

Insulation Analysis

for

College Grove United Methodist Church *College Grove, TN*

February 5, 2010

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Table of Contents

Background 3

Site Visit 3

Electric Billing History 3

Energy Utilization Index (EUI) 7

 Electrical 7

Energy Savings Opportunities (ESO's) 8

 Lighting 8

 HVAC 11

 Building Envelope 14

 Service Water Heating 15

 Appliances 15

Financing 17

Summary 18

Bibliography 19

Disclaimer 20

Background

Paul Sturdivant and College Grove United Methodist Church requested assistance from Middle Tennessee Electric to determine ways to reduce heating and cooling costs. TVA's Comprehensive Services performed a walk-through energy audit of the facility to determine opportunities for demand and energy savings.

The purpose of this report is to provide recommendations for energy conservation and recommendations for reductions in energy costs.

Site Visit

A site visit was made on January 11, 2010. During the site visit, a walk-through was completed of the facility, noting electrical loads (machinery, lighting, HVAC, etc.). TVA representatives met with Paul Sturdivant to help gather data about the facility and its daily operations.

Electric Billing History

To better understand how electrical loads contribute to the electric bill, a brief discussion of how electricity is measured and billed is given.

The electric bill for commercial customers consists of four charges. These are the customer charge, the demand charge (based on peak kilowatts), the energy charge (based on used kilowatt-hours) and the fuel cost adjustment.

- **Customer Charge:** The customer charge is fixed and covers the utility's administrative expenses.
- **Demand Charge:** The demand is the average electrical load (measured in kW), measured over 30 minutes. The demand charge is the charge for the highest kilowatt demand recorded during the billing period.
- **Energy Charge:** The energy charge is the charge for the use of energy during the billing cycle (measured in kilowatt-hours).
- **Fuel Cost Adjustment:** The fuel cost adjustment is an adjustable monthly charge added to the energy (kWh). It reflects the cost of fuel purchased to generate electricity such as coal and natural gas.

Table 1. GSA-1 rate effective November 2009

GSA-1 (0 - 50 kW)	
Customer Charge -	
Per delivery point per month	\$16.60
Demand Charge - per kW	
All kW	\$0.00
Energy Charge - per kWh -	
First 1500 kWh	\$0.08815
Additional kWh	\$0.08815

Table 2. Electric Billing History

Billing Date	kWh	kW	kVA	Power Factor	Billed Demand	kWh Cost	kW Cost	Customer Charge	Final Charges
Dec-08	1,587	0.00	0.00	N/A	0.00	\$163.89	\$0.00	\$16.60	\$180.49
Jan-09	1,258	0.00	0.00	N/A	0.00	\$123.72	\$0.00	\$16.60	\$140.32
Feb-09	1,064	0.00	0.00	N/A	0.00	\$104.64	\$0.00	\$16.60	\$121.24
Mar-09	1,159	0.00	0.00	N/A	0.00	\$113.99	\$0.00	\$16.60	\$130.59
Apr-09	736	0.00	0.00	N/A	0.00	\$68.45	\$0.00	\$16.60	\$85.05
May-09	701	0.00	0.00	N/A	0.00	\$65.19	\$0.00	\$16.60	\$81.79
Jun-09	829	0.00	0.00	N/A	0.00	\$77.10	\$0.00	\$16.60	\$93.70
Jul-09	1,150	0.00	0.00	N/A	0.00	\$103.58	\$0.00	\$16.60	\$120.18
Aug-09	1,671	0.00	0.00	N/A	0.00	\$150.51	\$0.00	\$16.60	\$167.11
Sep-09	693	0.00	0.00	N/A	0.00	\$62.42	\$0.00	\$16.60	\$79.02
Oct-09	896	0.00	0.00	N/A	0.00	\$79.90	\$0.00	\$16.60	\$96.50
Nov-09	710	0.00	0.00	N/A	0.00	\$62.59	\$0.00	\$16.60	\$79.19
Totals	12,454					\$1,175.97	\$0.00	\$199.20	\$1,375.17

Example Calculation For					Nov-09				
Service Charge / Month				\$16.60	x	1	=		\$16.60
				\$0.00					
All kW / Month				\$0.00	x	0.00	=		\$0.00
						kW Cost	=		\$0.00
First 1500 kWh / Month				\$0.08815	x	710	=		\$62.59
Additional kWh / Month				\$0.08815	x	0	=		\$0.00
						kWh Cost	=		\$62.59
						Total Cost	=		\$79.19

