GRACE EPISCOPAL

ENERGY AUDIT REPORT
(ASHRAE LEVEL 2)

Prepared for:
The City of Alexandria, T&ES Office of Environmental Quality. Prepared with funding from DOE's Energy Efficiency & Conservation Block Grant.

Prepared by:
2rw Consultants Inc.
100 Tenth Street, NE
Charlottesville, VA

September 2011

Table of Contents

Acronyms Defined 4

1. Executive Summary 5

2. Existing Conditions 7

Building Envelope 8
Building Occupancy and Usage 8
Building Floor Plan 8
Current Energy Saving Measures 9
Heating Ventilation and Air Conditioning (HVAC) 10
Lighting & Electricity 10
Other Energy Users 11
Water 11

3. Utility Analysis 12

Existing Facility Energy and Water Consumption 12
Energy Utilization Assessment 13
Electricity 14
Rate Schedule 14
Trends in Electricity Use 16
Natural Gas 19
Rates 19
Trends in Gas Use 19
Water & Sewer 21
Rate Schedule 21
Trends in Water Use 21

4. Energy Conservation Measures 23

ECM 1: Lighting System Upgrade 24
Scope of Work - Lighting Upgrade (T12) 24
ECM 2: Auditorium Lighting System Upgrade 26
Scope of Work - Lighting Upgrade (Halogen Flood Lights) 26
ECM 3: Lighting Conservation Measures 27
Scope of Work – Occupancy & Vacancy Sensor Installation 28
ECM 4: Install Higher Efficiency HVAC Equipment 28
Scope of Work - Install Higher Efficiency HVAC Equipment 30
ECM 5: Install Water Conserving Fixtures 31

©2011

Scope of Work - Install Water Conserving Fixtures....31
ECM 6: DHW Heating System Efficiency Upgrades....32
Scope of Work – Utilize Existing Boilers for DHW heating....33
ECM 7: Improving Building Practices....34
Scope of Work – Improve Building Practices....35
ECM 8: Building Envelope Upgrades....35
ECM 9: Upgrade to Energy Efficient Appliances....36
Scope of Work – Upgrade to High Efficiency Refrigerators....37
5. Recommendations....38
Lighting....38
HVAC....38
Water Conservation and DHW System....38
Appliances....39
Recommendation Summary....39

©2011

Acronyms Defined

ACGIH - American Conference of Industrial Hygenists
Acronyms Defined
AHRI - Air Conditioning, Heating and Refrigeration Institute
AHU - Air Handler Unit
ANSI – American National Standards Institute
ASA - Alexandria Sanitation Authority
ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers
CBECS - Department of Energy's Commercial Building Energy Consumption Survey
CDD - Cooling Degree Days
cf - cubic feet CFM - Cubic Feet per Minute
CFL - Compact Fluorescent
CMU - Concrete Masonry Unit
CO - Carbon Monoxide
CO-2-eq - Carbon Dioxide Equivalent
COP – Coefficient of Performance
DDC - Direct Digital Control System
DHW - Domestic Hot Water
DOE – Department of Energy
DX – Direct Expansion
ECM - Energy Conservation Measure
EDDM – Ethylene Propylene Diene Monomer
EER – Energy Efficiency Ratio
EPA - U.S. Environmental Protection Agency
EPACT 2005 - Energy Policy Act of 2005
EPDM - Ethylene Propylene Diene Monomer
EPR - Energy Performance Rating
FCU - Fan Coil Unit
gpf - Gallons per Flush
gpm - Gallon per minute
gpw - Gallons per wash
GSHP – Ground Source Heat Pump
HDD - Heating Degree Days
HDPE – High Density Polyethylene
HHW - Heating Hot Water
HP – Horsepower
HPWH – Heat Pump Water Heater
HUD - Department of Housing and Urban Development
HVAC - Heating Ventilation and Air Conditioning
HVU - Heating Ventilation Unit
kWh - Kilowatt-hour
LED – Light Emitting Diode
MBH - Thousand BTU's per hour
NFPA - National Fire Protection Agency
ppm - Parts per million
SHGC – Solar Heat Gain Coefficient
TMY - Typical Meteorological Year
VSD – Variable Speed Drives

©2011

1. Executive Summary

Rising energy costs have caused the energy budgets of facilities across the country to increase dramatically in the past years. Electric utility companies are continuing to increase electric rates to cover their increased generating costs, while natural gas and oil prices remain volatile due to political unrest in the Middle East, impacts on supplies of the commodities, and natural disasters. In response to these rising costs, the City of Alexandria commissioned 2rw Consultants to perform an energy audit at Grace Episcopal in Alexandria, VA.

An Energy Star Target Finder ™ analysis of the utility consumption for the building indicates that the facility has significant opportunity for energy conservation. Table 1 presents the energy and water conservation measures identified and analyzed by the 2rw team; all of the items were analyzed independently and the savings were measured from the baseline consumption, with the exception of DHW where savings are based on water use estimates post installation of water conserving fixtures. Please note some opportunities are mutually exclusive, for example three different options are presented for replacing the T12 fluorescent light fixtures. These options are to provide stake holders the opportunity to select the most appropriate measure to meet their goals.

Table 1: Energy Conservation Measures Analysis Results

Project Description	Annual Energy Savings				Total Project Cost ($)	Simple Payback (Yrs)
	Electrical (kWh)	Natural Gas (therms)	Water (kgal)	Total Savings ($)		
ECM 1a- Lighting- T8 Fixture Upgrade	29,675	-	-	$2,255	$92,989	41
ECM 1b- Lighting- T8 Ballast/Bulb Upgrade	17,350	-	-	$1,319	$41,440	31
ECM 1c- Lighting- T5 Upgrade	16,607	-	-	$1,262	$130,325	103
ECM 2a- Lighting- LED floodlight Upgrade	5,761	-	-	$438	$16,829	38
ECM 2b- Lighting- M.H. floodlight Upgrade	2,743	-	-	$208	$24,739	119
ECM 3- Lighting- O&V Sensors	5,391	-	-	$410	$29,633	72
ECM 4a- High Efficiency Chiller	11,870	-	-	$902	$155,006	172
ECM 4b- GSHP*	-17,612	5,100	-	$5,699	$386,400	68
ECM 5- Water Conserving Upgrades	-	11	151	$1,067	$5,949	6
ECM 6a- DHW High Efficiency Boiler**	-	42	-	$43	$13,903	323
ECM 6b- HW heat pump*,**	-1534	244	-	$221	$4,994	23
ECM 7- Improving Building Practices†	-	-	-	-	-	-
ECM 8- Green Roof††	-	-	-	-	-	-
ECM 9- High Efficiency Appliances	927	-	-	$70	$850	12

*This ECM replaces natural gas with electricity as its energy source

** Savings calculated from ECM5 instead of from baseline

† Insufficient automation system data provided for complete analysis

†† Minimal energy savings relative to implementation cost

The following table outlines the recommended ECMs for Grace Episcopal, the resulting energy savings, estimated cost, and simple payback.

©2011

Table 2: Recommended Energy Conservation Measures.

Line Item	Project Description	Annual Energy Savings				Total Project Cost ($)	Simple Payback (Yrs)
		Electrical (kWh)	Natural Gas (therms)	Water (kgal)	Total Savings ($)		
1	ECM 1b- Lighting- T8 Ballast/Bulb Upgrade	17,350			$1,319	$41,440	31
2	ECM 2a- Lighting- LED floodlight Upgrade	5,761			$438	$16,829	38
5	ECM 5- Water Conserving Upgrades		11	151	$1,067	$5,949	6
6	ECM 6b- HW heat pump*,**	-1,534	244		$221	$4,994	23

*This ECM replaces natural gas with electricity as its energy source

** Savings calculated from ECM5 instead of from baseline

The body of this report is organized into five major sections: Existing Conditions, Utility Analysis, Energy Conservation Measures (ECMs), Recommendations, and Appendices.

©2011

2. Existing Conditions

Grace Episcopal Church is located in Alexandria, Virginia and serves as a school and house of worship. It is a three-story building of approximately 31,000 square feet.

Figure 1: Street view of Grace Episcopal Church.

Figure 2: Aerial photograph of Grace Episcopal building from Microsoft Bing Maps.

©2011

Building Envelope

Grace Episcopal was constructed in three stages over 45 years beginning in 1948. The oldest section of the building is the Church and consists of double fieldstone masonry exterior walls and single pane stained and leaded glass windows. The school wing was completed in 1952 and is constructed of brick masonry with 2 inch rigid insulation and gypsum board. The windows in the school are wooden framed with single pane glass.

The third stage of construction in 1993 included the tower and parish offices, which connect the church and school wings, along with the addition of the narthex to the church wings. Renovations to the older wings were completed in this final stage as well. These sections are also constructed of brick masonry, insulation, and gypsum board. The parish office windows are wood framed insulated glass and the tower windows are metal framed, double-paned and tinted.

A sloped slate shingled roof makes up the majority of the building's roof envelope, and there is also a smaller flat roof of built up white ethylene propylene diene monomer (EPDM) rubber.

Building Occupancy and Usage

The building is comprised of school, church, and office spaces. The school is in session from September to mid-June and has 120 students and 30 faculty members. Some of the classrooms are also used during the summer months for day camp.

The Nave area of the church is primarily used on Sundays for services, and is occasionally used on Saturdays for weddings. There are also services during the weekdays on Tuesdays, Wednesdays, and Thursdays. The other rooms in the church are also primarily used on Sundays for service preparation and for Sunday school. According to staff members interviewed during the field visit, several rooms in the church are also used 4 to 5 days a week for meetings. The church offices are open Monday through Friday from 9-5 and have 10 staff members.

Building Floor Plan

Grace Episcopal is a three story building divided into three main areas by occupancy: school, church, and the common area/church offices. The figure below provides an illustration of the division of the building on the first floor; the second and third floors follow the same general theme.

©2011

Figure 3: First floor layout and divisions of the building.

Current Energy Saving Measures

Grace Episcopal has instilled the importance of saving energy and helping the environment in both its students and church members. The light switches throughout the buildings have signs made by students reminding occupants to please turn lights off when rooms are not in use and posters of energy conservation facts are spread throughout the hallways. Also, the Environmental Grace Committee was formed to create greater energy awareness in the parish. Other energy and water saving measures already implemented at the site include occupancy sensor lighting controls in the restrooms, a rainwater collection system for watering the garden, a composting system, and an artificial turf playing field that eliminates the need for irrigation.

Figure 4: Energy Conservation Signs.

Heating Ventilation and Air Conditioning (HVAC)

The heating and cooling system consists of eight Magic Aire Air Handler Units (AHUs) that are served by the boiler for heating (with the exception of one small heat pump serving the choir loft and a separate gas fired furnace for the Nave) and either the chiller or DX condensing units for cooling. The following table summarizes the zones and the associated HVAC equipment.

Table 3: Energy Conservation Measures Analysis Results.

