanical rooms within the facility. The air cooled condensing units are severely degraded and need to be replaced.

The overhead lighting consists of a mixture of 40 Watt T-12 and 32 Watt T8 lamps and electronic ballasts. The majority of the light fixtures are currently controlled by wall mounted switches.

Electricity is the only utility provided to facility. During the site assessment monthly utility data was provided for a single calendar year. In 2009 the facility consumed 648,950 kWh of electricity at a total cost of $187,955. The current overall blended electric rate is $0.29/kWh. This high electric rate puts precedence on reducing electricity use as it will significantly reduce the overall utility bills for the facility.

Table 1 summarizes the energy savings by conservation measure. The table provides an annotated list of measures, estimated economic impact, and implementation cost per energy conservation measure.

Table 1 - Energy Conservation Measures Summary

ECM #	ECM Description	Electricity Savings (kWh/yr)	Annual Cost Savings ($/yr)	Installed Costs ($)	Simple Payback Period	Net Present Value ($)	Saving to Investment Ratio (SIR)	Internal Rate of Return (IRR)	Site Energy Use Intensity Reduction (kBtu/ft^2)
ECM #1	Enable Computer Power Management Settings on Desktop Computers	54,833	$15,902	$2,436	0.2	$145,472	79	30.60%	8.62%
ECM #2	Install Programmable Thermostats to Control the Packaged Air Conditioning Units	54,565	$15,824	$5,850	0.4	$141,990	32.7	25.00%	8.58%
ECM #3	Install Daylighting Controls in the Main Atrium	10,589	$3,071	$3,230	1.1	$25,864	11.5	18.60%	1.66%
ECM #4	Retrofit the T-12 Lighting Systems with T8 Lamps and Electronic Ballasts	72,170	$20,930	$27,450	1.3	$171,883	9.2	17.30%	11.34%
ECM #5	Phase out Desktop Computers and CRT Monitors and Install Laptops with Docking Stations and LCD Monitors	85,134	$24,689	$52,200	2.1	$186,742	5.7	14.60%	13.38%
ECM #6	Install High Efficiency Packaged Units	118,874	$34,474	$154,800	4.5	$194,584	2.7	10.30%	18.69%
ECM #7	Install NEMA Premium Motors on AHU Supply Fans	3,317	$962	$5,145	5.3	$4,763	2.3	9.40%	0.52%
ECM #8	Convert the Constant Volume AHUs to Variable Air Volume System	5,893	$1,709	$86,075	50.4	($-53688)	0.2	n/a	0.93%
ECM #9	Replace the Roof with an Insulated Cool Roof	1,263	$366	$101,730	278	($-78786)	0	n/a	0.20%
	Totals	***406,638***	***$117,927***	***$438,916***	***3.7***	-	-	-	***63.92%***

**Note – the total savings listed in the table do not take into account the interactive effects of individual measures.*

Seven of the nine energy conservation measures had payback periods less than six years. All of these seven measures also had a net present value greater than zero, an SIR greater than 1, and an IRR greater than 5%. Thus, they were all found to be cost effective on a life cycle cost basis. The total savings values presented in the table are simply the sum of the energy savings and installed costs and do not take into account the interactive effects of the energy conservation measures. An additional series of parametric runs was created where all of the measures were added to one another to account for the interactive effects of the energy conservation measures and the correct cumulative savings are as follows:

- Annual Electricity Savings 230,096 kWh/yr
- Annual Cost Savings $66,728
- Installed Costs $438,916
- Simple Payback Period 6.58 years

Thus, the cumulative energy savings is 43.4% lower than the savings projected by simply summing all of the energy savings from the individual measures. This points to the importance of using energy modeling programs similar to eQUEST when analyzing the energy savings of multiple energy conservation measures in a single facility. The interesting aspect of this analysis also shows that since the local electric rates are so high, when all of the measures are combined they produce a good payback, even though two of the measures have poor payback periods as standalone measures. The nine energy conservation measures would reduce the total site energy use intensity (kBtu/ft^2) by 36.17%.

BACKGROUND

The Low-Carbon Communities in the Caribbean (LCCC) initiative is a collaboration between the US Department of Energy and the Organization of the Americas States under the Energy and Climate Change Partnership of the Americas (ECPA). The ECPA was announced during the 5th Summit of the Americas held in April 2009 in Port-of-Spain, Trinidad and Tobago, where thirty-four heads of state gathered to discuss energy development challenges in the Western Hemisphere.

The objective of the ECPA initiative is to enable participating countries to implement actions and strategies geared towards increasing the sustainability of their energy supplies while reducing carbon emissions from the energy sector through the development and use of renewable energy and energy efficiency systems.

The Organization of American States in partnership with U.S. Department of Energy's National Renewable Energy Laboratory (NREL) and the Caribbean Association of Electric Utilities (CARILEC) conducted a four-day, regional energy-auditing workshop at the Coco-Palm Resort in Rodney Bay St. Lucia from August 24 to 27, 2010. The Energy Auditing workshop co-funded by the OAS's Caribbean Sustainable Energy Program provided fundamental knowledge to strengthen the capacity to carry out energy audits and recommend efficiency measures for public, commercial, and hotel buildings. The workshop explored all major aspects of energy use, energy systems and technologies, energy conservation measures, energy auditing methodology, and hands-on building energy assessments involving on-site data collection and energy modeling tools.

The twenty-nine attendees included government officials, members of CARILEC, as well as representatives of the education, and tourism sectors from Antigua and Barbuda, the Bahamas, Barbados, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia and Saint Vincent and the Grenadines and other Caribbean nations.

CLIMATE DATA

The Ministry of Communications in St. Lucia is located approximately 15 minutes away from the Rodney Bay Marina in St. Lucia. The three story office building has an elevation of 48 ft and a latitude and longitude of 14.02°N, and 60.58°W, respectively. The climate in St. Lucia can be characterized as a tropical climate, similar to all of the surrounding Caribbean islands. The hot and humid conditions are partially tempered by sea breezes and prevailing northeastern trade winds. Since hourly weather data wasn't available for St. Lucia, historic weather data from Harry S Truman airport in the Virgin Islands was analyzed (Table 2). The average temperature and relative humidity remain fairly constant from season to season and the average wind speed is relatively high throughout the year.

Table 2 – Virgin Islands Monthly Weather Summary

Charlotte Amalie Harry S Truman, Virgin Islands												
Elevation: 19 ft				Latitude: 18.35 N				Longitude 64.97 W				
Average Temperature												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
°F	77	78	78	79	81	82	82	85	84	83	80	77
Dew-point Temperature												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
°F	66	69	68	68	72	72	72	73	73	73	75	67
Relative Humidity												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
%	70	75	71	70	75	72	72	67	70	71	85	72
Wind Speed												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
mph	9	11	12	13	10	13	10	11	10	9	9	12
Average Ground Temperature												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
°F	83	83	82	82	80	79	78	78	78	79	80	81

The hourly weather data was analyzed on a psychometric chart in an attempt to characterize the number of hours the outside air conditions are within the thermal comfort range defined by ASHRAE Standard 55 (the plots were created in the Climate Master tool referenced below).[i] There are only 155 hours (out of 8,760 hours per year) that the outside air conditions are within the acceptable comfort range. Thus, all of the remaining hours of the year, the outside air conditions are above the comfort range and air conditioning is needed to maintain a comfortable interior environment.

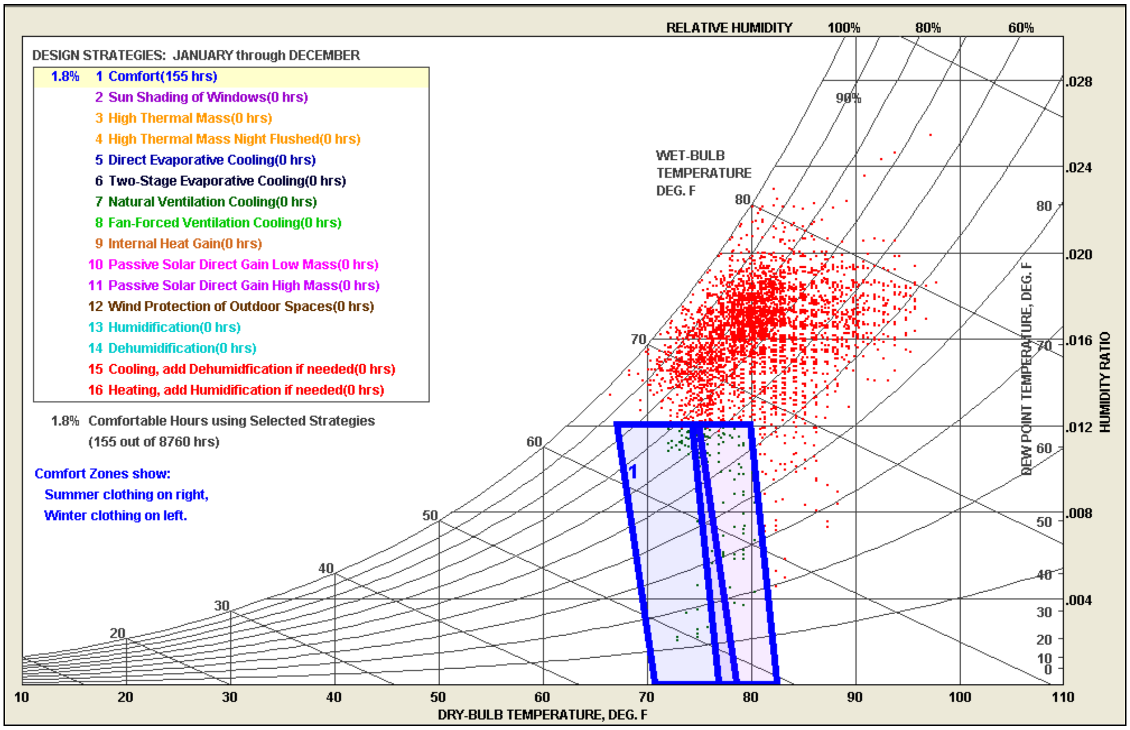


Figure 1 - Virgin Islands Psychometric Chart

The outdoor air temperature ranges from 74 °F to 92.6 °F (about 23 to 33 °C). Thus, the outside air temperature only varies over 18.6 °F temperature difference over the course of the year.