Security lights, rental fees and taxes are not included in these calculations

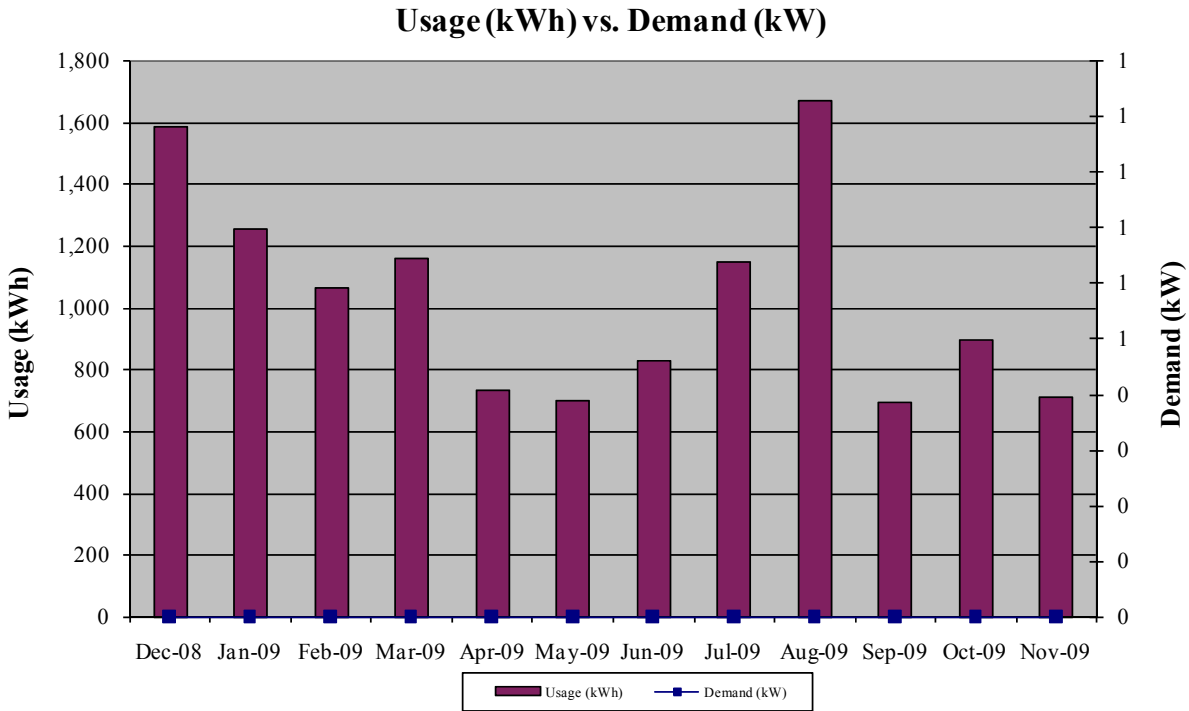


Figure 1. Usage vs. Demand

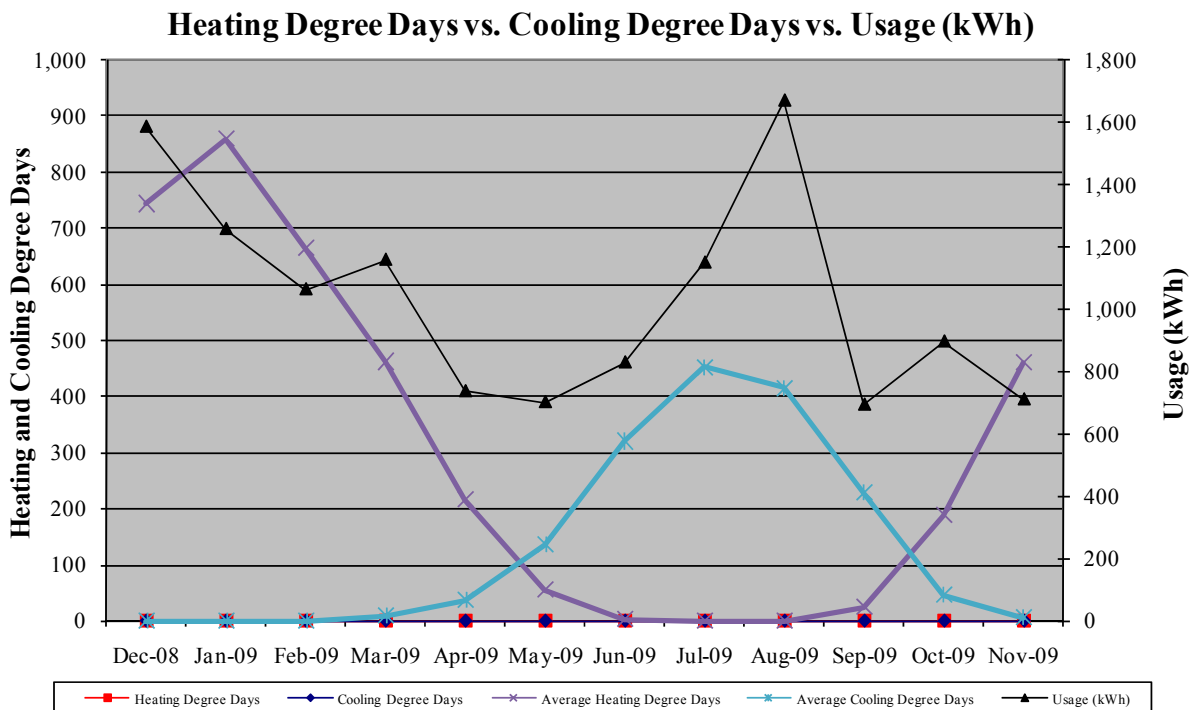


Figure 2. Usage Comparison for Heating Degree Days vs. Cooling Degree Days

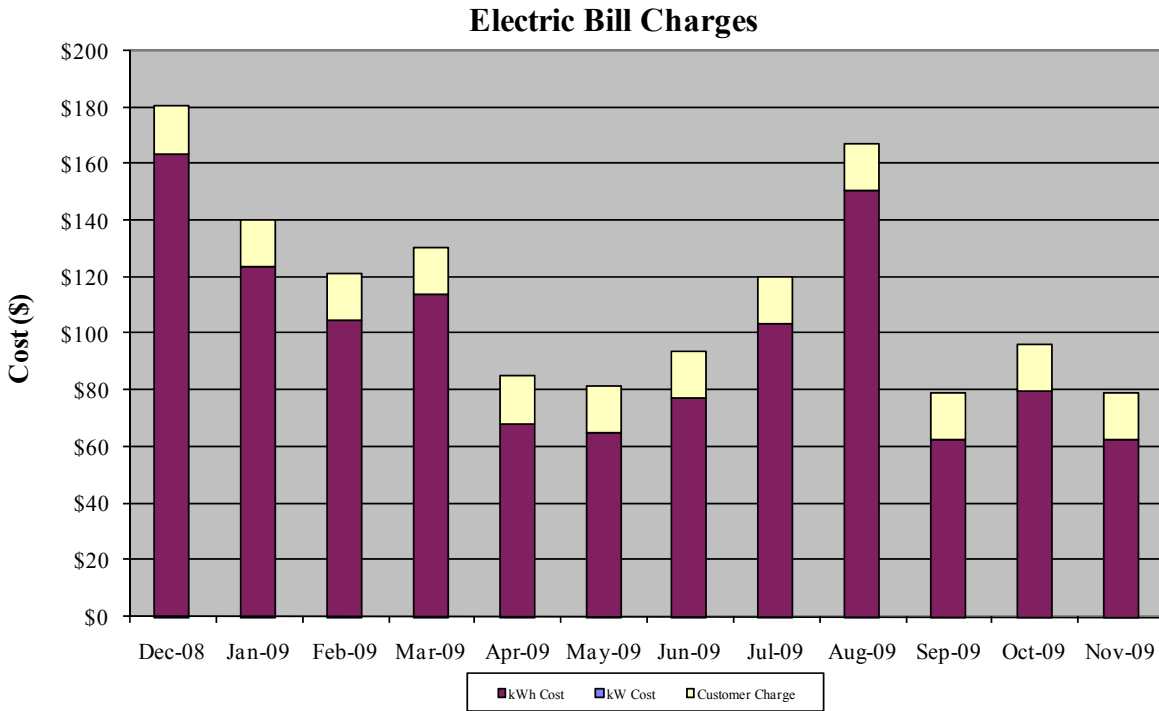


Figure 3. Electric Bill Charge

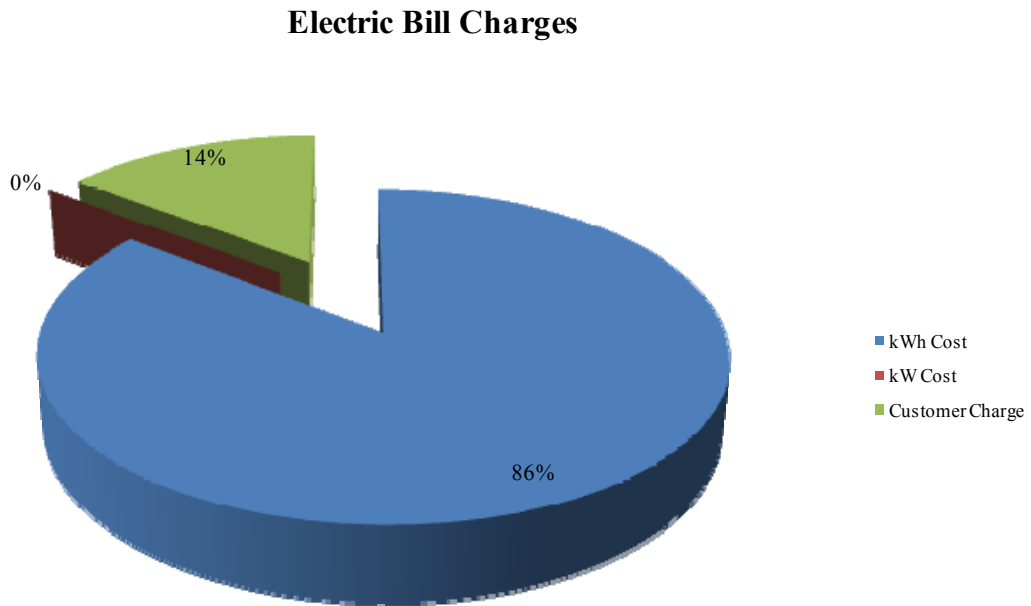


Figure 4. Percentage of Electric Bill Charges

Energy Utilization Index (EUI)

Electrical

The energy data was analyzed to determine the energy utilization of electricity for College Grove United Methodist Church. The time period was from December 2008 to November 2009. During this period of time, College Grove United Methodist Church used 12,454 kWh of electricity, which is equivalent to 42,497 kBtu per year. The facility's square footage is approximately 6,000. This equates to an annual energy consumption of 7 kBtu / ft².

According to data from the Commercial Buildings Energy Consumption Survey (CBECS), the average electrical usage for a Religious Worship building in Tennessee is 16 kBtu / ft² per year. College Grove United Methodist Church is operating approximately 43% lower than the average building of the same type in this area / climate of Tennessee.