ZONES		***AIR HANDLERS***	***SERVED BY***				
Zone	**Description**	**AHU**	**Htg**	**Clg**	**Model#**	**Clg tons**	**Condensing unit location**
1	"First Floor Link" Church offices, Corridor, Lobby, Commons, Restrooms	1	Boiler	ACUI	38AE012-500 38AKS008	16.8	on the roof
2	"Second Floor Link" Nursery, Sacristy, Church Library, Rector, Offices, St Mark's Meeting Room w/ Kitchen	2	Boiler	ACU2			on the roof
7	Choir Loft	3	ACU3	ACU3	38YRA048	4	outside behind Nave
4	"Undercroft" Choir Room, Children's Chapel, Vesting Rooms, Meeting Room	4	boiler	ACU4	38AE012-500	10	outside behind Nave
5	First & Second Floor School Classrooms, School Library	5*	Boiler	Chiller			N/A
6	First Floor School Offices, Kitchen	6	Boiler	Chiller			N/A
3	Third Floor. Church Kitchen, Meeting Rooms, Corridor	7	Boiler	Chiller			N/A
8	"Nave"	8	Furnace	ACU8	38AKS024	17.5	ACU8 behind Nave,
-	Auditorium, Stage, Storage	Unit Ventilators	Boiler	Chiller			N/A

*Classrooms served by fan coil units.

The chiller is a 60 Ton, 10.2 EER rated Trane air-cooled Nach unit. Chilled water is circulated with a 7.5 hp constant duty pump and air handling units served by the chiller have three-way control valves.

Heating hot water is generated by two high efficiency AERCO Modulex condensing, natural gas fired boilers and is circulated through the building by a constant volume pump. The air handling units have three-way control valves for heating hot water.

The HVAC system is controlled by a SOLO/FONE (TC1) Direct Digital Control System (DDC). It was noted through interviews with staff members during the site visit that the functionality of the existing control system is not well understood. Due to this deficiency, the systems are likely not set up for optimal building performance and energy efficiency.

Lighting & Electricity

Interior lighting consists primarily of 2’ by 4’ recessed parabolic, troffer fixtures containing either two or three T12 fluorescent lamps powered by magnetic ballasts. Other fixtures throughout the building include fluorescent down lights, halogen flood lights, metal halide wall sconces, and small pendant LEDs. All interior spaces are provided with manual wall switches for lighting control; each bathroom is also equipped with a wall mounted occupancy sensor. A timer is used to control some of the exterior lighting.

©2011

Other Energy Users

The offices contain typical office equipment such as computers, printers, and a Xerox machine; each classroom typically has one computer. There are 3 kitchens in the building. The first floor kitchen is equipped with a commercial sized refrigerator, commercial sized Energy Star freezer, convection oven, conventional oven with vent hood, dishwasher, coffee maker, and several sinks. The second floor kitchen is the smallest of the three and includes a top freezer refrigerator, sink, and microwave. The third floor kitchen is includes a large freezer and refrigerator, 12 piece stove top with vent hood, 2 ovens, dishwasher, ice maker, and 5 sinks; it was noted during the field visit that most of the equipment in the third floor kitchen is rarely used.

Water

Domestic hot water is supplied from a natural gas hot water heater in Mechanical Room 1; a small pump circulates domestic hot water through the building. Typical fixtures at the facility include 1.6 gallons-per-flush (gpf) toilets, 1.0 gpf urinals, and lavatories with 2.2 gallons-per-minute (gpm) aerators. In total, the restrooms have 9 toilets, 2 urinals, and 12 sinks.

The 3 kitchens have a total of 9 sinks and 2 dishwashers, with 5 of the sinks and 1 dishwasher in the third floor kitchen that sees infrequent use. There are two sinks and an instant hot water heater in the sacristy room as well one sink in the art room. There are several drinking water fountains throughout the building.

©2011

3. Utility Analysis

Existing Facility Energy and Water Consumption

Electricity to the building is provided by one electric service from a power company owned transformer. This transformer receives primary power from Dominion Virginia Power and is billed under the GS-2 schedule.

The following figure represents the baseline energy usage profiles for the building. The baseline energy use profiles were derived from utility data and data acquired during the site observation. Many of the distinctions between energy profiles utilizing the same site energy source were made possible through seasonal data variations. For example, the cooling and receptacle profiles are both derived from electricity use, yet, cooling electrical use occurs during warm seasons and receptacle energy use remains constant. Other energy profile distinctions were developed from data acquired from the on-site audit. *Receptacles* are defined as any plug allowing for current to be used to run a variety of electrical devices (computers, printer/fax units, clocks, etc). The total average energy and water consumption for Grace Episcopal over the past 3 years is **2,511 MMBtu/year** and **307 kgal/year**, respectively. Of that energy consumption, 53% (390,040 kWh/yr) is electricity and the remaining 47% (11,783 therms/yr) is natural gas.

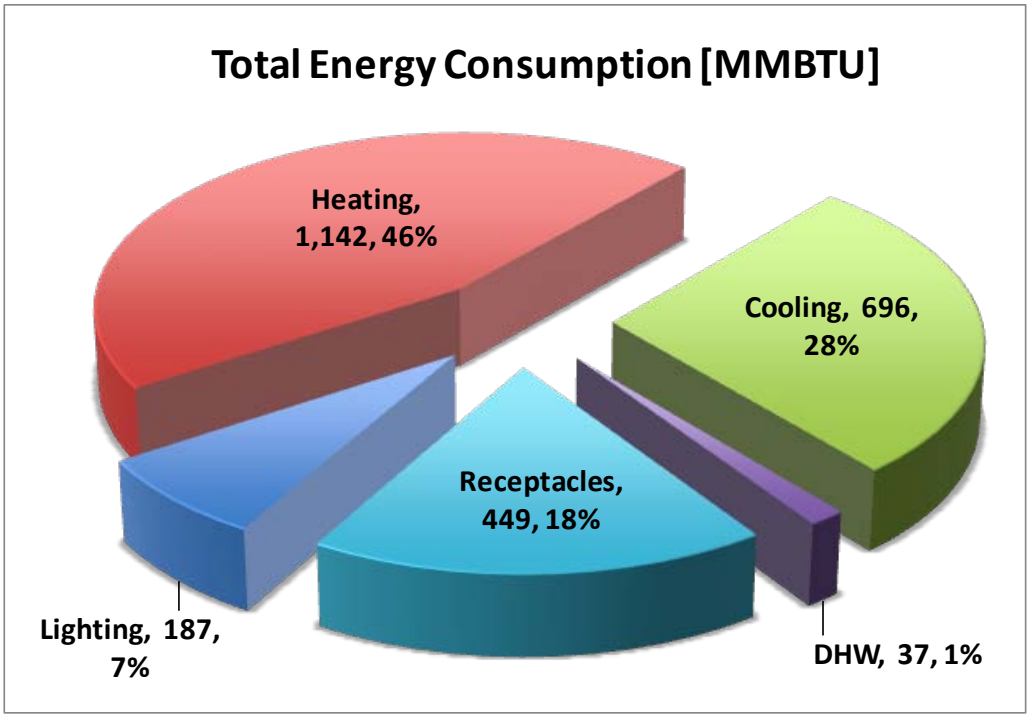

Figure 5: Estimated energy consumption for Grace Episcopal.

Savings estimates for energy and water conservation measures depend on the costs of utility resources among other factors. This section contains an assessment of the resource utilization, and an analysis of historical cost and consumption trends for electricity, natural gas, water, and sewer utilities.

©2011

Energy Utilization Assessment

An assessment of overall energy efficiency at Grace Episcopal has been determined based on the U.S. Environmental Protection Agency's (EPA) Energy Star Target Finder ™ program. Target Finder ™ uses information about a facility and its annual energy consumption to determine an Energy Performance Rating. The Energy Performance Rating (EPR) uses a scale from 1-100, with 100 being the most energy efficient. A building can receive an Energy Star ranking with an EPR of 75 or above. Target Finder ™ is based on the US Department of Energy's Commercial Building Energy Consumption Survey (CBECS) data.

The EPA has defined three categories of EPR scores. The EPA recommends a different course of action for each category. The definitions of the three categories are quoted below from the EPA's website.

> **Low ratings (1-49) - Greatest opportunities for investments**
> Buildings in this category have the most attractive returns for capital investments. Look for opportunities to upgrade lighting and other significant energy using systems, including system coordination. Renewing the commitment of key decision makers to energy management will be an important component of your strategy.
> **Middle ratings (50-74) - Fine tune O&M**
> Buildings with mid-range benchmarks should consider low- or no-cost activities such as re-commissioning campus buildings, developing and implementing preventative maintenance plans, increasing employee training, or re-assessing incentive, recognition, and reward systems to ensure that they drive energy performance. Often, these relatively low-cost efforts can turn these facilities into "top performers".
> **High ratings (75-100) - Reward and Learn**
> Buildings within this range are among the highest energy performers compared to other similar facilities in the US. Facility managers may consider sharing their energy management plans and operational strategies with other interested parties as they can continue to improve performance.
> **SOURCE: EPA**

Target Finder ™ has calculated an EPR of **38** for Grace Episcopal. This indicates there is significant room for improvement in energy use. The table below provides the estimated Target Energy performance results for Grace Episcopal and a representative average building. A target rating of 75 is shown because this is the EPR required for Energy Star building certification.

Table 4: Target Energy Performance Results (estimated).

	Grace Episcopal	Average Building	Target
Energy Performance Rating:	38	50	75
Site Energy Use Intensity (kBtu/SqFt/yr):	74	66	50
Total Annual Site Energy (kBtu):	2,509,116	2,238,581	1,701,265
CO2-eq Emissions (metric tons/yr):	262	233	177

Site Energy is the amount of energy consumed at the point of sale (e.g., that enters the building) without adjustment for energy loss in the generation, transmission, and distribution of energy. Site energy is also referred to as *Delivered Energy. Site Energy Use Intensity* is the amount of site energy used in producing a given level of output or activity.[1]

[1] U.S. Department of Energy, Energy Efficiency and Renewable Energy. (2008). *Energy intensity indicators in the us - terminology and definitions* Washington, DC: Retrieved from http://www1.eere.energy.gov

©2011

Electricity

Rate Schedule

Electricity is provided to the building by Dominion Virginia Power and is billed from the GS-2 (Non-Residential General Service) rate schedule. The bills are calculated based on a number of factors including a monthly service fee, the electrical energy used, and the electrical demand required. The components of the GS-2 billing rate schedule are given in the table below.

B. Demand Billing

1. Distribution Service Charges

   a. Basic Customer Charge
      Basic Customer Charge $21.17 per billing month.

   b. Distribution Demand Charge
      All kW of Demand @ $ 3.387 per kW

   c. Each Distribution kilowatthour used is subject to all applicable riders, included in the Exhibit of Applicable Riders.