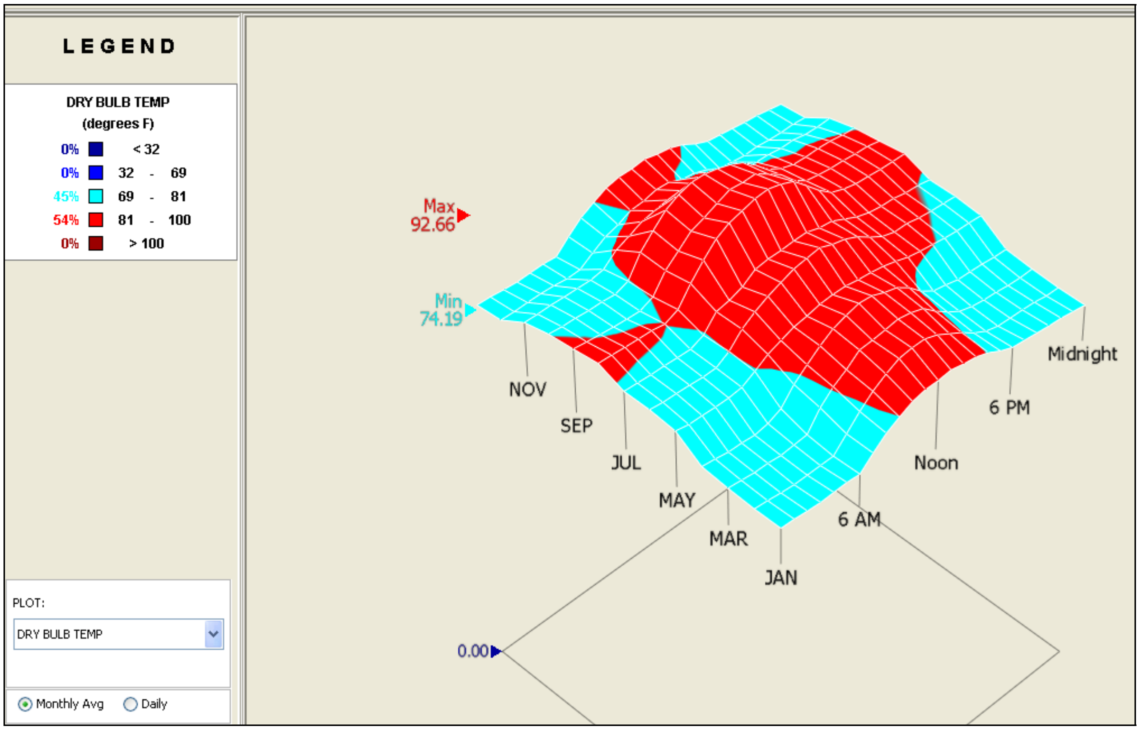


Figure 2 - Virgin Islands Dry bulb Temperature Contour Plot

ENERGY USE AND UTILITY RATE DATA

Electricity is the only utility provided to the facility. In 2009 the facility consumed 648,950 kWh of electricity at a total cost of $187,955. The current overall blended electric rate is $0.29/kWh. This high electric rate puts precedence on reducing electricity use as it will significantly reduce the overall utility bills for the facility.

Table 3 - Monthly Electricity Usage and Cost

Units	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
kWh	43,987	48,386	57,498	54,253	62,115	56,308	54,681	50,285	57,198	53,485	57,376	53,378
$EC	33,531	36,884	45,262	43,359	50,885	45,677	44,303	36,748	44,014	40,579	43,376	40,642
$US	$12,474	$13,721	$16,837	$16,129	$18,929	$16,992	$16,480	$13,670	$16,373	$15,095	$16,136	$15,119
$EC/kWh	$0.76	$0.76	$0.79	$0.80	$0.82	$0.81	$0.81	$0.73	$0.77	$0.76	$0.76	$0.76
$US/kWh	$0.28	$0.28	$0.29	$0.30	$0.30	$0.30	$0.30	$0.27	$0.29	$0.28	$0.28	$0.28

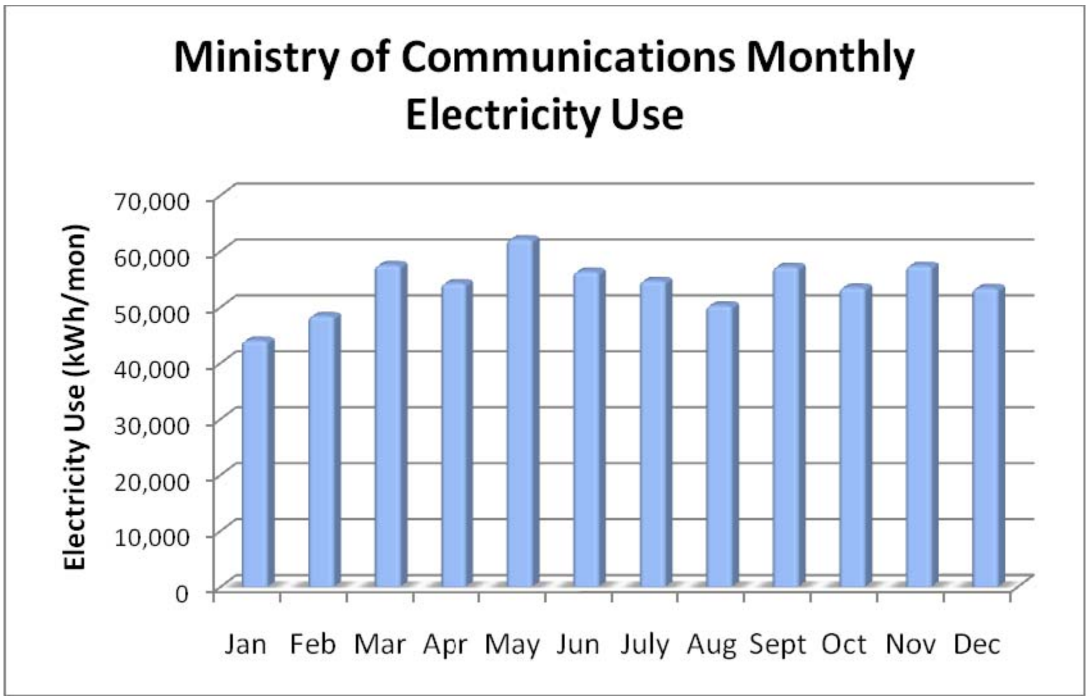


Figure 3 - Monthly Electricity Use

BUILDING OVERVIEW

The Ministry of Communications building is a three story office building with a square footage of approximately 39,996 ft^2 (3,716 m^2). The facility is an office building with a large open atrium in the middle of the facility and a number of offices that are open to the public.

Occupancy
The occupancy rate varies throughout the day. The facility is generally occupied during the following hours:

Monday – Friday

- 8:00 am to 4:30 pm

There are also a number of occupants who might work later than 4:30 pm depending on the day.

Heating, Ventilating, and Air conditioning (HVAC)
The HVAC system consists of a series of six packaged air conditioning units that utilize constant volume supply fans. The air cooled condensing units are located on the back of the facility and air handling units are located in mechanical rooms within the facility. The air cooled condensing units are severely degraded and need to be replaced.

Lighting
The overhead lighting consists of a mixture of 40 Watt T-12 and 32 Watt T8 lamps and electronic ballasts. The majority of the light fixtures are currently controlled by wall mounted switches.

BASELINE ENERGY MODEL

eQUEST was selected as the building simulation software tool to perform the energy modeling of the Ministry of Communications office building.[1] eQUEST is a modeling program developed by the DOE that evaluates the energy and cost savings that can be achieved by applying energy-efficiency measures such as increased insulation, passive solar heat gain, and high-performance HVAC, and lighting systems. eQUEST requires a detailed description of the building envelope (for thermal and optical properties), lighting and HVAC system characteristics, internal loads, operating schedules, and utility rate schedules.

A graphical representation of the energy model developed in eQUEST is shown in Figure 4, Figure 5.