Energy Savings Opportunities (ESO's)

Table 3 lists the energy savings opportunities for this facility.

Table 3. Energy Saving Opportunities

ESO	Description	Annual Cost Savings	Cost	Simple Payback (Yrs)
1	Replace T12 and Incandescent technology with T8 and CFL	\$249	\$1,382	5.6
2	Seal wall penetrations and caulk around windows	Varies	Varies	Varies
3	Install additional roof insulation	\$185	Varies	Varies

Lighting

Table 4 provides information regarding the cost of operating existing lighting fixtures. The table also presents recommended fixtures, with an estimated cost of purchase (materials only) and a simple payback for the investment.

Table 4. Existing Lighting Fixtures vs. Recommended Lighting Fixtures

Current Fixture Location	Current Fixture Description	Fixture Quantity	Replacement Fixture Description	Replacement Fixture Cost	Lamp kWh Savings	Occupancy Sensor kWh Savings	Total kWh Savings	kW Savings	Simple Payback (Years)	Annual Savings
Sanctuary	1F40T12	24	1F32T8	\$624.00	170	0	170	0.41	41.71	\$14.96
Sanctuary	Std. Incandescent, 25W	6	CFL, 7W Screw-In	\$30.00	45	0	45	0.11	7.57	\$3.96
Sanctuary	Std. Incandescent, 60W	6	CFL, 20W Screw-In	\$36.00	100	0	100	0.24	4.09	\$8.80