2. Electricity Supply (ES) Service Charges

   a. Generation Demand Charge

      1) For the billing months of June – September
         All kW of Demand @ $ 2.119 per kW

      2) For the billing months of October – May
         All kW of Demand @ $ 0.681 per kW

   b. Plus Generation kWh Charge

      First 150 kWh per kW @ 4.617¢ per kWh
      Next 150 kWh per kW @ 2.588¢ per kWh
      Next 150 kWh per kW @ 1.119¢ per kWh
      Additional kWh @ 0.272¢ per kWh

   c. Each Electricity Supply kilowatthour used is subject to all applicable riders, included in the Exhibit of Applicable Riders.

   d. Each kW of Demand billed is subject to all applicable riders, included in the Exhibit of Applicable Riders.

Figure 6: Monthly Rate Schedule for Electricity, Dominion Virginia Power.

©2011

The applicable riders for GS-2 rate schedule are provided in the table below.

Table 5: Applicable Riders for GS-2 Rate Schedule.

Rider	Description	Effective Date
A	Fuel Charger Rider A	For Usage On and After 07-01-10
R	Bear Garden Generating Station	For Usage On and After 04-01-11
S	Virginia City Hybrid Energy Center	For Usage On and After 04-01-11
T	Transmission	For Usage On and After 01-01-11
C1	Peak-Shaving	For Usage On and After 04-01-11
C2	Energy Efficiency	For Usage On and After 04-01-11
D	Tax Effect Recovery Factor	9/1/2009
EDR	Economic Development	8/11/1998
F	Receivers or Trustees	3/1/1954
G	Renewable Energy Program	On and After 01-01-09
J	Interruptible Electric Water Heating Service- Residential Customers	On and After 09-30-97
Credit Rider BRC	Base Rate Credit	Effective For Usage On and After 01-01-11 Through and Including 12-31-12

To estimate the cost savings for each conservation measure, an average rate of $0.076 per kilowatt-hour was used.

©2011

Trends in Electricity Use

The breakdown of Grace Episcopal's electricity consumption can be seen below in Figure 7; the average annual electricity consumption is **390,040**-kWh/year. It is estimated that 52% of Grace Episcopal's electricity consumption is used for space cooling.

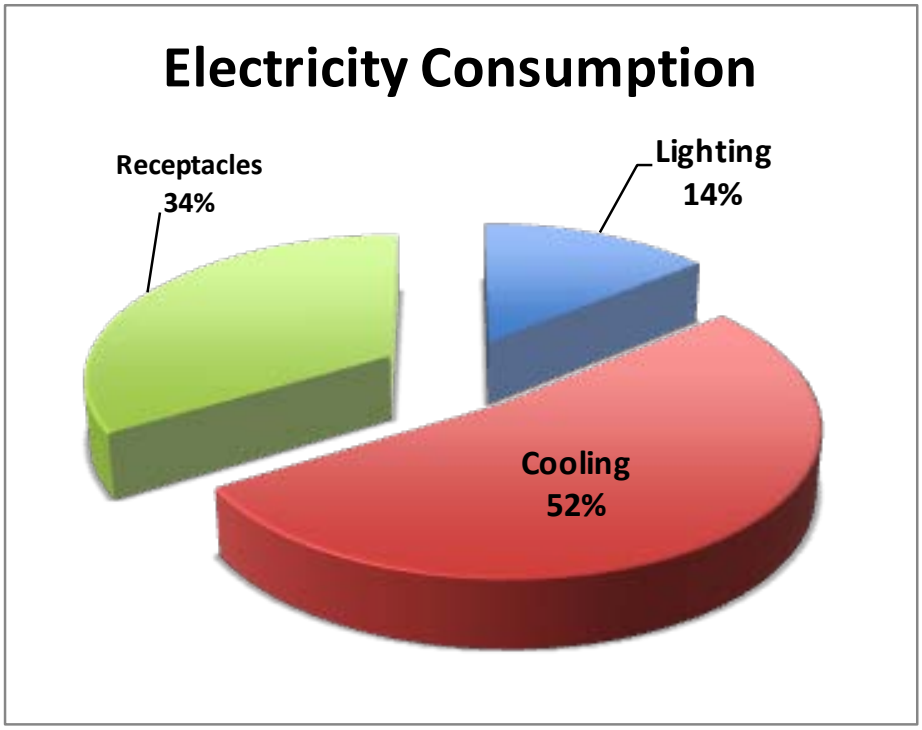

Figure 7: Breakdown of Electricity Consumption.

Figure 8 below illustrates electricity use over the period January 2008 through December 2010. The line labeled CDD illustrates the monthly cooling degree-days, indicating the magnitude of the weather-dependent space cooling load.

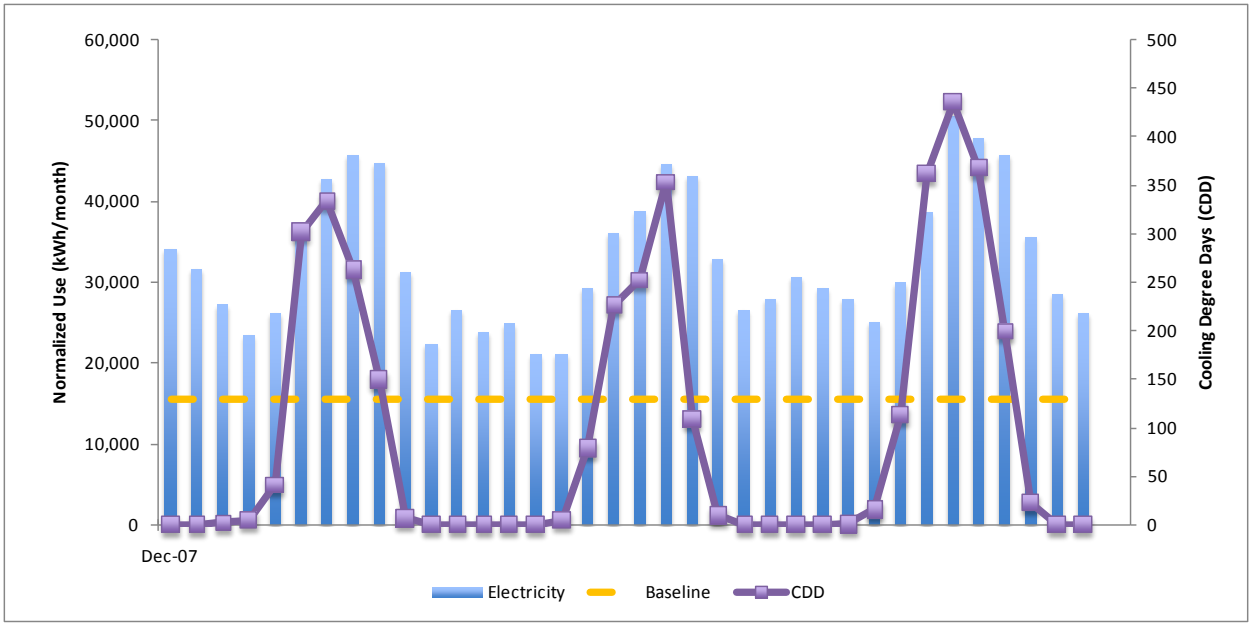

Figure 8: Electrical energy use, January 2008– December 2010.

A review of the electricity consumption indicates:

- Space cooling is a significant proportion of the total electricity use. It is likely that there is some space cooling during winter months due to high building occupancy from the school.
- The base load represents 48% of the electricity consumption - lighting, ventilation fans, computers, and other plug loads; this is represented by the yellow dashed line. For this facility, about 15,500 kWh per month is used for these purposes.

Figure 9 below displays electrical demand history for the building for March 2004 to March 2007. A review of the electrical demand indicates that space cooling constitutes a sizeable proportion of the total electrical demand.

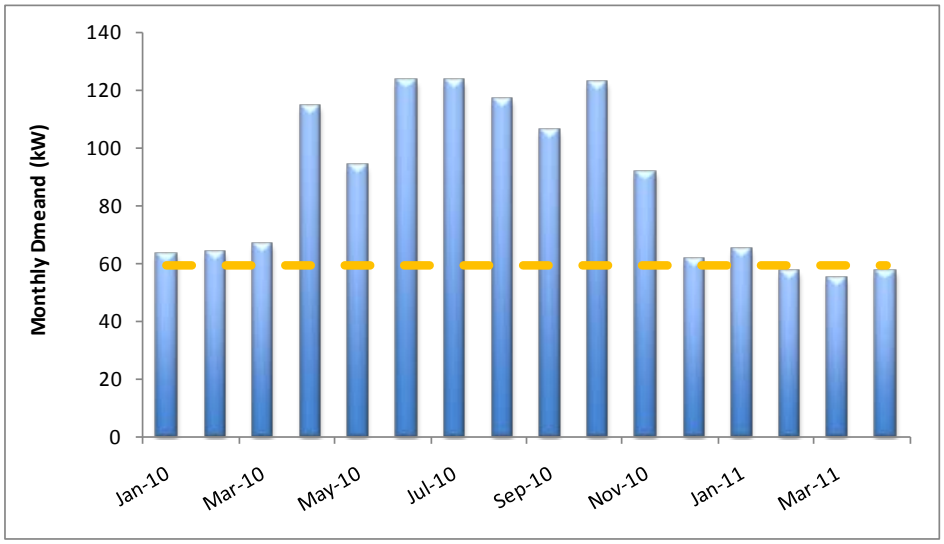

Figure 9: Electrical demand history, January 2010-April 2011.

Figure 10 below illustrates the history of the building's electrical load factor from January 2010 to April 2010.

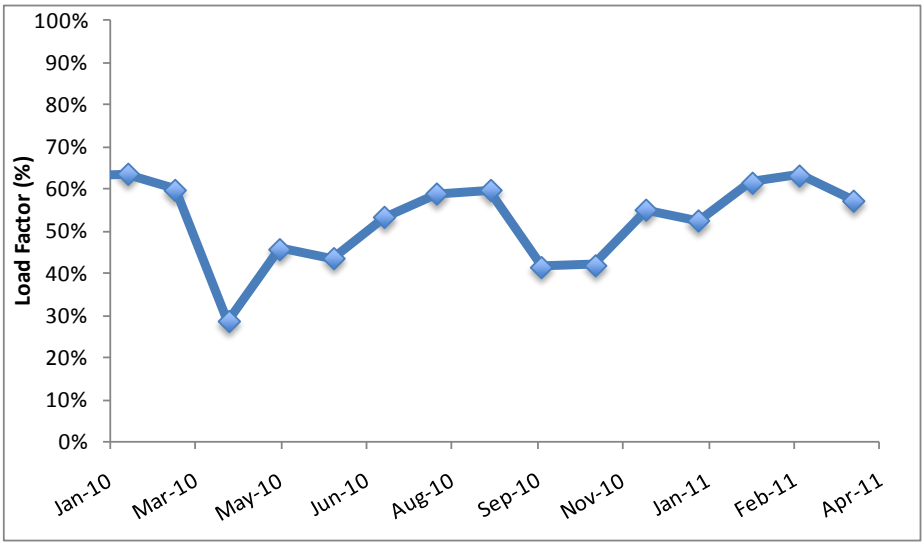

Figure 10: History of electrical load factor, January 2010-April 2011.