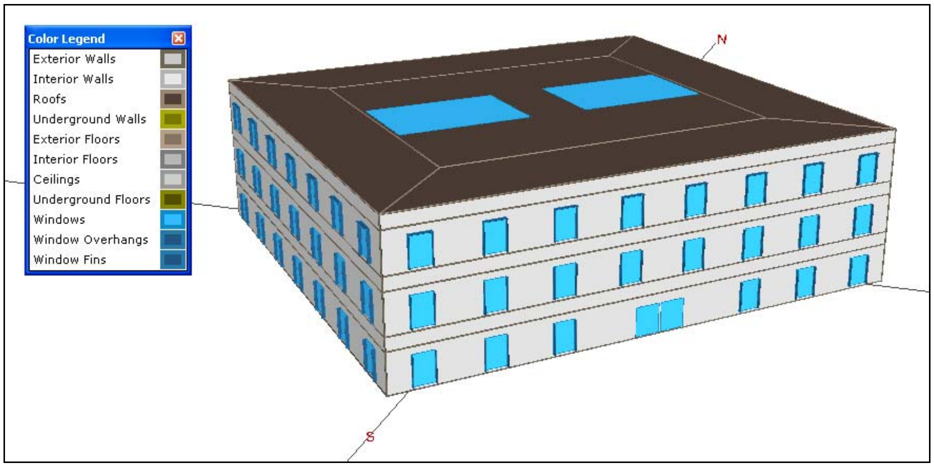


Figure 4 - eQUEST Energy Model - Building Rendering

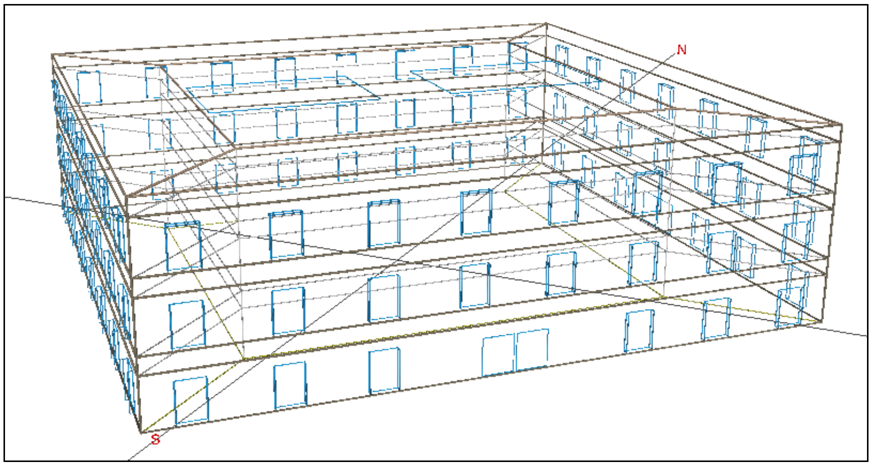


Figure 5 - eQUEST Energy Model - Building Rendering

[1] eQUEST – Energy modeling tool, http://doe2.com/equest/

The building envelope characteristics were built based off of approximate building dimensions and input into eQUEST to develop the building footprint and geometry. The windows were modeled with a width of 5 ft, and side fins were modeled on all windows, and overhangs were modeled on the top windows to account for the shading effects of the unique architectural elements around the windows.

The NREL team used the data gathered during the assessment to develop the eQUEST model. The general facility characteristics that were modeled are provided in Table 4.

Table 4 – eQUEST Summary Information

Ministry of Communications Office Building		
Project		
	Climate Zone	St. Lucia
	Building Type	Three Story Office Building
	Building Area	39,996 ft^2
	Above Grade Floors	3
	Below Grade Floors	0
Building Footprint		
	Building Orientation	Plan North West
	Zoning Pattern	Perimeter / Core
	Perimeter Zone Depth	15 ft
	Flr to Flr Height	12 ft
	Flr to Ceil Height	9 ft
	Roof Pitch	0 deg
Roof		
	Construction	6 in Concrete
	Roof, Built Up	Medium
	Ext. Insulation	None
Walls		
	Construction	6 in CMU
	Finish	Concrete, Medium
	Ext. Insulation	None
	Interior Insulation	None
Ground Floor		
	Earth Contact	6 in Concrete
		No perimeter insulation
Infiltration		
	Perimeter	0.038 (CFM/ft^2)
Ceilings		
	Int. Finish	Lay-In Acoustic Tile
Vertical Walls		
	Wall Type	Frame
Floors		
	Int. Finish	Ceramic / Stone Tile
	Construction	6 in Concrete
	Concrete Cap.	None

Table 5 – eQUEST Summary Information

Ministry of Communications Office Building		
Exterior Doors		
	Door Type	Glass
		2-S.E., 2-N.E.
Exterior Windows		
	Construction	Single Clear (1/4 in)
	Frame Type	0.86
	Visible Transmittance	Alum w/o Brk
	Percent of Gross Wall Area	25% on all 4 sides
	Overhangs	1 ft on all top windows
	Fins	0.75 ft on all windows
Building Operation		
	Schedule	8:00 am to 6:00 pm M-F
	Area Type	Office
	Design Occupancy	200 ft^2/person
	Design Ventilation	15 CFM/person
Equipment Power Density		
	Lighting	0.8 to 1.7 (Watts/ft^2)
	Misc. Loads	0.1 to 0.85 (Watts/ft^2) electric
HVAC System		
	System Type	Packaged Single Zone
	Cooling Source	DX Coils
	Heating System	No Heating
	Thermostat	69 to 71 F - Cooling – Occupied
		69 to 71 F - Cooling – Unoccupied
Fan Schedules		
	Operates	7:00 am to 8:00 pm
Chilled Water Plant		
	DX Coils	EER = 8.5

The total electricity consumption predicted by the eQUEST model was calibrated to within 10% of the monthly utility bills and 2% of the annual utility data. During the calibration it was observed that the usage for the month of August was lower than expected and the usage for the month of May and November was higher than expected. To account for this three individual seasons were created in eQUEST (Figure 6).

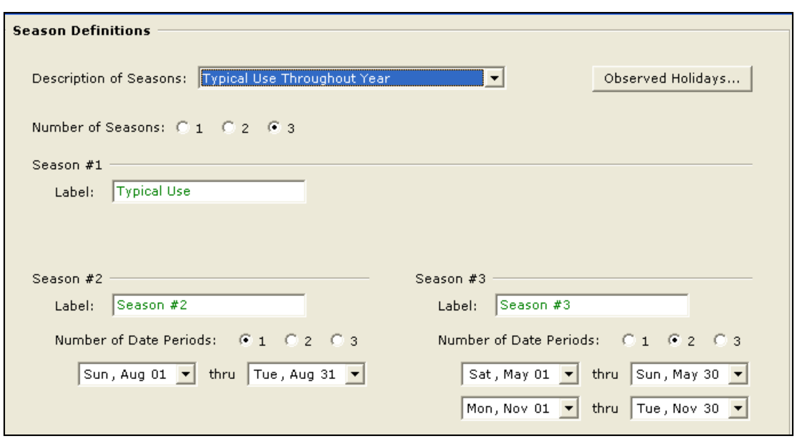


Figure 6 - eQUEST Energy Model - Building Rendering

Custom schedules were then created for the temperature set points, lighting energy use and plug loads to calibrate the model. A graphic of the three plug load schedules are provided below.

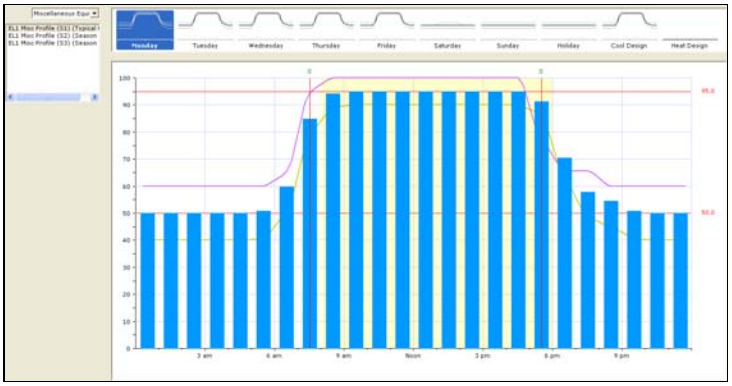


Figure 7 - eQUEST Energy Model - Building Rendering

The three schedules can be selected by clicking on the schedule listed on the left and the values can be changed by modifying the four numbers in red in the graph. The calibrated model results versus the actual utility bills are provided in the following figure.