Hall	2F34T12	3	2F32T8	\$81.00	202	0	202	0.07	4.54	\$17.82
Office	4F34T12	2	2F32T8	\$54.00	386	0	386	0.21	1.59	\$34.01
Office	Std. Incandescent, 25W	4	CFL, 7W Screw-In	\$20.00	131	0	131	0.07	1.73	\$11.55
Office	Std. Incandescent, 60W	12	CFL, 20W Screw-In	\$72.00	874	0	874	0.48	0.93	\$77.01
Bathroom	Std. Incandescent, 60W	1	CFL, 20W Screw-In	\$6.00	25	0	25	0.04	2.73	\$2.20
Basement	2F34T12	16	2F32T8	\$432.00	699	0	699	0.38	7.01	\$61.61
Basement	4F34T12	1	2F32T8	\$27.00	193	0	193	0.11	1.59	\$17.01
Totals				\$1,382.00	2,824	0	2,824	2.12		\$248.93

Interior Surfaces

The lighter in color the interior surfaces of the facility are, the more efficient the lighting system will be. For best results, ceilings should have a reflectance of 70 to 90 percent. This can be achieved by using smooth white acoustical tile or painting the ceiling white. Any ceiling tiles that are water damaged or discolored should be replaced. The walls should also use light colors to help reflect the light.

Linear Fluorescents

The current T12 fixtures should be replaced with T8 fixtures with electronic ballasts. Many factors should be considered such as the lamp color and ballast type before purchasing the new fixtures to ensure low energy costs and user acceptance.