The *load factor* is defined as the ratio of average electrical power usage within a system to its maximum or "peak power" usage. Plotting the load factor on a monthly basis creates a graphical representation of the electrical power usage in comparison to the peak electrical demand which can serve to help identify current usage profiles and building schedule. A review of the load factor indicates that no seasonal trend is apparent.

©2011

Natural Gas

Rates

Grace Episcopal receives natural gas from Washington Gas. Over the past year, the average price of natural gas for the building was about $1.35 per therm (1 therm = 100,000 Btu). To estimate the cost savings for each conservation measure, an average rate of $1.35 per therm was used.

Trends in Gas Use

The breakdown of Grace Episcopal's natural gas consumption can be seen below in Figure 11; the average annual natural gas consumption is **11,783**-therms/year. The majority of Grace Episcopal's natural gas consumption is used for heating, with a small portion used for heating domestic hot water (DHW).

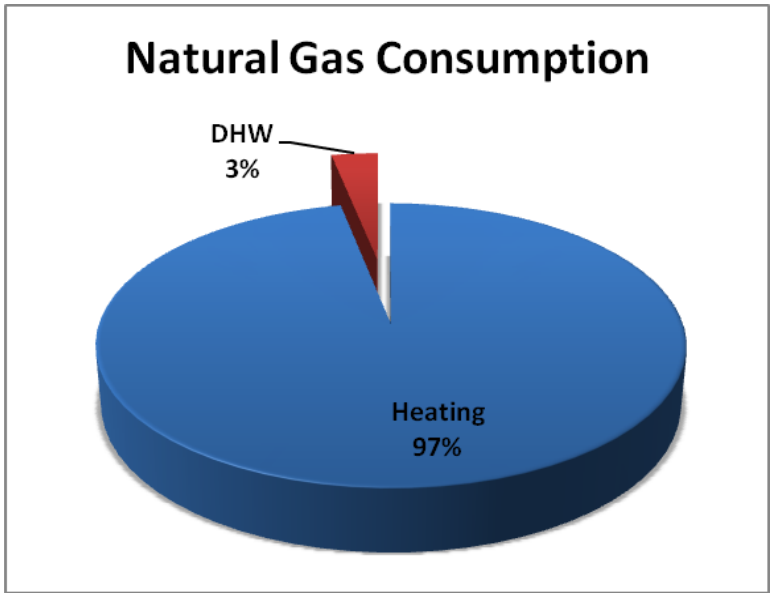

Figure 11: Breakdown of natural gas consumption.

Figure 12 below illustrates natural gas use for the building over a three year period from December 2007 to December 2010. The line labeled HDD illustrates the monthly heating degree-days, indicating the magnitude of the weather-dependent space heating load. The yellow baseline represents the natural gas for domestic hot water, everything above the baseline is natural gas used for heating.

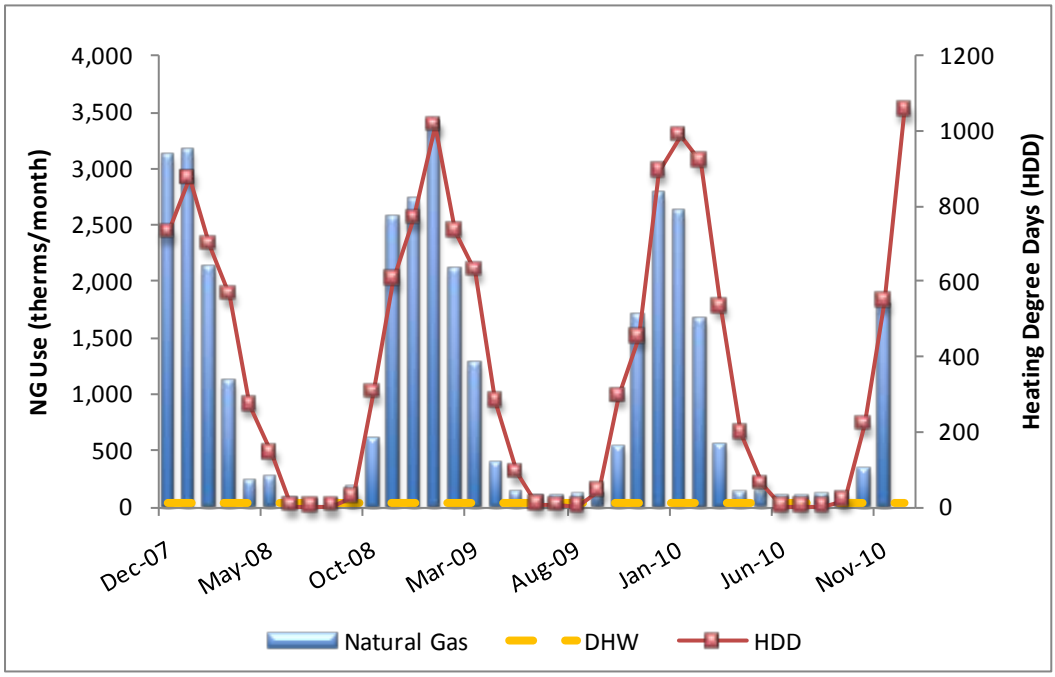

Figure 12: Natural gas use history, December 2007 – December 2010.

A review of natural gas use reveals the following trends:

- Natural gas use is significantly dependent upon weather, peaking during the winter months when space heating requirements are greatest.
- HVAC represents a significant majority of the natural gas use.
- DHW represents a very small portion of the natural gas use, around 29 therms per month.

©2011

Water & Sewer

Rate Schedule

Water and sewer utilities are provided by Virginia American Water Company and the sewer utility is the Alexandria Sanitation Authority (ASA). The average cost of water and sewer utilities combined has been about $6.11 per thousand gallons(kgal) over the past year. The ASA bill is calculated based on the total gallons purchased for consumption from Virginia American Water Company.

To estimate the cost savings for each conservation measure, an average rate of $7.00 per kgal was used.

Trends in Water Use

The breakdown of Grace Episcopal's water consumption can be seen below in Figure 13; the average annual water consumption is **307**-kgal/year. The majority of Grace Episcopal's water consumption is estimated to be used for toilets. The 13.1% labeled as "other" comes from uses not included in our analysis such as irrigation, outdoor hose bibs, water fountains, and miscellaneous sinks, and kitchen usage.

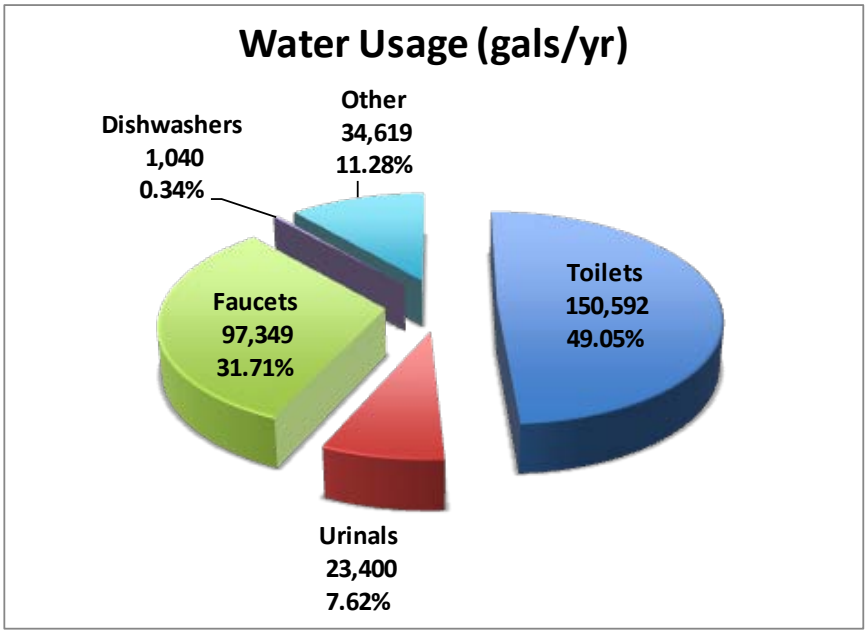

Figure 13: Breakdown of water consumption in gallons per year.

Historical water use at the building over the past year is shown in Figure 14. The billing for water was on a quarterly basis, every 91 days.

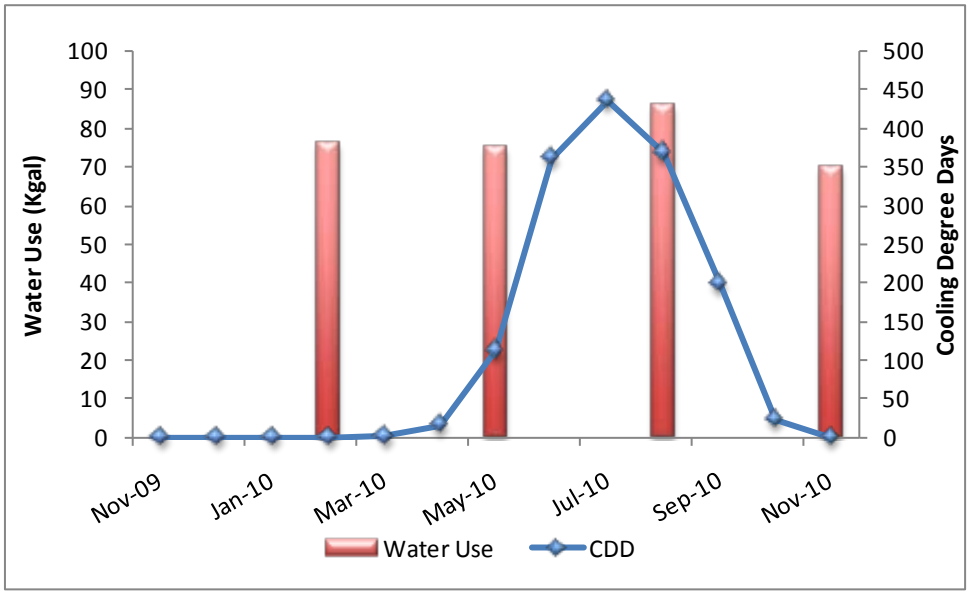

Figure 14: History of water use, November 2009 – November 2010.

The history of water use reveals the following trends:

- The consumption chart indicates no clear seasonal dependence in water use.
- Average water use is over 800 gallons per day.

4. Energy Conservation Measures

The following table outlines the ECMs pursued for this building, including the estimated annual energy savings, energy cost savings, implementation costs and simple payback period of each measure. Implementation cost estimates were developed through a combination of obtained contractor quotes and the RS means cost data reference manuals provided by Reed Construction Data Inc. Contractor quotes may vary significantly depending on contractor experience, economies of scale, market reputation, regional affluence, amongst other factors. The RS means cost data reference manuals were also used to provide rational, average market appropriate implementation cost estimates. In some instances, highly energy efficient technologies are not included within the manuals due to rapid technological innovation and low product volume distribution. In these cases, a premium is added to a standard energy consuming appliance or technology. Energy efficient premium estimations vary by the type of technology and relative market value and serve to provide conservative project cost estimations.