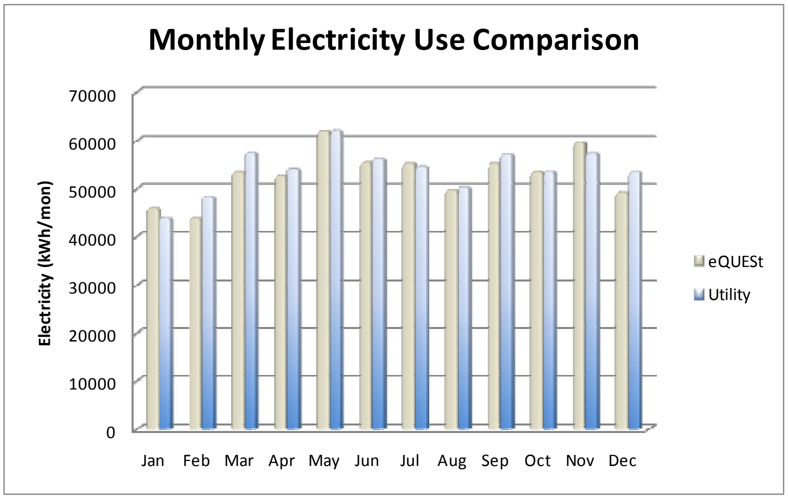


Figure 8 - eQUEST Electricity Calibration Comparison

Table 6 – eQUEST Summary Information

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
eQUESt	45,930	43,950	53,340	52,620	62,050	55,550	55,370	49,800	55,350	53,330	59,600	49,300	636,200
Utility	43,987	48,386	57,498	54,253	62,115	56,308	54,681	50,285	57,198	53,485	57,376	53,378	648,950
Percent Diff.	***-4.4%***	***9.2%***	***7.2%***	***3.0%***	***0.1%***	***1.3%***	***-1.3%***	***1.0%***	***3.2%***	***0.3%***	***-3.9%***	***7.6%***	***2.0%***

The breakout of electricity use is shown in the bar graph below. It is apparent that the air conditioning load makes up the majority of the load, followed by lighting, and plug loads.

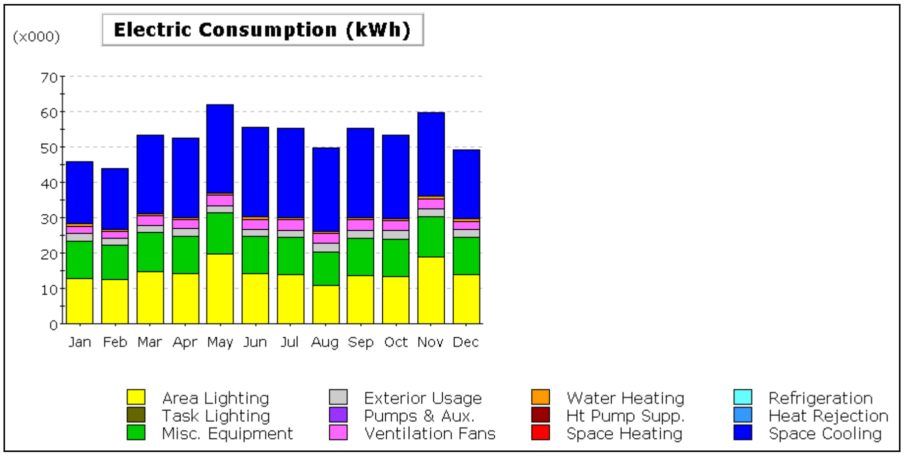


Figure 9 - eQUEST Electricity Calibration Comparison

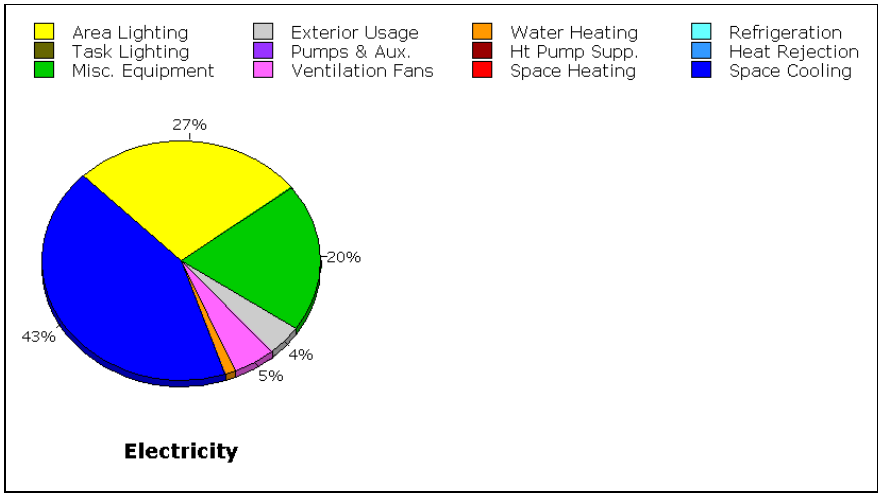


Figure 10 - Annual Energy Use by End-Use

The pie graph shows that 43% of the energy used within the building is associated with cooling energy use, followed by 27% for lighting, and 20% for plug loads. This points to the fact that the energy auditing team should focus on HVAC, lighting and plug load measures as they will save the most energy.

The monthly average demand for the building is provided in the following figure. It is apparent that the peak is set by the cooling system and the monthly average peak demand is around 150 kW.

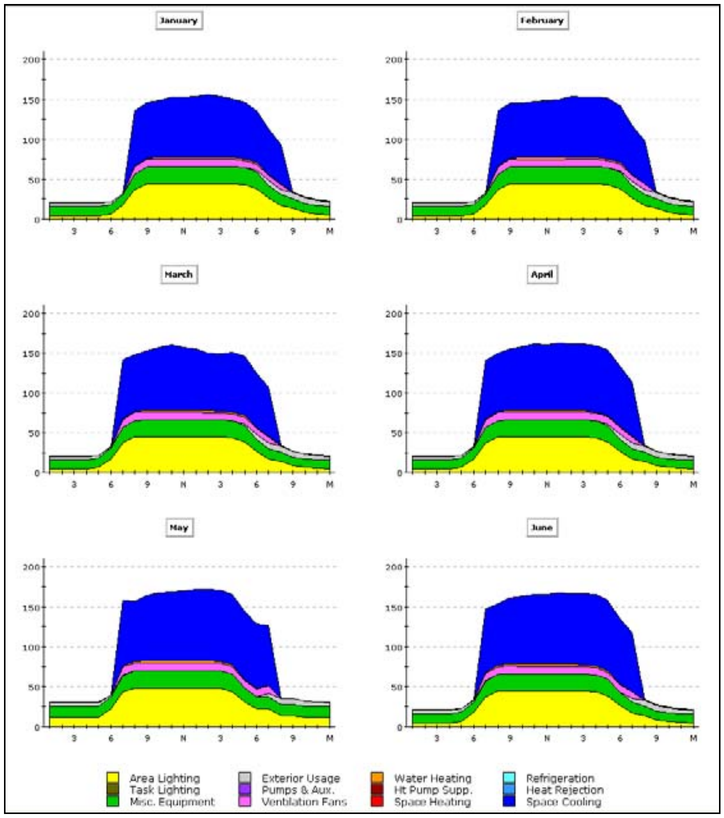


Figure 11 – Monthly Average Peak Demand

**It should be noted that the assessment team was able to gather a substantial amount of information about the facility and produce a representative energy model of the building. Yet, there are a few minor pieces of information that weren't collected and a few assumptions were made in the analysis. The results are presented here to serve as an educational tool for the trainees and also to present the relative savings potential of each measure. Even though the savings projections shouldn't be taken as exact savings, they still point to the potential of each measure and are good first pass projections of energy savings. It is recommended that the site collect additional data on the cost effective measures to verify the eQUEST assumptions and get bids from contractors on installed costs and implement the cost effective measures.

ENERGY CONSERVATION MEASURES

1. Plug Loads

1.1. Recommendation: Enable Computer Power Management Settings on Desktop Computers

Current Condition: There are a total of 87 desktop computers in the facility. The computer power settings observed were set to turn off the monitor after 20 minutes of inactivity but would never put the computer into standby mode for some of the computers and some of the workstations (computer, monitor combination) remained on 24/7. Although some of the monitor settings were adequate, the computer should be set to go into standby after 10 minutes of inactivity. The current condition was modeled in eQUEST assuming 50% of the total plug loads in the building remain on 24/7, which is a conservative assumption based on the fact that the majority of the plug load energy use is associated with the desktop computers and monitors (Figure 12).

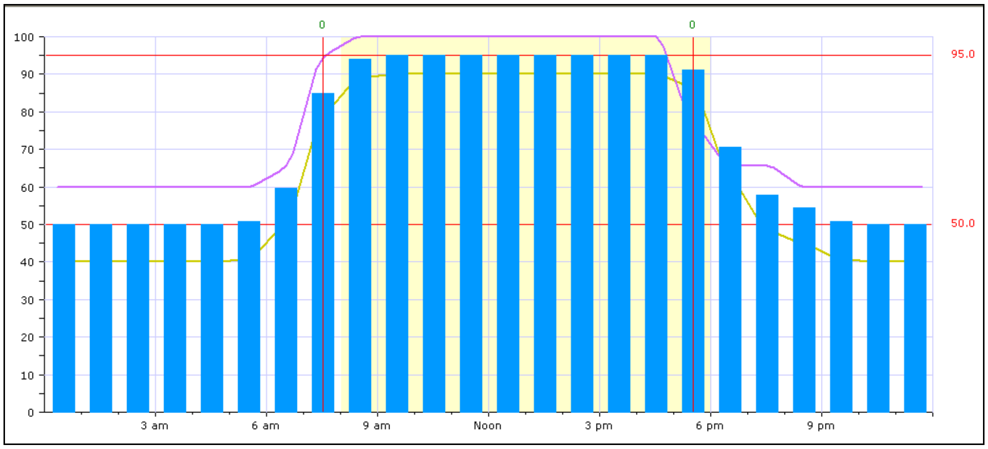


Figure 12 – eQUEST 24 hr Plug Load Schedule

There are at least five commercial computer power management software vendors: Surveyor, EZ Save, EZ GPO, Energy Saver Pro, and Night Watchman. Table 7 compares the operational attributes of each software program profiled:[ii]

Table 7 -Vendor Comparison - Computer Power Management Software

	Surveyor	EZ Save	EZ GPO	Energy Saver Pro	Night Watchman
Controls					
• PCs	✓		✓	✓	✓
• Monitors	✓	✓	✓	✓	✓
System shutdown	✓	✓	✓		✓
Group-specific settings	✓			✓	✓
Consumption & savings reports	✓	✓		✓	
Simulation of savings	✓			✓	

Source: Platts

The software programs listed above are centrally administered programs that perform the following functions:

- Polls computers on a network to determine each monitor and computer's power management settings
- Generates reports on the result of the polling
- Sets appropriate power management settings on monitors and computers on the network
- Sets appropriate screen saver settings on monitors on the network so that users retain screen saver images

Recommended Action: Review the site specific needs for this facility and select an appropriate centrally administered computer power management software vendor. For the purposes of this assessment the analysis team assumed that the site would implement the Surveyor software program which advertises the greatest user options.