If new fixtures are purchased, give consideration to direct/indirect fixtures. These fixtures direct a large portion of the light upward to prevent glare at the work surfaces. It is also reported that indirect lighting creates a more pleasant environment. Since direct/indirect fixtures are more expensive, the cost assumptions in this report are for traditional direct troffers.

The current lamps should be replaced with 3100 lumen, 82+ CRI, 5000K, 24,000 hour rated based on 3 hour cycles with instant start ballasts. Examples of these types of lamps are the GE F32T8/XL/SPX50/HL/ECO and the Philips F32T8/ADV850/ALTO. These lamps have a higher Scotopic/Photopic (S/P) ratio than earlier lamp versions which promote higher levels of perceived brightness. This allows a facility to illuminate a space with fewer lamps. The facility should work to standardize lamps to reduce inventory costs and prevent fixtures from having a mixture of lamp types.

The ballasts should be replaced with High Efficiency Electronic ballasts. High efficiency ballasts can save 3-5 watts per fixture compared to standard ballasts. Examples of these types of ballasts are Advance Optanium and GE Ultramax. A full listing of high efficiency lamp and ballast manufactures can be found at <http://www.cee1.org/com/com-lt/lamps-ballasts.xls>.

When purchasing fixtures, it is recommended to specify the lamp and ballast type otherwise the supplier may supply standard ballasts and lamps. Instant start ballasts should be used in areas with long burn times such as hallways. Program start ballasts should be used in areas that are turned on and off 3 to 5 times or more a day.

Consider implementing group relamping rather than spot relamping when changing fluorescent lamps. Less labor is required with group relamping because the maintenance staff is already at the site and setup to perform the work. Group relamping can be performed after hours to minimize interruptions. More uniform light output is achieved with group relamping because lamps are removed before they reach end of the lumen depreciation curve. Group relamping is also an excellent opportunity to clean the fixture and lens to improve fixture efficiency.

Table 5. Cost savings example from group relamping (Courtesy of Energy Star)

	Relamp cycle (hours)	Average lamps replaced per year	Average material cost per year	Average labor cost per year	Total average cost per year
Spot relamping on burnout	20,000	525	\$945	\$3,938	\$4,883
Group relamping at 70% of rated life	14,000	750	\$1,350	\$1,425	\$2,775
Difference	-6,000	225	\$405	(\$2,513)	(\$2,108)

Notes: Assumes labor costs of \$7.50 for relamping and cleaning, material costs of \$1.80 per lamp and 3,500 hours per year operation.

Notes: Assumes labor costs of \$1.90 for relamping and cleaning, material costs of \$1.80 per lamp and 3,500 hours per year operation.

Compact Fluorescents

If possible, all incandescent lights should be replaced with Compact Fluorescent (CFL) lighting. To prevent inadvertently changing a CFL back to an incandescent bulb, pin-based CFL's with hard-wired electronic ballasts should be used. If installation costs are an issue, screw in CFL bulbs with built in ballasts are acceptable.

To save energy, find the bulbs with the light output you need and then choose the one with the lowest wattage. You can also look for a CFL that is labeled as equivalent to the incandescent bulb you are replacing.

The color of light may also affect how bright a light appears, even if the lumens are the same. Since most people are use to the soft yellowish glow from incandescent light bulbs, CFL's that produce light closer to the color of daylight (color temperatures above 3000K) may appear brighter because the color of the light is less yellow.

Exterior Lighting

Exterior lighting should use either metal halide, fluorescent or compact fluorescent technology. High pressure sodium lights should be avoided due to their reduced visibility and low color rendering index.

Metal halide fixtures should be limited to 360 watts and use pulse-start lamps and ballasts. Pulse start technology is more energy efficient than probe start fixtures. Fluorescent and compact fluorescent fixtures should use high efficiency electronic ballasts. Due to the low ambient temperatures, the compact fluorescent should be classified as amalgam lamps.

Astronomical timers should be used to control the exterior lighting. These timers can retain their settings for up to 10 hours following a power interruption. Timers are more beneficial than photo sensors because lamps may be left on during the day when a photo sensor fails. This wastes electricity until the sensor can be replaced. If the exterior lighting is not necessary for security, it is recommended to turn the lighting off during unoccupied periods.

HVAC

Table 6 documents the HVAC equipment present at the facility and the savings that can be achieved if the equipment were replaced with units with an Energy Efficiency Rating (EER) of 13.2. Specific equipment recommendations aren't made, however, since detailed analysis is required to determine proper unit sizing and other factors.