Table 6: Summary of Energy Conservation Measures Analyzed for the Building.

Project Description	Annual Energy Savings				Total Project Cost ($)	Simple Payback (Yrs)
	Electrical (kWh)	Natural Gas (therms)	Water (kgal)	Total Savings ($)		
ECM 1a- Lighting- T8 Fixture Upgrade	29,675	-	-	$2,255	$92,989	41
ECM 1b- Lighting- T8 Ballast/Bulb Upgrade	17,350	-	-	$1,319	$41,440	31
ECM 1c- Lighting- T5 Upgrade	16,607	-	-	$1,262	$130,325	103
ECM 2a- Lighting- LED floodlight Upgrade	5,761	-	-	$438	$16,829	38
ECM 2b- Lighting- M.H. floodlight Upgrade	2,743	-	-	$208	$24,739	119
ECM 3- Lighting- O&V Sensors	5,391	-	-	$410	$29,633	72
ECM 4a- High Efficiency Chiller	11,870	-	-	$902	$155,006	172
ECM 4b- GSHP*	-17,612	5,100	-	$5,699	$386,400	68
ECM 5- Water Conserving Upgrades	-	11	151	$1,067	$5,949	6
ECM 6a- DHW High Efficiency Boiler**	-	42	-	$43	$13,903	323
ECM 6b- HW heat pump*,**	-1534	244	-	$221	$4,994	23
ECM 7- Improving Building Practices†	-	-	-	-	-	-
ECM 8- Green Roof††	-	-	-	-	-	-
ECM 9- High Efficiency Appliances	927	-	-	$70	$850	12

*This ECM replaces natural gas with electricity as its energy source

** Savings calculated from ECM5 instead of from baseline

† Insufficient automation system data provided for complete analysis

†† Minimal energy savings relative to implementation cost

©2011

ECM 1: Lighting System Upgrade

Upgrade T12 Fixtures with Magnetic Ballasts

Since the Energy Policy Act of 2005 (EPACT 2005), the U.S. Department of Energy has been implementing regulations to phase out the production of T12 fluorescent technology, as they are significantly less efficient than newer T8 and T5 technology. The regulation states: "As of July 1, 2010, the most commonly used T12 magnetic ballasts are no longer being manufactured in the United States. By July 2012, production of most T12 lamps will cease as well."[2] It is recommended that these lamps be upgraded because it may become difficult to locate replacements and prices may increase as supplies decrease. T8 and T5 lamps are generally not compatible with T12 fixtures and will most likely need to be replaced as well.

The largest advantage to T8s and T5s is that they have the ability to create the same amount of light in lumens as a T12 lamp, but with less wattage. Installing these higher efficiency lamps can maintain current lighting levels while decreasing energy consumption and cost.

A key component in a lighting system is the ballast. A ballast regulates the current through a lamp at a desired constant value and may provide the required starting voltage and current.[3] The ballast factor is, "a measure of the actual lumen output for a specific lamp-ballast system relative to the rated lumen output measured with a reference ballast under ANSI test conditions (open air at 25 degrees C [77 degrees F)."[4] The majority of older T12 fixtures are equipped with magnetic ballasts that are less efficient than newer electronic ballasts. One of the reasons why T8 and T5 fixtures can produce more light is the electronic ballast factor is higher than 100 percent, while magnetic ballasts are under 100 percent. All fluorescent lamps deteriorate over time and will begin to dim, but electronic ballasts go through this process much slower than magnetic ballasts, thus increasing lamp life.

Scope of Work - Lighting Upgrade (T12)

Three options for upgrading the T12 fixtures were analyzed for energy and cost savings. The options are:

1. Replace fixtures - Remove the 2'x4' parabolic fixtures containing F40T12 lamps with magnetic ballasts and replace with similar parabolic fixtures containing F32T8 lamps with electronic ballasts. The 3 lamp fixtures will all be replaced with 2 lamp fixtures.

2. Retrofit fixtures - Remove the existing lamps and magnetic ballasts from existing 2'x4' parabolic fixtures and replace with F32T8 lamps with electronic ballasts in the existing fixtures.

3. Replace fixtures - Remove the 2'x4' parabolic fixtures containing F40T12 lamps and magnetic ballasts and replace with similar troffer fixture containing F28T5 lamps and electronic ballasts.

The following generally outlines how each of these upgrades would be completed, along with the calculated savings.

---

[2] Xcel Energy. "Lighting Efficiency Rebates: T12 Phaseout." 2010. 19 Jul 2011. <http://www.xcelenergy.com/staticfiles/xe/Marketing/NM-Bus-Lighting-T12-Phaseout-Info-Sheet.pdf>.

[3] *Merriam-Webster* . 19 Jul 2011. <http://www.merriam-webster.com/dictionary/ballast>.

[4] "Light Guide: Fluorescent Ballasts." *Lightsearch.com*. 19 Jul 2011. <http://www.lightsearch.com/resources/lightguides/ballasts.html>.

©2011

1. Install Electronic Ballast T8 Fixtures
    - Remove existing T12 fixtures as required to facilitate installation of T8 fixtures.
    - Provide replacement T8 troffer fixtures for all T12 parabolic fixtures.
        - Number of Fixtures- **230**
    - Provide F32T8 lamps for upgraded fixtures.
        - Number of lamps- **460**

Table 7: Estimated energy consumption post F32T8 fixture and lamp implementation.

Baseline		Post 1a Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
45,603	$ 3,465.82	15,928	$ 1,210.49	**29,675**	**$ 2,255.32**

The estimated cost for this energy conservation measure is **$92,989** with a simple payback of **41** years.

OR

2. Install Electronic Ballasts & F32T8 Lamps
    - Remove existing T12 fixtures as required to facilitate installation of T8 fixtures.
    - Provide replacement ballasts for all fixtures.
        - Number of Ballasts- **230**
    - Provide F32T8 lamps for fixtures.
        - Number of lamps- **634**

Table 8: Estimated energy consumption post electronic ballast and F32T8 bulb implementation.

Baseline		Post ECM 1b Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
45,603	$ 3,465.82	28,253	$ 2,147.22	**17,350**	**$1,318.60**

The estimated cost for this energy conservation measure is **$41,440** with a simple payback of **31** years.

OR

3. Install Electronic Ballast T5 Fixtures
    - Remove existing T12 fixtures as required to facilitate installation of T5 fixtures.
    - Provide replacement T5 troffer fixtures for all T12 parabolic fixtures
        - Number of fixtures- **230**
    - Provide F28T5 lamps for upgraded fixtures.
        - Number of lamps- **634**

Table 9: Estimated energy consumption post F28T5 fixture and bulb implementation.

Baseline		Post 1c Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
45,603	$ 3,465.82	28,996	$ 2,203.66	**16,607**	**$ 1,262.16**

The estimated cost for this energy conservation measure is **$130,325** with a simple payback of **103** years.

©2011

ECM 2: Auditorium Lighting System Upgrade

Upgrade Halogen Flood Light Fixtures

Although halogen flood lights are effective at delivering high light output, they also use a large amount of electricity, produce a significant amount of heat, and have an abbreviated life cycle of approximately 4,200 hours. The lamps for these fixtures are relatively inexpensive, but due to their shorter life and higher energy use, end up with a higher life cycle cost than newer flood light technology.

LED flood lights are one of the newer lighting technologies that use significantly less electricity than traditional lighting. LED lights with an estimated lifespan of 30,000 hours, last significantly longer than fluorescent, halogen, and metal halide lamps. The main disadvantage to LED lights is the high capital cost; however investment in this technology can result in a significant energy savings over time.

The 250W halogen flood lights can also be replaced with 150W metal halide lamps producing equivalent illumination. This solution would require replacing the fixture as well as the lamps, however advantages over the existing fixtures include less lighting energy consumption, less heat dissipated to the space and longer lamp lifespan (approximately 24,000 hours) resulting in lower replacement and maintenance costs. The metal halide lamps do not perform as efficiently as LEDs but have a lower initial cost. The analysis results for both of these options are presented below.

Scope of Work - Lighting Upgrade (Halogen Flood Lights)

Two options for upgrading the halogen flood light fixtures located in the nave and the auditorium both involve removing the existing fixtures. The first option is to upgrade to LED floodlights and the second option is to upgrade to metal halide floodlights. The following generally outlines how each of these upgrades would be completed, along with the calculated savings.

A. Install LED Floodlight Fixtures
   - Remove existing halogen floodlight fixtures as required to facilitate installation of LED floodlight fixtures.
   - Provide and install replacement LED floodlight fixtures and lamps.
     - Number of Fixtures- **33**
     - Number of lamps- **33**

Table 10: Estimated energy consumption post LED fixture and lamp replacement implementation.

Baseline		Post 2a Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
6,858	$ 521.21	1,097	$ 83.39	**5,761**	**$ 437.81**

The estimated cost for this energy conservation measure is **$16,829** with a simple payback of **38** years.

OR

B. Install Metal Halide Floodlights
   - Remove existing halogen floodlight fixtures as required to facilitate installation of metal halide floodlight fixtures.

©2011

- Provide and install replacement lamps and fixtures.
  - Number of fixtures – **33**
  - Number of lamps- **33**

Table 11: Estimated energy consumption post metal halide fixture and lamp replacement implementation.

Baseline		Post 2b Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
6,858	$ 521.21	4,115	$ 312.72	**2,743**	**$ 208.48**

The estimated cost for this energy conservation measure is **$24,739** with a simple payback of **119** years.

ECM 3: Lighting Conservation Measures

Occupancy and Vacancy Sensors

Occupancy sensors and vacancy sensors automatically turn off lights in unoccupied areas by sensing the presence or absence of motion. Occupancy sensors automatically turn the lights on when motion is detected. Vacancy sensors on the other hand, require a manual input to turn on and will turn off automatically once there is no motion for a set period of time.

Vacancy sensors have the potential for greater energy savings, however occupancy sensors are better suited to some situations. For example, a hallway or storage room would benefit from an occupancy sensor so the lights would turn on whenever someone entered the area. Another room that would benefit from an occupancy sensor is a kitchen. This is because an occupant may be coming and going from the kitchen with their hands full and would not want to have the lights go out automatically requiring a manual switch, and free hand, to turn back on.

A vacancy sensor however, would be the best option in room that receives a significant amount of sunlight to ensure that the lights are only turned on when the space requires artificial lighting. Other ideal locations to install occupancy or vacancy sensors are: electrical rooms, mechanical rooms, communications rooms, break rooms, offices, conference rooms, restrooms, lounges, laundry rooms, and supply closets, where occupancy is intermittent or of short duration.

The sensors typically use infrared and/or ultrasonic technology to sense when someone is in the room. The infrared sensor works well in open spaces since it depends on the reflections of infrared light to detect motion. Ultrasonic sensors send out an inaudible, high pitch noise and depend on the reflections back to determine if there is movement. These sensors work much better in crowded spaces than infrared sensors since they do not rely on a direct line of sight to detect motion. Typically ultrasonic sensors are slightly more expensive than infrared sensors.