Electricity Savings:	*54,833 kWh/yr*
Cost Savings:	*$15,902/yr*
Implementation Costs	*$2,436*
Simple Payback	*0.2 years*

Challenges and Steps: Implementing computer power management settings is a strait forward measure that can be implemented on a computer by computer basis or centrally administered through a commercial software program to ensure continuous savings. The majority of building owners throughout the United States have either implemented this measure or are in the process of implementing it. The only complication that might arise is associated with local IT issues in getting the central software programs approved and implemented.

Assumptions: The computers and monitors are assumed to go into standby mode 12 hrs per day and reduce the night time plug load fraction from 50% to 15%. The eQUEST plug load schedules were modified to turn the computers off at night and on the weekends (Figure 13).

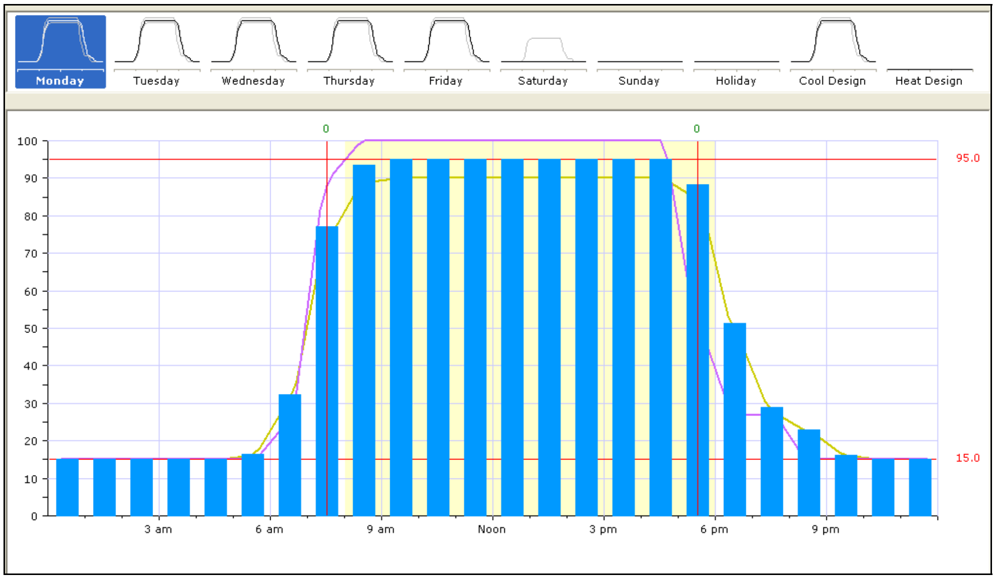


Figure 13 - Revised 24 hour Plug Load Schedule

The installed estimates come from quotes directly from the software vendor.

Table 8: Itemized Installed Cost Estimate

Replace Desktop Computers with Laptop Computers							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Install Central Computer Power Management System	87	License @	$28.0	0	$85	$2,436
						Total	**$2,436**

1.2. Recommendation: Phase out Desktop Computers and CRT Monitors and Install Laptops with Docking Stations and LCD Monitors

Current Condition: All of the computers are desktop computers, for a total of 89, and approximately 15% of the monitors are cathode ray tube (CRT) monitors. A 19" CRT monitor uses 104 Watts when it is on versus 11.7 Watts used by a 15" LCD monitor and a laptop computer will use 30 Watts – 40 Watts when operating, versus the 90 Watts observed for the desktop computers. Thus, the new laptop computer and LCD monitor combination will reduce the energy use per work station by 60% - 70%. The current equipment power densities per zone are provided below.

Miscellaneous Loads and Profiles

	Area Type	Percent Area (%)	Electric Load (W/SqFt)	Electric Sensible Ht (frac)	Natural Gas Load (Btuh/SF)	Natural Gas Sensible Ht (frac)
1:	Office (Executive/Private)	80.0	0.85	1.00	0.00	1.00
2:	Corridor	10.0	0.10	1.00	0.00	1.00
3:	Restrooms	5.0	0.00	1.00	0.00	1.00
4:	Conference Room	5.0	0.10	1.00	0.00	1.00

Figure 14 - Current Equipment Power Density

Recommended Action: Replace all of the desktop computers with laptop computers and docking stations and all of the CRT monitors with LCD monitors. The new laptops and docking stations can connect to and operate with the current monitors just as the desktop computers currently do.

Challenges and Steps: Replacing the desktop computers with laptop computers and docking stations is a strait forward measure. The site will need to install a new locking system so that the laptop computers can be locked up at night in order to prevent theft of the computers.

Electricity Savings: *85,134 kWh/yr*
Cost Savings: *$24,689/yr*
Implementation Costs *$52,200*
Simple Payback *2.1*

Assumptions: The new laptop computers and LCD monitors were assumed to reduce the equipment power density by 50% within each space (Figure 15). Since there were only a few CRT monitors, their installed costs were assumed to be included in the laptop costs provided below.

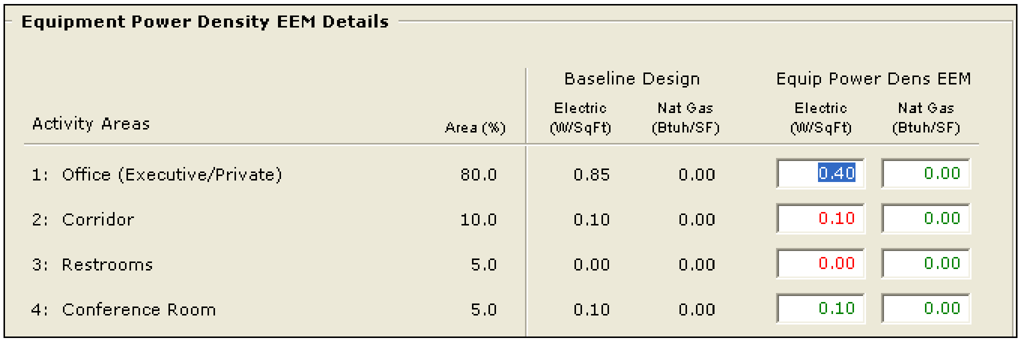


Figure 15 - Revised 24 hour Plug Load Schedule

Installed costs were taken from internet searches of laptop computer costs.

Table 9: Itemized Installed Cost Estimate

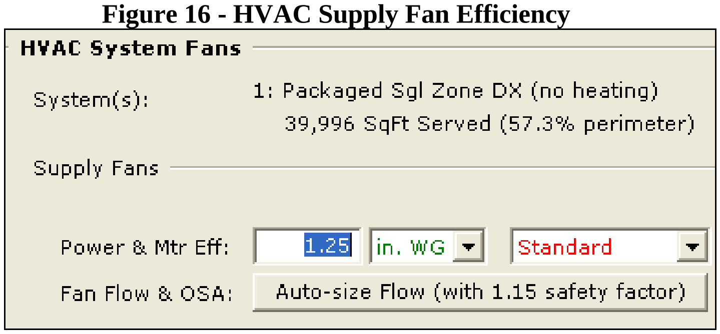
Replace Desktop Computers with Laptop Computers							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Replace desktop computers with laptop computers	87	Computer @	$600.0	0	$85	$52,200
						Total	**$52,200**

2. Motors

2.1. Recommendation: Install NEMA Premium Motors on AHU Supply Fans

Current Condition: The constant volume supply fans that provide conditioned air to the facility currently utilize standard efficiency motors. There are six 5 hp supply fan motors, all of which are open drip proof, 1800 RPM, asynchronous induction motors, with a rated NEMA efficiency that is approximately 82.6%. The motors are currently operated when the HVAC system is operating. The fan efficiency was modeled in eQUEST as 'standard' efficiency motors (Figure 16).

Figure 16 - HVAC Supply Fan Efficiency



Recommended Action: Replace the six constant volume, asynchronous induction motors with premium efficiency motors which exceed NEMA MG1 and IEEE 841. The highest efficiency 5 hp open drip proof, 1800 rpm motor listed in Motor master is a Baldor Super-E with an efficiency of 91%, which will increase the efficiency of the motor systems by 8.4%.