Table 6. List of HVAC Units

Make	Model	Unit Quantity	Tonnage	System Type	Current EER	kWh Savings	kW Savings	Annual Savings
Gibson	JS3BA-060KB	2	5	Central A/C Split	9.0094	8,563	3.67	\$754.86
Gibson	JS3BA-042KB	1	3.5	Central A/C Split	9.0094	2,997	1.29	\$264.20
Totals						11,561	4.96	\$1,019.07

If lighting or building upgrades are performed, heating and cooling load calculations should be performed prior to purchasing any new or replacement equipment. More efficient lighting and better envelope management can reduce the amount of cooling load required. This translates into a smaller unit with lower initial capital costs. These calculations also ensure that the correct size unit is installed to prevent overcooling, humidity problems and under cooling.

In general, it is not cost effective to replace a working HVAC unit with a more efficient one. Payback periods of 15-20 years are expected in this scenario. For that reason, it is recommended that when HVAC units fail, they be replaced with the most energy efficient unit available.

Air Distribution System

Ensure that a maintenance program is in place to clean all heat exchanger surfaces (heating and cooling coils, fan coil terminal units, radiators, etc.) and check the refrigerant charge annually. Clean air distribution surfaces and replace filters at least quarterly. Also check the ductwork to ensure that leakage does not occur.

Every five years perform testing, adjusting and balancing (TAB) on the HVAC system. Testing may need to be done sooner if areas of the building have been changed, renovated or changed purpose. Check dampers for control air leaks, ease of movement and isolation to ensure that they are operating correctly.

By ensuring that the heat exchanges are clean and performing regular TAB testing, energy savings can range up to 10 percent of the heating and cooling costs.

Before replacing the existing heating and cooling equipment, optimize the existing air distribution system. By optimizing the air distribution system, smaller and more efficient HVAC equipment may be purchased. This will result in a lower initial capital cost.

Consider converting constant volume air systems to variable air volume systems. Variable volume systems allow the use of variable speed drives. Variable speed drives can control the amount of air supplied in relation to the demand and reduce the amount of energy required.

Ensure that HVAC fan motors are not oversized. If the motors are found to be oversized, replace them with premium efficient motors, energy efficient belts (cogged v-belt) and variable speed drives.

Efficiency

Any air conditioning system less than 5.4 tons should have at a minimum a SEER rating of 13.0. The gas heating efficiency should be a minimum of 80% AFUE. Heat pumps less than 5.4 tons should have a minimum SEER rating of 13.0 and a minimum HSPF rating of 7.7. When units are installed on the roof, the HVAC package condensate drains should be routed to avoid having constant water standing. Consider variable speed compressors due to their enhanced energy savings during part load operation and the ability to remove humidity during low sensible heat periods. These efficiency ratings are minimums and should be exceeded whenever possible.

Controls

One of the best ways to reduce energy consumption of HVAC systems is by providing better system control. Calibrate thermostats, humidistats and pressure and temperature sensors annually. The use of programmable thermostats can reduce energy consumption during periods the facility is unoccupied, thus saving energy. A 7-day programmable thermostat or zone temperature sensors with a building automation system (BAS) is recommended to ensure all schedules can be accommodated.

Programmable thermostats should be installed and locked so that the settings cannot be changed. The thermostats should allow for night and weekend setbacks and should be set for cooling or heating rather than auto to avoid simultaneous heating and cooling of the area. During the cooling season, the occupied/unoccupied temperature set points should be 76°F/85°F. During the heating season, the occupied/unoccupied temperature set points should be 68°F/55°F.

Temperature setbacks save energy by not running the HVAC system when the building is not occupied. If setbacks are used, it may be necessary to start the HVAC system prior to the arrival of the occupants in order to reach the desired temperature set point. The start time will depend on the building construction, the type of equipment used, the size of the area being conditioned and the temperature difference. Potential energy savings from using night set backs are shown in Figure 5.