Installing these sensors can reduce the energy consumption and cost for lighting significantly. However, savings will depend on the amount of time the lights were unnecessarily left on before installing the sensor.

The following generally outlines that which will be required to achieve the calculated savings for lighting system upgrades in Grace Episcopal.

©2011

Scope of Work – Occupancy & Vacancy Sensor Installation

1. Install Vacancy Sensors
    - Remove existing light switches as required to facilitate installation of vacancy sensors.
    - Provide switch-mounted vacancy sensors with line-level control for offices and classrooms.
        - Approximate number of sensors - **36**
        - Lighting system shall require manual input to turn on, and automatically turn off after space is unoccupied for a period of 15 minutes (adjustable).

2. Install Occupancy Sensors
    - Provide **ceiling mounted**, dual technology occupancy sensors for open areas like hallways, stairwells, and common areas. Ensure proper coverage of the room, install multiple sensors as required. Self power wireless technologies such as those manufactured by Leviton (or equal) shall be permissible.
        - Approximate number of sensors – **32**
        - Lighting system shall automatically turn on and stay on when motion is detected, and automatically turn off after space is unoccupied for a period of 15 minutes (adjustable).
    - Provide **switch-mounted** occupancy sensors with line-level control for storage, mechanical, and electrical rooms.
        - Approximate number of sensors - **18**
        - Lighting system shall automatically turn on and stay on when motion is detected, and automatically turn off after space is unoccupied for a period of 15 minutes (adjustable).

Table 12: Estimated energy consumption post Occupancy & Vacancy Sensor implementation.

Baseline		Post ECM 3 Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
49,761	$ 3,781.81	44,369	$ 3,372.07	**5,391**	**$409.74**

The estimated cost for this energy conservation measure is **$29,633** with a simple payback of **72** years.

ECM 4: Install Higher Efficiency HVAC Equipment

High Efficiency Chiller Upgrade

Chiller technology continues to improve with consistently increasing efficiencies. For example, chillers are now being manufactured with magnetically levitated compressors which eliminate the heat generated by the friction of bearings; variable speed compression is also now more economically implemented for greater part-load efficiency. For a building owner, replacing an older chiller with a more efficient one can result in reduced energy use and increased savings.

Install Ground or Ground-Water Source Heat Pumps

A heat pump uses the vapor compression refrigeration cycle to produce heating or cooling by removing heat from one lower temperature medium (source) and rejecting it to another higher temperature medium

©2011

(sink). In the case of an air-to-air heat pump the medium from which heat is being absorbed and rejected is air. In heating mode, the heat pump is able to absorb heat from the outside air and reject it to the indoor air. This is reversed for cooling, absorbing heat from the indoor environment and rejecting it outside.

The efficiency of heat pumps is measure by the Coefficient of Performance (COP) which is the ratio of heating or cooling effect produced to energy consumed. The COP depends on the temperature difference between the source and sink so it changes throughout the year with better performance when the temperature differential is less. A Ground Source Heat Pump (GSHP) uses the relatively constant temperature of the ground to assist with this process and uses considerably less electricity than conventional air-to-air heat pumps since it is not exposed to hot and cold air temperature extremes above ground. Deep geothermal wells, typically 100 to 500 feet deep provide the source (heating mode) and sink (cooling mode) for the building condition loads. GSHPs circulate water through the wells to transfer heat to and from the ground into the building.

The main components of a GSHP system would be the following:

- Water-to-air heat pumps in each zone or a water-to-water heat pump to provide hot and chilled water to central mechanical equipment.
- Water loop piped throughout the building.
- Condenser water loop plumbed to heat pumps.
- Heat source and heat sink (geothermal wells).

The schematic diagram in the figure below explains the concept graphically.

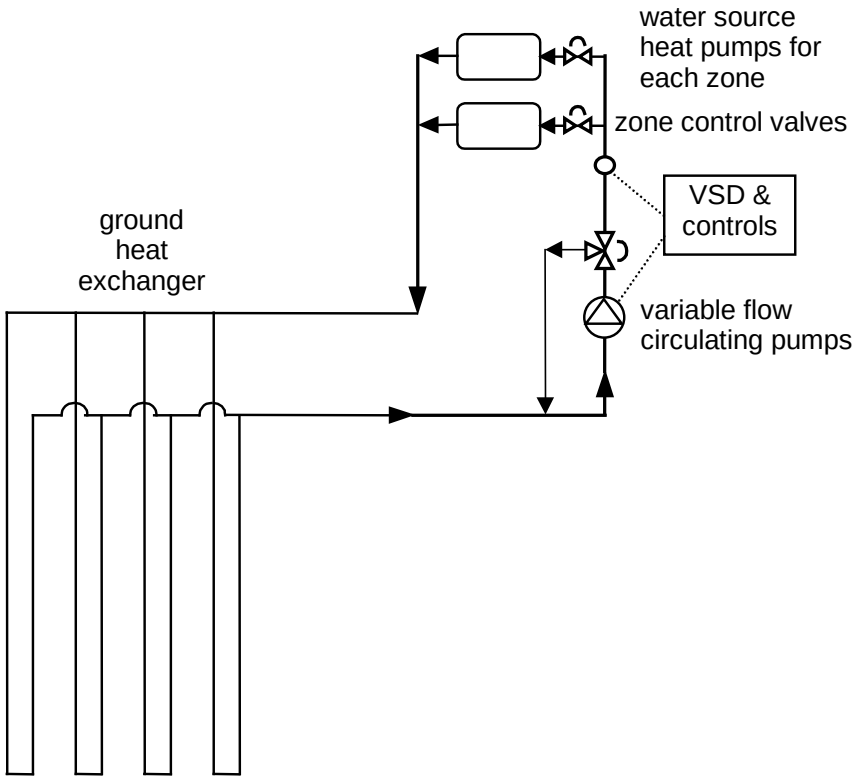

Figure 15: Ground Source Heat Pump (GSHP) System Schematic.

©2011

Scope of Work - Install Higher Efficiency HVAC Equipment

A. Install higher efficiency chiller
   - Remove existing chiller located in the rear of the building and remove piping as necessary to facilitate installation of new equipment. Recycle all equipment in accordance with all federal, state, and local laws.
   - Provide two new 30 ton Airstack (or equal) air cooled compressor chillers with variable frequency drive and a full load performance rating of 1.02 kW/Ton or better at AHRI rating conditions.
   - Provide piping and other appurtenances as required to reconnect existing piping to new unit.
   - Provide control wiring as necessary to connect chiller to building automation system.

Table 13: Estimated energy consumption for the building after implementation of a higher efficiency chiller.

Baseline		Post ECM 4a Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
61,537	$ 4,676.78	49,666	$ 3,774.64	**11,870**	**$902.14**

The estimated cost for this energy conservation measure is **$155,006** with a simple payback of **172** years.

OR

B. Install Ground Or Ground-Water Source Heat Pumps
   - Remove 4 existing condensing units and 1 existing heat pump.
   - Install Ground Or Ground-Water Source Heat Pumps
     - Heat Pump
       - Provide two 10 ton, one 17.5 ton, and one 4 ton water to air heat pumps. Units shall have a minimum cooling efficiency of 17 EER and a minimum heating efficiency of 3.8 COP at ARI rated conditions for ground loop heat pumps. Refrigerant shall be R-410A.
       - Provide miscellaneous electrical wiring, piping, ductwork, and appurtenances as required to facilitate installation of new equipment.
     - Well Field
       - Bore 55, 400-foot vertical well holes spaced 20 feet on center.
       - Provide 3/4" HDPE piping connected between bore holes to provide a closed loop.
       - Infill well holes with thermally conductive grout rated at 1.05 Btu/hr/ft/˚F or better.
       - Provide 120 gpm, 80 feet of head circulation pump, with variable frequency drive, and water treatment skid.
       - Provide approximately 800 feet of 2 inch HDPE piping inside building as required to connect each heat pump to ground loop piping.
       - Provide control valves, isolation valves, and balancing valves for each heat pump connection.

©2011

Table 14: Estimated energy consumption for the building after implementation of GSHP.

Baseline			Post ECM 4b Implementation			Savings		
Electricity Use [kWh/yr]	Natural Gas Use [therms/yr]	Energy Use [$/yr]	Electricity Use [kWh/yr]	Natural Gas Use [therms/yr]	Energy Use [$/yr]	Electricity Use [kWh/yr]	Natural Gas Use [therms/yr]	Energy Use [$/yr]
84,224	5,100	$13,439	101,836	-	$ 7,740	**(17,612)**	**5,100**	**$5,699**

The estimated cost for this energy conservation measure is **$386,400** with a simple payback of **68** years.

ECM 5: Install Water Conserving Fixtures

Provide Low Flow Toilets

Many older toilets consume 3.5 gallons per flush (gpf) or more. Currently manufactured toilets use between 0.8 and 1.6 gpf, many with similar or superior flushing capabilities as compared to the older, higher volume models. Significant water and sewer savings will be achieved by installing new low-flow toilets throughout all facilities. The toilets on site are 1.6 gpf.

Provide Low Flow Aerators

Aerators are installed to restrict water flow and form a particular spray pattern. In response to government mandated minimum flow rates as well as market desire for more efficient use of potable water, manufactures have developed new products that provide a similar user experience while consuming less water. Aerators for public lavatories are now available, and recommended, with flow rates of 0.5 gallons per minute. For break room and kitchen sinks, flow rates are recommended to be 1.0 to 1.5 gallons per minute. The restrooms on site were equipped with 2.2 gpm aerators.

Scope of Work - Install Water Conserving Fixtures

- Install Low Flow Toilets
  - Remove existing toilet fixtures.
  - Provide nine (9) ultra high efficiency toilet fixtures (0.8 gpf) similar to the Stealth™from Niagra Conservation.
  - Provide wax rings and necessary appurtenances to complete installation.
  - Reconnect sanitary and domestic cold water piping as required.
- Install Water Flow Restrictors On Faucets
  - Install twelve 0.5 gpm low-flow aerators on faucets in restrooms.

Table 15: Estimated water consumption for the building after implementation of a Water Conserving Measures

Baseline			Post ECM 5 Implementation			Savings		
Water Use [kgal/yr]	Natural Gas Use [therms/yr]	Water & Energy Cost [$/yr]	Water Use [kgal/yr]	Natural Gas Use [therms/yr]	Water & Energy Cost [$/yr]	Water Use [kgal/yr]	Natural Gas Use [therms/yr]	Water & Energy Cost [$/yr]
307	351	$ 1,874.84	156	244	$ 808.07	**151**	**107**	**$ 1,066.77**

The estimated cost for this energy conservation measure is **$5,949** with a simple payback of **6** years.

©2011

ECM 6: DHW Heating System Efficiency Upgrades

Heat Exchanger on Existing High Efficiency Boiler Loop

Grace Episcopal has recently upgraded their heating system with high efficiency heating hot water boilers, but still uses a less efficient natural gas domestic hot water (DHW) heater. Harnessing the efficiency of the new boilers through the use of a heat exchanger can cut energy costs for DHW heating.