Challenges and Steps: Although premium efficiency motors have many beneficial attributes, there are some fundamental design considerations that need to be addressed before the new motors are purchased. The two most important considerations are related to motor speed and the buildings electric power system.[iii]

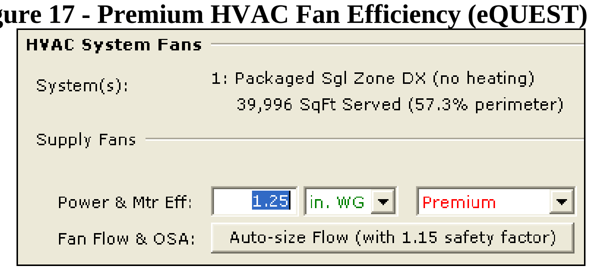
Motor Speed: There can be a significant variance in motor speed based on motor type; energy efficient motors usually have higher full-load operating speeds than standard motors. If the current motor is properly sized, it is important that the retrofit options have as close to the same "rated" operating speeds as possible. In this application where the motor drives a constant volume centrifugal fan, a higher operating speed (RPM) could change the system operating characteristics and have a detrimental effect on the system as a whole. Prior to retrofit, site personnel should talk to the particular motor manufacturer to understand a motor's rated speed (rpm) to ensure its retrofit application is appropriate.

Electric Power System: The NEMA Premium Efficiency motors discussed above have a higher inrush current than standard-efficiency motors. This current can cause certain types of magnetic circuit-breakers to trip – depending on their size. If a facility has breaker-tripping issues after premium-efficiency motors are installed, a review of breaker limits is suggested.

Electricity Savings:	*3,317 kWh/yr*
Cost Savings:	*$962 /yr*
Implementation Costs	*$5,145*
Simple Payback	*5.3 years*

Assumptions: It was assumed that six 5 hp NEMA premium motors were installed on the main air handling units. The recommendation was implemented in eQUEST by changing the supply fan motors to premium efficiency. In the background (detailed mode eQUEST) this increased the total fan efficiency from 50% to 55% which represents a 9% increase in efficiency and is representative of the actual savings that would be realized through the implementation of this measure. In addition, the motors were allowed to auto size in eQUEST.

Figure 17 - Premium HVAC Fan Efficiency (eQUEST)



Installed cost estimates were taken from RS Means Facility Maintenance and Repair Cost Data.

Table 10: Itemized Installed Cost Estimate

Replace Standard Motors with Premium Efficiency Motors							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Remove 5 HP Motor	6	Motor @	$0	1.5	$75	$675
2	Install Premium Efficiency 5 HP Motor	6	Motor @	$460	3.8	$75	$4,470
						Total	**$5,145**

3.

Lighting Systems

The primary overhead lighting systems in the Ministry of Communications facility consist of a mixture of 4 ft T8 lamps and electronic ballasts and 4 ft T12 lamps and magnetic ballasts. The majority of the lamps were T12 with magnetic ballasts. The assessment team recorded illuminance levels and lighting power densities (Watts/ft^2) that are on the order of 60 – 80 foot candles and are higher than those recommended by the Illumination Engineering Society (IES) and the American Society of Heating, Refrigeration and Air conditioning Engineers (ASHRAE). Table 11 provides a listing of the appropriate lighting levels for various activities and the corresponding lighting power density (LPD) requirements of ASHRAE 90.1:[2]

Table 11 - IES Recommended Light Levels

IESNA Recommended Horizontal Illuminances and ASHRAE/IESNA 90.1 LPD Recommendations		
Space Type	**Illuminance (fc)[3]**	**LPD (W/ft^2)**
Open Offices	30 to 50 (5 to 10 with task lighting)	1.1
Private Offices	50	1.1
Conference Rooms	30	1.3
Corridors	5	0.5
Restrooms	10	0.9
Lobby	10	1.3
Copy Rooms	10	
Classrooms	30	1.4
Gymnasiums	100	1.1
Dining Areas	10	0.9
Kitchen	50	1.2
Labs	50	1.4
Libraries	30	1.2 (reading area), 1.7 (stacks)
VDT Areas	3	
Museums (display areas)	30	1
General Warehousing/Storage	10	0.8
Inactive Storage	5	0.3
General Manufacturing	30	1.2 (low bay), 1.7 (high bay)
Residences (General)	5	
Parking Areas (uncovered)	0.2	0.15

[2] Light Levels, http://tristate.apogee.net/lite/bblevel.asp

[3] Foot Candles (fc) is a non-SI unit of illuminance or light intensity widely used in photography, film, television, conservation lighting, and the lighting industry. The unit is defined as the amount of illumination the inside surface of a 1-foot radius sphere would be receiving if there were a uniform point source of one candela in the exact center of the sphere (this unit is commonly used in the U.S.).

For more specific information on lighting retrofits and savings, the site should consider purchasing the ISNEA *Advanced Lighting* Guidelines[iv]. For more information on exterior lighting guidelines, refer to the IES *Recommended Lighting Levels for Exterior Lighting*[v].

3.1. Recommendation: Install Daylighting Controls in the Main Atrium

Current Condition: There are two oversized skylights in the main atrium that provide sufficient illumination to light the space during normal business hours. During the site assessment the assessment team took light level measurements with the lights on and then with all of the lights in the atrium turned off and the light levels only dropped from 180 fc to 150 fc, which is more than enough illumination for the space.

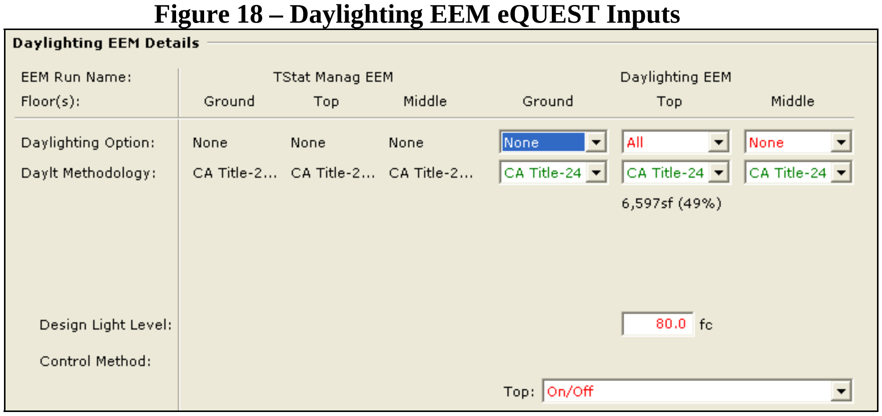
Recommended Action: Install a single photocell to turn the lights off when the daylight levels within the space are sufficient to illuminate the space. Based on the size of the oversized skylights and daylight saturation within the space a simple on/off control system is appropriate for this space.

Challenges and Steps: The new daylighting controls will take some getting used to by the personnel working in the space. The system will also require some basic commissioning to get the sensor in the correct location and to make sure it is operating correctly.

Electricity Savings: *10,589 kWh/yr*
Cost Savings: *$3,071/yr*
Implementation Costs *$3,230*
Simple Payback *1.1 years*

Assumptions: The energy savings were calculated in eQUEST by adding a daylight sensor to all of the top floors and turning the sensor on/off at an illuminance level of 80 fc. Since the skylights provide light down to the first floor, this measure is difficult to implement in eQUESTs wizard mode energy model and this is the best work around (Figure 18).

Figure 18 – Daylighting EEM eQUEST Inputs



Installed cost estimates were taken from RS Means Facility Maintenance and Repair Cost Data and additional labor hours for commissioning were added to the overall installed costs.

Table 12: Itemized Installed Cost Estimate

Install Daylighting Controls in the Main AtriumShowroom							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Daylight level sensor, ceiling mounted, on/off control	5	Daylight sensor @	$211.0	1	$75	$1,430
2	Daylight System Comissioning	-	Hours @	$0	24	$75	$1,800
						Total	**$3,230**

3.2. Recommendation: Retrofit the T-12 Lighting Systems with T8 Lamps and Electronic Ballasts

Current Condition: The majority of the office space utilize linear fluorescent lighting to illuminate the offices and hallways. The lamps and ballasts were a mixture of 40 Watt T12 lamps with magnetic ballasts and 32 Watt T8 lamps with electronic ballasts. The magnetic ballasts that drive the 40 Watt T12 lamps have a ballast factor[4] of 1.275 and result in a total wattage per lamp of 51 watts. The current lighting systems were modeled in eQUEST with the following lighting power densities (Figure 19).