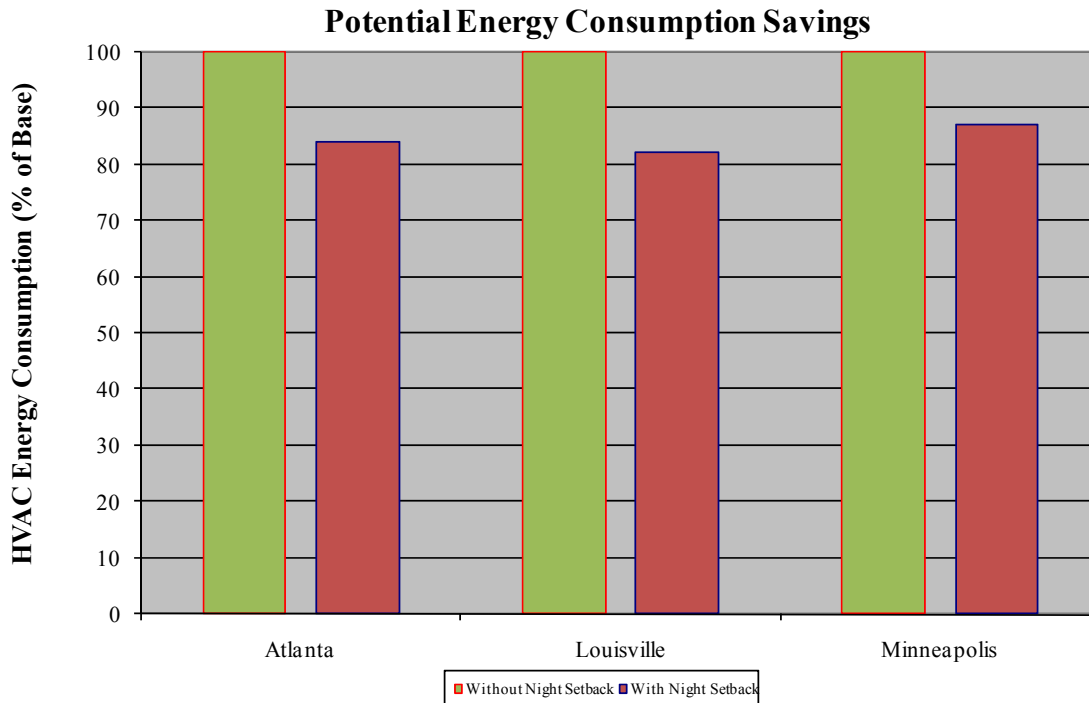


Figure 5. Energy saving potential of night set back (Murphy & Maldeis, 2009)

When the HVAC units are started in the morning, the schedule should stagger the unit start times to avoid setting the monthly demand in the morning.

Ensure that building management systems, time-clocks, timers and controls are scheduled and set correctly. Ensure that the HVAC system is only operating when the building is occupied.

Control tune-ups can provide up to 30 percent savings of the heating and cooling costs.

Building Envelope

Infiltration

During the inspection, openings were found in the building envelop in the mechanical room around the HVAC air and refrigerant piping. Gaps were also found around the doors and the seals around the stained glass windows have deteriorated and are allowing unconditioned air to enter the building.

Locate and correct any infiltration leaks in and around windows, doors, walls and roofs. Weather stripping, caulk and insulation can reduce or eliminate many of the building leaks.

Reducing the amount of infiltration will reduce the load on the heating and cooling system. Approximate savings for reducing infiltration can be up to 5 percent of the heating and cooling costs.

Insulation

During the inspection, it was not possible to get access to the attic; therefore, it is not know what the current level of insulation is. It appears from outside of the building that the roof over the Sanctuary is unvented attic space.

For this area of the country, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommends the following levels of insulation.

For roofs that do not have attic space and the insulation is installed above the deck, a minimum of R-25 continuous insulation rigid board should be installed. This insulation should be staggered so that board edges do not meet between layers.

For roofs with insulation below the roof, a minimum of R-30 should be installed. If the insulation is to be installed above a drop ceiling or in an unventilated attic, it should be installed at the roof line. Insulation installed in a ventilated attic should be installed at the ceiling line. The insulation should be installed in a manner to prevent it from being compressed. When insulation is compressed, the performance of the insulation is reduced.

The Department of Energy's eQuest software was used to determine the savings that would occur if additional attic insulation were added. Since the attic was inaccessible, it was assumed that since the building is over 40 years old that little to no insulation was installed during construction.

The simulation assumed that additional insulation was added to the entire attic area in the amount of R-38. With this additional level of insulation, approximately \$185 could be saved annually. This equates to 773 kWh of electricity and 152 Therms of natural gas.

Windows

The seals around the windows in the Sanctuary have deteriorated and are allowing outside air to infiltrate into the building. These seals should be caulked to prevent the infiltration.

Any single pane windows in the building should be replaced with double pane windows. Window manufacturers market special “solar low-e” windows for warm climates. Windows on the North and South sides of the building should have a Solar Heat Gain Coefficient (SHGC) no higher than 0.35. Windows on the East and West sides of the building should have a SHGC no higher than 0.25.

These values are for the entire fenestration assembly in compliance with National Fenestration Ratings Council (NFRC) procedures and are not simply center-of-glass values. The U-factor for all orientations should be no higher than 0.42. A low SHGC is much more important for low energy use than the window assembly U-factor.

Consider installing window films to reduce the amount of solar radiation heat gain and loss in the building. Window shading can be installed to reduce the amount of solar heat gain in the building.