Heat Pump Water Heaters (HPWH)

Heat pump water heaters (HPWHs), also called hybrid water heaters, use the heat found in the ambient air, which can be as low as 45 degrees, to heat water through a process similar to that described in the previous section describing heat pumps. This saves significant energy over straight electric resistance heating, but heats the water slowly. During periods of high hot water demand, the HPWH shifts to regular electric resistance water-heating elements. Depending on cold water supply temperatures, ambient air temperatures and patterns of hot water use, HPWHs are two to three times more efficient than standard electric water heaters. HPWHs both cool and dehumidify the air that passes through them, a potential benefit during cooling seasons, but a drawback during heating seasons. The heat pump can be integral to the system or separate from the storage tank. An "add-on" HPWH can be used to convert a conventional electric resistance water heater to a HPWH.

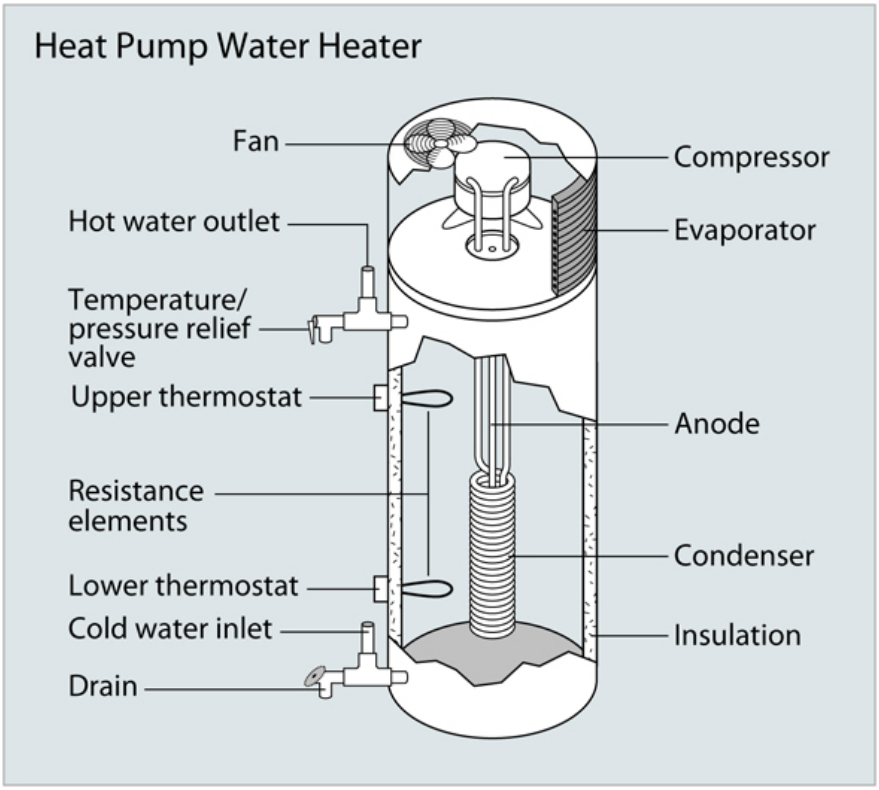

Figure 16: Heat Pump Hot Water Heater System Schematic.[5]

[5] US DOE's Energy.gov

Scope of Work – Utilize Existing Boilers for DHW heating

A. Use existing high efficiency boilers to heat DHW during the winter months
   - Remove existing DHW heater
   - Install new piping loop with a pump off of the existing Heating Hot Water (HHW) loop
   - Install double wall heat exchanger in the new loop
   - Run the DHW through the heat exchanger

The schematic diagram in the figure below explains the concept graphically.

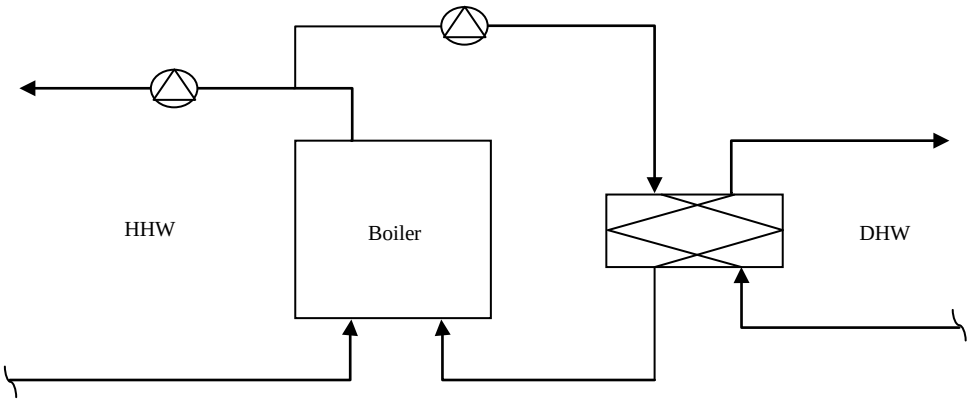

Figure 17: New HHW and DHW heating diagram.

Table 16: Estimated DHW energy consumption and savings using heat exhanger off existing boiler.

Baseline		Post ECM 6a Implementation		Savings	
Natural Gas Use [therms/yr]	Natural Gas Use [$/yr]	Natural Gas Use [therms/yr]	Natural Gas Use [$/yr]	Natural Gas Use [therms/yr]	Natural Gas Use [$/yr]
244	$ 337.27	203	$ 294.27	**42**	**$43.00**

The estimated cost for this energy conservation measure is **$13,903** with a simple payback of **323** years.

OR

B. Install a heat pump hot water heater.
   - Remove existing DHW heater.
   - Install an 80-gallon high efficiency heat pump hot water heater similar to the Whirlpool Energy Star model.
   - Reconnect domestic hot water piping as required.

Table 17: Estimated energy consumption for the building after implementation of a HPWH.

Baseline			Post ECM 6b Implementation			Savings		
Electricity Use [kWh/yr]	Natural Gas Use [therms/yr]	Energy Use [$/yr]	Electricity Use [kWh/yr]	Natural Gas Use [therms/yr]	Energy Use [$/yr]	Electricity Use [kWh/yr]	Natural Gas Use [therms/yr]	Energy Use [$/yr]
-	244	$ 337	1,534	-	$ 117	**(1,534)**	**244**	**$221**

The estimated cost for this energy conservation measure is **$4,994** with a simple payback of **23** years.

©2011

ECM 7: Improving Building Practices

After completing the field audit for Grace Episcopal we noticed several control strategies that could help to improve the buildings performance. The following are suggested in order to reduce energy bills and to maintain ASHRAE ventilation standards.

Optimize Cooling Schedules to Fit Occupancy

During the field visit, it was noted that the average room temperature was 70°F; this is a relatively cool temperature setting especially considering the majority of these rooms were not in use. In order to reduce cooling costs, it is suggested that the building take advantage of scheduling in order to ensure specific areas are not being cooled when unoccupied. This is especially important in a building similar to this where certain rooms are only used during the school months; the months the students are out of school are the hottest months of the years and reducing these cooling loads could yield significant energy savings.

Ventilation

Ventilation in a building can be natural or mechanical, or a combination of the two. Natural ventilation is provided from windows, louvers, and doors, while mechanical ventilation is provided by supply and return air ducts. Natural ventilation must have the operating mechanisms easily accessible for building occupants to control at their discretion. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) states that for natural ventilation, "the minimum operable area to the outdoors shall be 4 percent of the floor area being ventilated."[6] The figure below provides an example where natural ventilation is adequate with windows B and C equal to 4% of the floor area in the specified area.

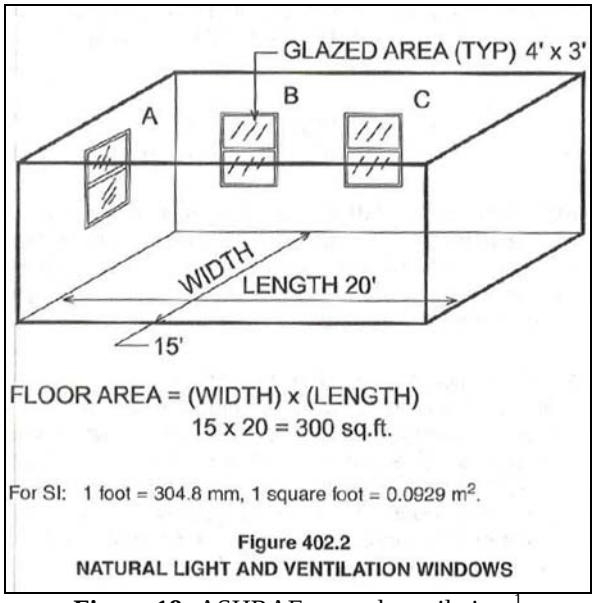

Figure 18: ASHRAE natural ventilation.[1]

[6] *2009 International Mechanical Code*. 2009. Print.

Mechanical ventilation provided by the air handlers should be set to operate continuously when a space is occupied. This, along with setback temperatures, can be most effectively implemented via scheduling rather than manually changing settings at each unit. Note, that if ventilation has not been provided at adequate levels previously, then increasing the amount of outside air can actually use more energy, but is necessary to maintain good indoor air quality and provide a safe environment for occupants.

Scope of Work – Improve Building Practices

- Optimize schedules to fit occupancy
    - Implement setback temperatures for both heating and cooling when spaces are unoccupied
- Ensure compliance with ASHRAE ventilation standards
    - Schedule air handlers to provide continuous ventilation when spaces are occupied.

ECM 8: Building Envelope Upgrades

Green Roofs

A green roof is planted with vegetation creating improved thermal properties and increasing usable space. The two types of green roofing systems are extensive and intensive; extensive systems have a thinner layer of soil, while intensive systems have a thicker layer soil. The type of system you chose is based on the weight load that a specific roof can handle.

There are numerous advantages to having plant life on the roof a building, for example, the foliage absorbs heat and thus reduces the heating and cooling costs of the building as well as reducing the urban heat island effect. Another advantage is they can reduce storm water runoff by absorbing rain water, while simultaneously filtering out pollutants and heavy metals. Green roofs also provide a natural habitat for birds and insects and filter pollutants and CO2 from the air. Financially, green roofs can increase a roof's life span and can also increase real estate value. The main disadvantage to green roofs is the high upfront costs for the materials and installation.

The area of Grace Episcopal that would be appropriate for a green roof system is approximately 2,500 square feet located on the flat roof area between the church and school. A representative from GreenGrid Roofs stated an estimated cost for an area of this size to be approximately $22/sqft, with materials comprising approximately 68% of this cost and installation accounting for the remaining 32%. A system such as this is not likely to recoup its cost through energy cost savings, but may create additional value for the school by improving the aesthetic environment and by serving as an educational tool.

A typical green roof installation would include the following steps:

- Note: Do not install on a saturated roof surface or under freezing weather conditions.
- Waterproof the ethylene propylene diene monomer (EPDM) rubber roof area.
- Sweep away all debris from waterproofed surface prior to installation
- Install pre-planted GreenGrid trays into straight rows, tightly against each other.