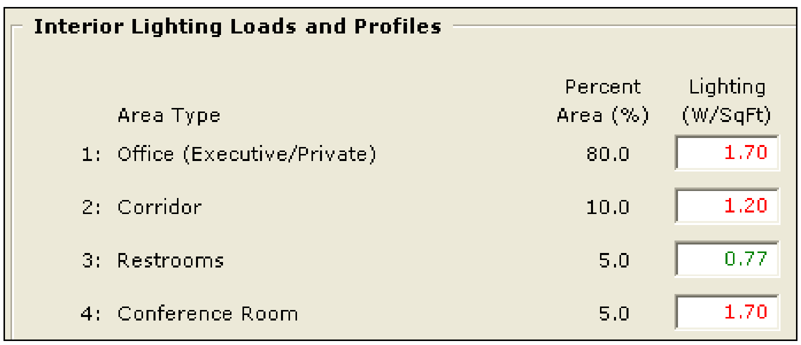


Figure 19 - eQUEST Lighting Power Densities

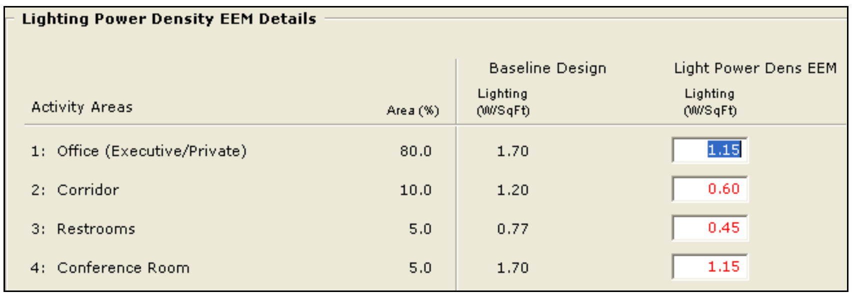
Recommended Action: Replace all of the T12 lamps and magnetic ballasts with T8 lamps and electronic ballasts. The site should install 32 Watt T8 lamps and program start ballasts with a ballast factor of 0.80, resulting in a fixture wattage per lamp of 25.6 Watts. Thus, the new lamp/ballast combination will reduce the connected lighting load by 50.2%.

Challenges and Steps: This lighting retrofit will require the replacement of each ballast and lamp and an electrician onsite to replace all the lamps/ballasts. This is still a relatively simple procedure that should not encounter any significant difficulties. In order to maintain long term energy savings the site will need to modify their procurement process and institutionalize the acquisition of the recommended program start ballasts.

[4] The Ballast Factor is defined as the light output (in lumens) with a test ballast, compared to the light output with a laboratory reference ballast that operates the lamp at its specified nominal power rating, see references list for more information.

Electricity Savings: *72,170 kWh/yr*
Cost Savings: *$20,930/yr*
Implementation Costs *$27,450*
Simple Payback *1.3 years*

Assumptions: The energy savings were calculated in eQUEST by reducing the lighting power density by 32% to 50% depending on the zone. Installed costs were estimated with RS Means based on rough fixture and lamp counts. Since the assessment team didn't analyze ever lamp and ballast a better count of T12 lamps and magnetic ballasts should be collected.


Lighting Power Density EEM Details

Activity Areas	Area (%)	Baseline Design Lighting (W/SqFt)	Light Power Dens EEM Lighting (W/SqFt)
1: Office (Executive/Private)	80.0	1.70	1.15
2: Corridor	10.0	1.20	0.60
3: Restrooms	5.0	0.77	0.45
4: Conference Room	5.0	1.70	1.15

Figure 20 - eQUEST Revised Lighting Power Densities

The installed cost estimates were taken from RSMeans Facilities Maintenance and Repair.

Table 13: Itemized Installed Cost Estimate

Retrofit T12 Lamps and Magnetic Ballasts with T8 Lamps and Electronic Ballasts							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Remove Indoor fluorescent ballasts and lamps	200	Ballast @	$0	0.33	$75	$4,950
2	Lamps	600	Lamp @	$2.5	0.08	$75	$5,250
3	Install Linear Fluorescent Electronic Ballast	200	Ballast @	$36.0	0.67	$75	$17,250
						Total	**$27,450**

4. HVAC Systems and Building Envelope

4.1. Recommendation: Install Programmable Thermostats to Control the Packaged Air Conditioning Units

Current Condition: The packaged air conditioning units are currently turned on and off through a series of wall mounted thermostats located in the mechanical rooms that house the air handling units. The outside air intake to the systems has been mostly blocked off so the sensors are primarily reading return air temperatures throughout the space. With the current system if the facility staff doesn't turn the units off at night they will operate 24 hours a day, seven days a week. The system was modeled in eQUEST assuming the system operates either from 7:00 am to 8:00 pm or 7:00 am to 7:00 pm depending on the season. The systems were set up to maintain a space temperature of 69 °F – 71 °F during the operational hours of the fan (Figure 21 and Figure 22).

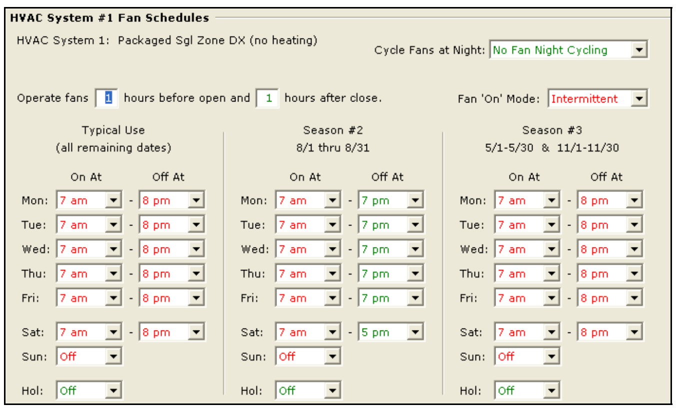


Figure 21 - eQUEST Fan System Schedules

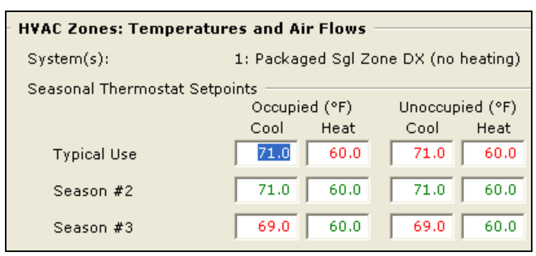


Figure 22 - eQUEST Occupied and Un Occupied Set Point Temperature

Recommended Action: Install a total of 15 wireless temperature sensors that tie into a central control system. Each of the temperature sensors per zone should be located in representative spaces throughout the zone and set up such that an average space temperature is taken and used to control the packaged unit.

Figure 23 shows the network topology of an example wireless sensor network installed in a research facility at the Pacific Northwest National Laboratory.[5]

[5] ASHRAE Journal , April 2008, *6 Steps to Successful Energy Management,* Moran, Mike, Berman, Marc

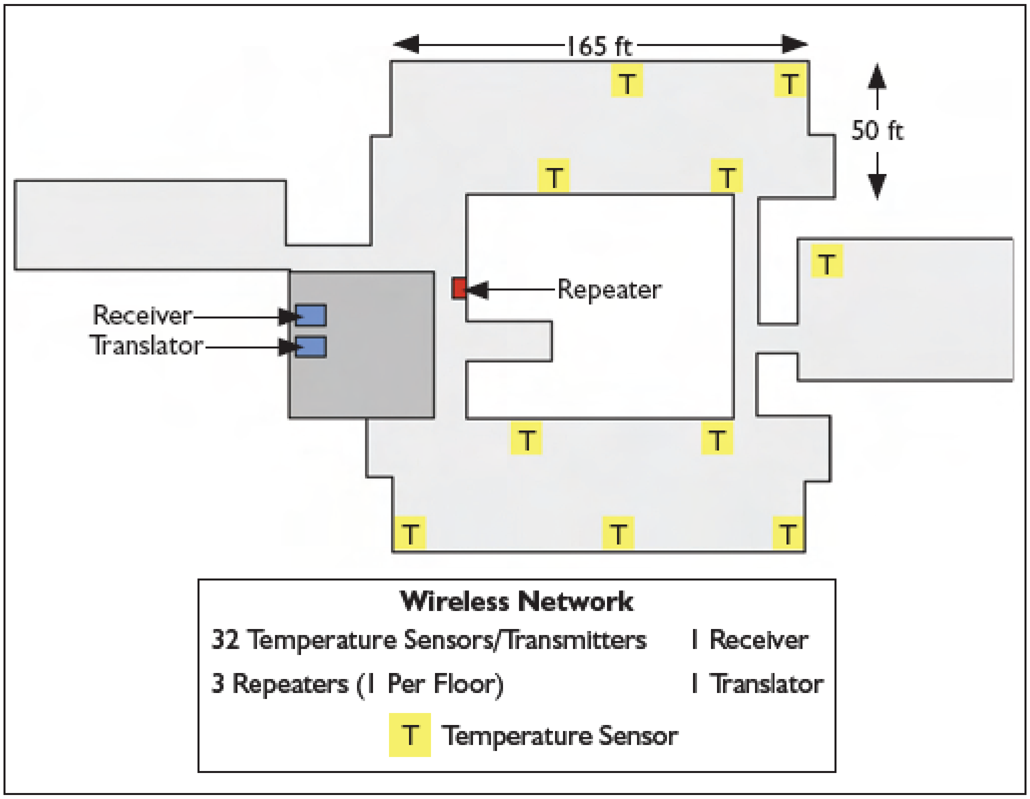


Figure 23 - Wireless Temperature Sensor Network in a Building in Richland, WA

This wireless data acquisition system should include the following components: sensors, signal conditioners, transmitter, repeater (when needed), a receiver and a connection to a processor (DDC system) where the data can be processed using control algorithms. The DDC system should then be programmed to average the temperature set-points throughout the space. The Ministry of Communications facility would realize the following benefits through the utilization of a wireless temperature sensor data acquisition system:

- Reduction in over-cooling of interior spaces; reducing the amount of occupant complaints and creating a more comfortable building.
- Reduction in energy use within the facility due to the reduction in over-cooling

Challenges and Steps: This control system retrofit will require the installation of a number of wireless temperature sensors and building automation system. This system would need to be installed and commissioned by an experienced HVAC technician.