Doors

If the doors are replaced, the new doors should be insulated double-panel metal doors with a U-factor of 0.37 and a SGHC similar to the above window ratings. The U-factor measures the heat loss that occurs through the material. Typically, the lower the number the better the material will be at reducing heat loss/gain. Thresholds and new weather-stripping should also be installed to prevent infiltration.

Service Water Heating

Explore opportunities for heat recovery. Hot-water temperature requirements vary by local and state code and should be followed. Typical codes require water to be supplied between 100°F to 120°F. When water temperatures need to be higher for activities such as dishwashing, the use of booster heaters at the end point is recommended.

When water heaters are installed, it should be as close to the destination as possible to reduce the heat losses. Hot water pipes should be insulated to reduce the amount of heat that is lost to the surroundings. Pipes less than 1.5 inches in diameter should have 1 inch of insulation. Pipes greater than 1.5 inches in diameter should have 1.5 inches of insulation.

Low flow lavatory faucets should be used to reduce the amount of hot water consumed.

Appliances

Plug Loads

Encourage building occupants to turn off and unplug equipment that is not in use. Ensure that new equipment (computers, refrigerators, copiers, vending machines) is Energy Star rated. This equipment uses less energy than conventional models and produces less internal heat. Energy Star equipment has power management features which reduce the amount of wasted standby energy. These features must be enabled to obtain the benefit.

Make sure that all office equipment is configured to use the Sleep mode during periods of inactivity. A typical computer and LCD monitor can use approximately 150 watts when in use. When both are in a Sleep mode, the energy usage is reduced to about 4 watts combined.

Financing

There are numerous Federal and State programs available to help finance energy efficiency upgrades. Regardless of the program chosen, it is recommended that the accounting and tax departments be consulted to determine the facility's specific requirements and eligibility. A full listing of various incentives can be found at the DSIRE website <http://www.dsireusa.org/>.

EPAAct 2005

One option is the Federal tax deductions available from the EPAAct 2005 program. This program will provide \$0.30 - \$1.80 per square foot of tax deductions depending on the technology used and the amount of energy reduced. To be eligible for these deductions, the upgrades must meet or exceed ASHRAE 90.1-2001 standards as well as certification requirements. This program focuses on a business's lighting, HVAC and building envelope.

Part of the certification requirements require a qualified person to certify the work that has been performed. The IRS Notice 2006-52 concerning energy efficient commercial buildings state that a Qualified Individual –

- (1) Is not related (within the meaning of §45(e)(4)) to the taxpayer claiming the deduction under § 179D;
- (2) Is an engineer or contractor that is properly licensed as a professional engineer or contractor in the jurisdiction in which the building is located; and
- (3) Has represented in writing to the taxpayer that he or she has the requisite qualifications to provide the certification required under section 4 of this notice (in the case of an individual providing the certification) or to perform the inspection and testing described in section 4.05 of this notice (in the case of an individual performing the inspection).

While this is not an endorsement, two known contractors in this area include CGI Electric and Stones River Electric.

Summary

In summary, the following recommendations are suggested.

Lighting

- Replace T12 lamps and ballasts with T8 technology.
- Replace incandescent bulbs with compact fluorescent.
- Implement group relamping of the linear fluorescent bulbs to save maintenance costs.

HVAC

- Perform testing and air balancing every five years.
- Clean all heat exchanger surfaces and check the refrigerant charge annually.
- Calibrate the thermostats annually.
- Implement temperature setbacks during unoccupied periods.

Building Envelope

- Seal gaps around the windows and doors.
- Add additional insulation in the attic areas.

Service Water Heating

- Insulate all hot water pipes.
- Install low flow lavatory faucets.
- Lower hot water temperatures.

Appliances

- Purchase energy star appliances.
- Implement standby mode on both the computers and the monitors.

The total annual reduction in operating costs identified in the walk-through energy audit totals \$433.93 or 31.6% of last year's bill. The total demand reduction is 2.12 kW and the total energy usage reduction totals 3,597 kWh.

Bibliography

Murphy, J., & Maldeis, N. (2009). Using Time-of-Day Scheduling to Save Energy. *ASHRAE Journal* , 43.

Disclaimer

This report was prepared by Tennessee Valley Authority (TVA) representatives as a service of Middle Tennessee Electric (MTEMC). MTEMC and TVA partner to provide services to assist commercial and industrial customers in efficiently using electricity. Although this analysis has been performed using standard engineering methods and calculations, actual energy usage may differ from that estimated in this report due to differences in operation of equipment, weather, etc. No warranty or guarantee of any kind is given with regard to the information contained in this report. Any use made of this report or any information contained in it, shall be at the user's sole risk and responsibility. MTEMC and TVA do not endorse any suppliers of equipment or services that are referenced in this report for specifications or prices.