Because a green roof will add weight to the current roofing system, a comprehensive study must be completed by a licensed structural engineer to ensure the structure is capable of supporting the green roof.

©2011

Windows

Older windows can allow for significant heat gains and losses in a building, lowering overall building energy efficiency and increasing heating and cooling bills. There are several ways in which heat gain and loss occurs: conductive transfer due to the lower insulating properties of glass versus the surrounding wall, radiative heat gain from the sun, and convective transfer from air leakage through and around the window frame.

Three main components that affect a window's efficiency are the frames, glazing or glass, and operation.[7] When exploring glazing options, two performance characteristics to consider are the U-value and the solar heat-gain coefficient (SHGC). The U-value is the rate at which a window conducts non-solar heat flow; the lower the U-value, the higher the insulating properties of the window. The SHGC is a measure of how much heat a window blocks from sunlight. A low SHGC means less solar heat is being transmitted through the windows.[8] A low SHGC would be appropriate on the south, east, and west facing facades in a climate with significant cooling loads such as Alexandria, VA.

ECM 9: Upgrade to Energy Efficient Appliances

High Efficiency Refrigerators & Freezers

Refrigeration technology has improved significantly over the past several decades. One of the reasons for this is the implementation of the 1993 federal standards that resulted in a significant spike in efficiency.[9] Table 18 provides an outline of the improvements in the efficiency of refrigerators in the United States since 1990.

Table 18: Energy efficiencys of newer refrigerators (Energy Star).

REFRIGERATOR ENERGY EFFICIENCY CHANGES	
Standard/Spec Change	**Description**
1993 Federal Standard	30% more efficient than the 1990 standard
1997 ENERGY STAR	20% more efficient than the 1993 standard (44% better than the 1990 standard)
2001 Federal Standard	30% more efficient than the 1993 standard (51% better than the 1990 standard)
2001 ENERGY STAR	10% more efficient than the 2001 standard (56% better than the 1990 standard)
2004 ENERGY STAR	15% more efficient than the 2001 standard (58% better than the 1990 standard)
2008 ENERGY STAR	20% more efficient than the 2001 standard (61% better than the 1990 standard)

The U.S. Department of Energy (DOE), through its Energy Star program, has created an application that estimates potential energy and cost savings achievable by replacing older appliances with newer Energy Star rated models. The application can be seen below in Figure 19.

[7] EERE. "Energy Savers - Window Selection." 13 Jul 2011. <http://www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13370>.

[8] EERE. "Energy Performance Ratings for Windows, Doors, and Skylights." 13 Jul 2011. http://www.energysavers.gov/your_home/windows_doors_skylights/index.cfm/mytopic=13320

[9] "Launching a Refrigerator and Freezer Recycling Program." *Energy Star*. Web. 13 Jul 2011. <http://www.energystar.gov/ia/products/recycle/documents/StartAFridgeFreezerRecyclingProgram_FINAL.pdf>.

©2011

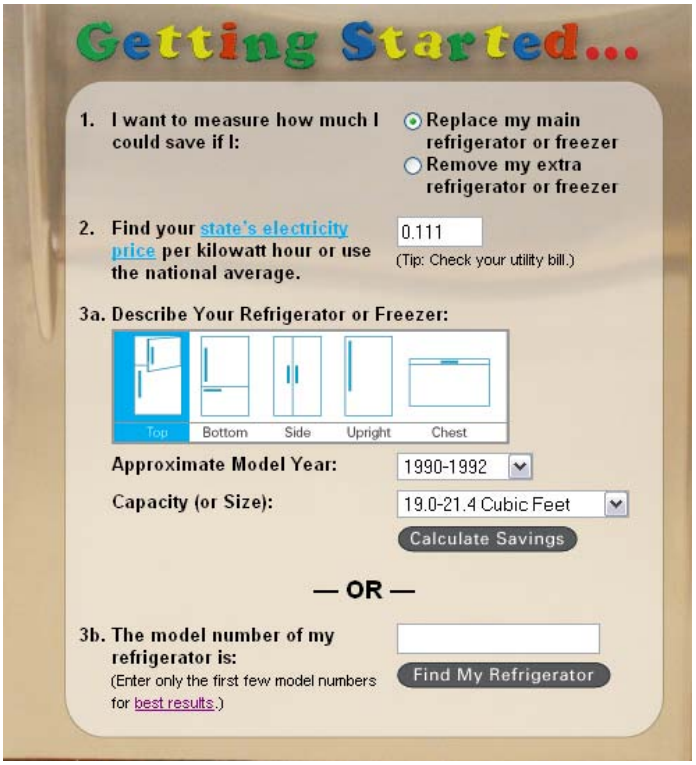

Figure 19: Refrigerator Retirement Savings Calculator (Energy Star).[10]

Scope of Work – Upgrade to High Efficiency Refrigerators

There are two commercial refrigerators, two commercial freezers (one is Energy Star), and one top freezer refrigerator on site. Upgrading all non-Energy Star appliances to newer technologies and/or implementing an Energy Star purchasing policy for future appliance purchases is another way to maximize energy efficiency in a facility. The results shown below are applicable to the top freezer refrigerator located in the kitchen on the second floor and are based on the Energy Star Refrigerator Retirement Savings Calculator.

Table 19: Estimated electricity consumption after upgrading a 20 year old top freezer refrigerator.

Baseline		Post ECM 9 Implementation		Savings	
Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]	Electricity Use [kWh/yr]	Electricity Use [$/yr]
1,361	$ 103.00	434	$ 33.00	**927**	**$ 70.00**

**Note: Savings information based off of the Energy Star savings calculator for a 20 year old top freezer refrigerator upgrade in Virginia.*[11]

[10] "Refrigerator Retirement Savings Calculator." *Energy Star*. 13 Jul 2011. <http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator&screen=1>

[11] "Refrigerator Retirement Savings Calculator." *Energy Star*. Web. 13 Jul 2011. <http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator&which=4&rate=0.076&rconfig=Top+Freezer&screen=4&manu=1990-1992&tvol=21.5-24.4+Cubic+Feet&submit.x=91&submit.y=5&model=>

©2011

5. Recommendations

Lighting

It was noted during the field visit to Grace Episcopal that the building occupants are already conscientious about turning off lights when a space is unoccupied and this was taken into consideration when formulating the basis for the analysis detailed in this report. Because of this, the energy use estimates are conservative and simple payback times longer than typically expected. Some lighting upgrades are still recommended for the T12 fluorescent and halogen flood lights.

The majority of existing lighting at Grace Episcopal consists of 2' by 4' recessed parabolic, troffer fixtures containing either two or three T12 fluorescent lamps powered by magnetic ballasts. The T12 fluorescent lamps will soon no longer be in production in the United States because of their low efficiencies and it is strongly recommended that they are upgraded to higher efficiency T8 lamps. Another reason to upgrade lamps is that it will likely become difficult locate T12 replacements and as supplies decrease it is expected that prices will increase. It is also recommended that the magnetic ballasts be replaced with electronic ballasts to both improve the efficiency of the fixture and to extend the life of the lamps.

It is also recommended that the halogen flood lights in the auditorium be upgraded to LED floodlights. It was noted through interviews with staff members that this room receives regular use and would benefit from more efficient lighting.

In order to conserve as much energy as possible, it is also suggested that occupancy and vacancy sensors be installed in some, if not all areas of the building. Areas recommended for occupancy sensors include hallways, stairwells, and mechanical and storage rooms. Vacancy sensors are recommended for classrooms, church activity rooms, and offices.

HVAC

It was noted through interviews with staff members during the site visit that the functionality of the existing control system is not well understood. Due to this deficiency, the systems are likely not set up for optimal building performance and energy efficiency. It is recommended that the staff be educated on the system and settings optimized to prevent heating or cooling unoccupied areas and also ensure adequate ventilation is occurring throughout the building in compliance with the Mechanical Code. Since the heating boilers were recently upgraded to high efficiency models and savings from a chiller upgrade would be minimal, no equipment upgrades are recommended at this time.

Water Conservation and DHW System

Implementing water conserving plumbing fixtures for toilets and lavatories is highly recommended due to the relatively low cost of implementation and the potentially high water and energy cost savings. The current toilet fixtures are adequate at 1.6 gpf, but considering their high rate of use, they could be cost effectively upgraded to ultra high efficiency toilet fixtures (0.8 gpf). More than 50% of the building's water consumption comes from toilets and urinals. Implementing these fixtures will cut the water consumption in half.

©2011

Switching out the existing 2.2 gpm lavatory aerators with 0.5 gpm aerators could also save significant amounts of water and energy. Due to the low cost and simplicity of installation, this measure may be completed without the use of a contractor.

Domestic hot water system upgrades were analyzed based on water use estimates after water conserving fixture upgrades are implemented. A heat pump hot water heater is recommended for implementation to replace the existing natural gas hot water heater. Due to the relatively low demand for hot water at this facility, a HPWH could be expected to perform at peak efficiency a majority of the time.

Appliances

There are two commercial refrigerators, two commercial freezers (one is Energy Star), and one top freezer refrigerator on site. We recommend upgrading all non-Energy Star appliances to newer technologies at the end of equipment life. Implementing an Energy Star appliance purchasing policy is an effective way to ensure future purchases comply with the Church and School's long term energy efficiency goals. It is also recommended that appliance donations be evaluated for their life cycle costs.

Recommendation Summary

The estimated annual electricity, natural gas, and water usage for this facility is 390,040-kWh, 11,783-therms, and 307-kgal respectively. If the recommended energy conservation projects were to be implemented at this facility, an estimated energy savings of **21,576-kWh** of electricity, **255-therms** of natural gas, and water savings of **151-kgal** could be achieved. This results in a **6%** reduction in electricity, **2.2%** reduction natural gas, and **49%** reduction in potable water. Given the current utility rates, the estimated cost savings is **$3,044** excluding rate escalation.

The proposed construction cost for this packaged project is $69,212 with a combined simple payback of 23 years, exclusive of capital cost savings from existing equipment replacement. For more detailed engineering and economic analysis of these energy conservation measures refer to the body of the report and corresponding ECM appendices.

The following table outlines the recommended ECMs for Grace Episcopal, the resulting energy savings, estimated cost, and simple payback.

Table 20: Recommended Energy Conservation Measures.

Line Item	Project Description	Annual Energy Savings				Total Project Cost ($)	Simple Payback (Yrs)
		Electrical (kWh)	Natural Gas (therms)	Water (kgal)	Total Savings ($)		
1	ECM 1b- Lighting- T8 Ballast/Bulb Upgrade	17,350			$1,319	$41,440	31
2	ECM 2a- Lighting- LED floodlight Upgrade	5,761			$438	$16,829	38
5	ECM 5- Water Conserving Upgrades		11	151	$1,067	$5,949	6
6	ECM 6b- HW heat pump*,**	-1,534	244		$221	$4,994	23

*This ECM replaces natural gas with electricity as its energy source

** Savings calculated from ECM5 instead of from baseline

©2011