Electricity Savings:	*54,565 kWh/yr*
Cost Savings:	*$15,824/yr*
Implementation Costs	*$5,850*
Simple Payback	*0.4 years*

Assumptions: The revised occupied and un-occupied temperature set-points that were modeled in eQUEST are provided in the following figure.

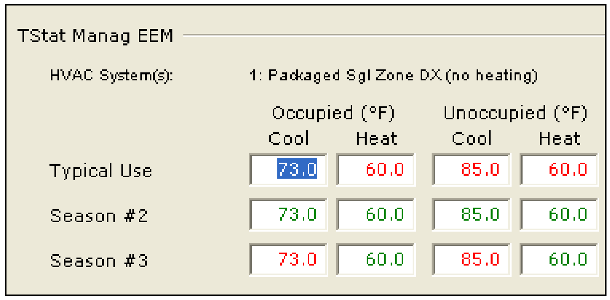


Figure 24 - eQUEST Revised Occupied and Unoccupied Set Point Temperature

Installed cost estimates were taken from representative costs from past projects.

Table 14: Itemized Installed Cost Estimate

Install Programmable Thermostats							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Programmable Thermostat	15	Thermostat @	$200.0	2	$75	$5,250
2	Thermostat Comissioning	-	Hours @	$0	8	$75	$600
						Total	**$5,850**

4.2. Recommendation: Install High Efficiency Packaged Units

Current Condition: The current packaged air conditioning units are standard efficiency units with an estimated EER of 8. During the site assessment the assessment team analyzed the condition of the air cooled condenser coils and observed a number of operational deficiencies:

- The refrigerant insulation was missing from a number of refrigerant lines running to the packaged air handling units. This can result in a 5% to 10% reduction in cooling system efficiency.
- The condenser coils were constructed with aluminum fins and copper tubes. These dissimilar metals react differently to saline based corrosion and consequently the fins were very corroded. The assessment team was able to pull off the fins and could feel the corrosion on the plates, which will have the effect of significantly reducing the cooling system efficiency.

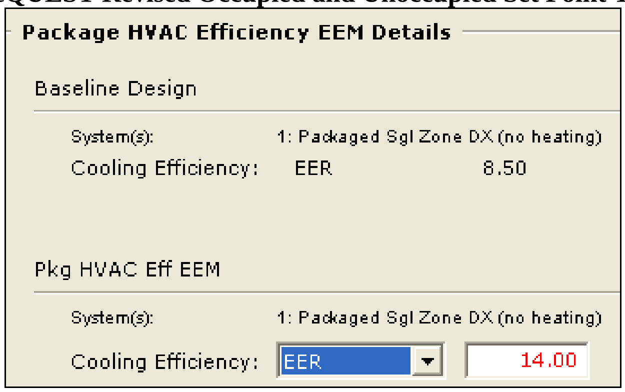
Recommended Action: Replace the condensing units and potentially the entire air handling unit with new condenser coils. The unit should have a minimum EER rating of 14, utilize a variable speed supply fan, and a full copper condenser coil. This will dramatically reduce the cooling energy use of the facility and help to make sure the cooling system can always meet the cooling load within the space.

Challenges and Steps: The site will need to consult a local HVAC technician to determine if just the condenser coils can be replaced or if they are better off replacing the packaged air handling units as well. The site will need to closely monitor the EER rating and material selection of the condenser coil to make sure they are specified correctly by the site.

Electricity Savings: *118,874 kWh/yr*
Cost Savings: *$34,474/yr*
Implementation Costs *$154,800*
Simple Payback *4.5 years*

Assumptions: The revised EER that was modeled in eQUEST is provided below.

Figure 25 - eQUEST Revised Occupied and Unoccupied Set Point Temperature



Installed cost estimates were taken from RSMeans.

Table 15: Itemized Installed Cost Estimate

Replace Air Conditioner							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Remove air conditioner	6	AC @	$0.0	40	$85	$20,400
2	Replace air conditioner, 20 ton	6	Hours @	$15,600	80	$85	$134,400
						Total	**$154,800**

4.3. Recommendation: Convert the Constant Volume AHUs to Variable Air Volume System

Current Condition: The current packaged air handling units utilize direct expansion cooling coils to condition the air and constant volume(CV) supply fans to provide conditioned air to the facility. In a CV system, variations in the thermal requirements of the building are satisfied by varying the temperature of a constant volume of air delivered to the building. This volume can be set to satisfy applicable ventilation standards. CV systems are far less energy efficient than VAV systems and will result in increased fan energy use and cooling system energy use.

The way this particular system is controlled there are no terminal boxes in the zones and no way to regulate air flow within each zone. This leads to the system providing too much air to the closest zones and not enough air to the zones that are further away from the air handling units.

Recommended Action: Install a variable frequency drive on all of the supply air fans and install variable air volume boxes within the space to regulate air flow within each zone. Before the VAV boxes and air outlet modifications are made, the facility should implement the lighting energy conservation measures listed below. This will reduce the cooling load within the building, and reduce the required air flow rate of each individual VAV box. In addition, the VAV boxes will need to include a space level thermostat and an air damper that is operated by a DDC system to regulate flow rates within each zone.

Challenges and Steps: This is the most complicated energy conservation measure that has been proposed and will need to be designed by an experienced HVAC technician. Additional thought will need to be put to locating VAV boxes and designing the system. The installation of the system will also be disruptive to onsite staff members and will need to be carefully planned out. For the purposes of this assessment, it was assumed that four variable frequency drives will need to be installed and 25 VAV boxes.

Electricity Savings: *5,893 kWh/yr*
Cost Savings: *$1,709/yr*
Implementation Costs *$86,075*
Simple Payback *50.4 years*

Assumptions: The HVAC systems were changed in eQUEST and modeled as a VAV system. The VAV boxes were allowed to have a minimum flow rate of 15%.

Installed cost estimates were taken from RSMeans assuming 25, 400 CFM VAV boxes were installed.

Table 16: Itemized Installed Cost Estimate

Install VAV Terminal Boxes							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	VAV Terminal, cooling only, with actuators/controls, 400 cfm	25	VAV Box @	$2,945	0	$75	$73,625
2	Install Variable Frequency Drives on AHUs	6	Motor @	$2,075	0	$75	$12,450
						Total	**$86,075**

4.4. Recommendation: Replace the Roof with an Insulated Cool Roof

Current Condition: The current roof is a typical built up roof with a rock bed finish. The roof is constructed of 6 in concrete and has no thermal insulation. The current construction results in significant heat gain through the roof that has to be removed from the space by the air conditioning systems.

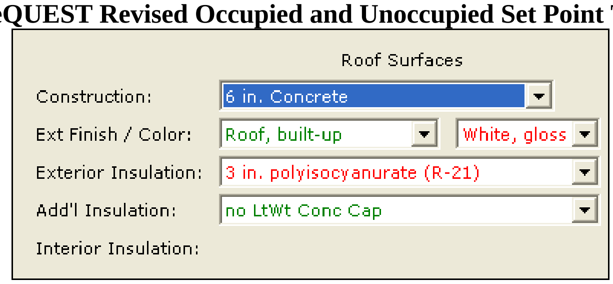
Recommended Action: Replace the current roof with an insulated cool roof. A cool roof in this climate is typically made of a white plastic membrane. Three inches of exterior board insulation should be installed underneath the cool roof. The cool roof has the effect of reflecting the suns energy, which significantly reduces the heat load on the roof.

Challenges and Steps: This is a relatively simple measure to implement. Due to the high upfront costs associated with this measure, the site should wait until the roof needs to be replaced to implement this measure.

Electricity Savings: *1,263 kWh/yr*
Cost Savings: *$366/yr*
Implementation Costs *$101,730*
Simple Payback *278 years*

Assumptions: The revised roof construction characteristics that were modeled in eQUEST are provided below.

Figure 26 - eQUEST Revised Occupied and Unoccupied Set Point Temperature



Installed cost estimates were taken from RSMeans.

Table 17: Itemized Installed Cost Estimate

Total Roof Replacement (with R30 Insulation)							
Item	Description	No. of Units	Unit	Equipment / Materials Unit Cost	Install Man hours	Man hour Rate	Labor & Equip Cost
1	Set Up, secure and take down ladder	133	100 sq ft @	$0	0.02	$65	$173
2	Remove existing membrane/insulation	133	100 sq ft @	$0	3.501	$65	$30,341
3	Remove flashing	133	100 sq ft @	$0	0.026	$65	$225
4	Install 5" perlite insulation	133	100 sq ft @	$200	1.143	$65	$36,572
5	Install flashing	133	100 sq ft @	$2	0.037	$65	$553
6	Install fully adhered 180 mil membrane	133	100 sq ft @	$59	2	$65	$25,199
7	Clean up	133	100 sq ft @	$0	1	$65	$8,666
						Total	**$101,730**

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[iv] Illumination Engineering Society, Lighting Handbook https://www.iesna.org/shop/

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