UUCB Quantitative Energy Audit

There are 2 parts to an energy audit. We have to look at electricity usage and heat loss. Electricity usage is measured in kiloWatt-hours (kWh). The utility charges us around 12 cents per kWh. And since we generate electricity in New York primarily by burning natural gas, every kWh generated is responsible for an average of 1.34 pounds on CO_2.

Electricity

The UUCB electric bill is $4582/year. As a part of our overall budget (which is around $200,000), this looks small. But let's look at how much CO_2 this represents.

According to the NYSEG yearly summary of kWh use, our total usage is 52880 kWh per year

52880 kWh x 1.34 pounds of CO_2 per kWh = 70859 pounds of CO_2 per year = **35.43 TONS per year.**

Heating

We heat with natural gas at UUCB. Our gas bill is $6700/year. According to the NYSEG summary, our usage is 7183 Therms per year. This is equivalent to 0.95 x 7183 = 6823.85 CCF. (One CCF is 100 Cubic Feet). There are 12 pounds per CCF of CO_2 from burning natural gas, so:

6823.85 CCF x 12 pounds/ CCF = 81886 pounds of CO_2 or **40.94 TONS of CO_2 / year.**

Our total "Carbon Footprint" is 35.43 + 40.94 = 76.37 TONS of CO_2 per YEAR

This is equivalent to driving 215,000 miles at 25 mpg.

Work of the Audit

We need to look at both electricity use ("electric loads") and the heat loss of the building (thermal loads). The electricity use is from lights and appliances. We have to note

1. each light or appliance
2. how many of each type there are
3. how many Amps or Watts is uses when on
4. how long it is on each day
5. how many days per week is it used.

These numbers will be put into the spreadsheet where we can calculate how many kWh each thing uses. It is done like this:

Watts x hours = Watt-hours.
Watt-hours/1000 = kiloWatt-hours (kWh)

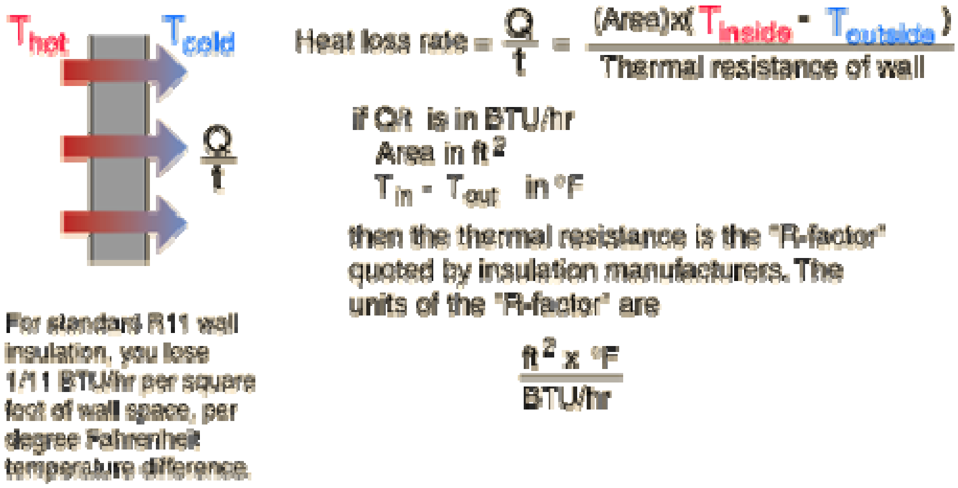
The W in Watts is usually capitalized because this unit was named for James Watt, the inventor of the steam engine. A kWh is a unit of ENERGY, while a kW is a unit of POWER. It is ENERGY that we are charged for by the utility.

For the thermal load, we have to calculate the heat loss. Heating and Air people use the older energy unit, the BTU (British Thermal Unit). This can be converted into cubic feet of natural gas because the energy content of natural gas is a well-known quantity. The BTUs per hour one needs to supply to the building via the heating plant is equal to the number of BTUs lost per hour.

Heat is lost in 2 ways.

1. Through the ceiling, walls and windows via conduction
2. Through cracks and openings in the walls, windows and doors via air leakage.

Heat Loss via conduction



from Hyperphysics see http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

We can calculate the heat loss for the year via conduction if we know the area of each window, wall, door, the R-value of them and the number of heating-degree-days.

What's a heating-degree-day?

The difference between the inside and outside temperature varies all the time, but we can quantify differences over the course of the year by using the "Heating-Degree-Day" or HDD. To calculate the heating degree days for a particular day, find the day's average temperature by adding the day's high and low temperatures and dividing by two. If the number is above 65, there are no heating degree days that day. If the number is less than 65, subtract it from 65 to find the number of heating degree days.

For example, if the day's high temperature is 60 and the low is 40, the average temperature is 50 degrees. 65 minus 50 is 15 heating degree days.

Binghamton normally has 7237 Heating-Degree Days (HDD). For details, see http://cdo.ncdc.noaa.gov/climatenormals/clim81/NYnorm.pdf

Heat loss for the year in BTUs is

[Area in square feet x 24 hours per day x HDD per year] / R

Note that R is defined as [temperature difference in F x area in sq. ft. x time in hours] / heat loss in BTUs.

So we calculate the heat loss for each area of different R value and add them all up.
One of the things you have to check is what insulation exists in the walls, roof and doors.

Single-pane windows: R= 0.91 w/storm R= 2
Double-pane windows (1/2 air gap) R= 2.04
See R-value table for other R-values.

The biggest culprits for heat loss by conduction are

1. Heat loss through the roof
2. Heat loss through the windows

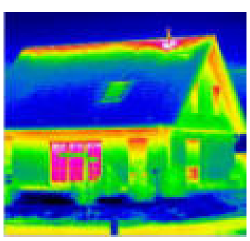
Heat loss via leaks
To find out the leak-rate of the building, we have to measure it. This is done using a "blower-door". This device sucks air out of the building with a big fan and measures the pressure change as a function of time. This tells the leak-rate. Very often, the heat lost due to leaks exceeds the loss due to conduction!

pressure gauge

Blower-door

See http://www.energyconservatory.com/products/products1.htm for more details.

An Infrared (IR) Camera can detect exactly where the leaks are by looking for warm air in IR photos.



(source: Sierra Pacific http://www.x20.org/thermal/)

Pat Dundon, The Insulation Man, will come by and do the blower-door and IR camera measurements for us. Check out his company at http://www.insulationman.com/ .

As you go through the building, feel free to make notes on items such as

- Obvious heat leaks (like broken glass, warped window sash and so on)
- Pipes that need insulation (measure or estimate the length of the pipe in need)

Tricks for finding out electricity use

- For light bulbs in high places, find a replacement bulb in the utility closet and look on the package or bulb for Watts
- Use binoculars to see Watt-rating on bulb face
- Climb up ladder as a last resort.
- If no label is obvious on an appliance, note down what the make and model. We can look it up on the Internet.
- We will have to estimate hours of usage for some appliances and lights
- Some labels tell you the Watts the thing uses, sometimes the label shows Amps. Since Amps x Volts = Watts, knowing the Amps (current) and the building voltage tells us the Watts.
- Look at the circuit breaker boxes to see if we forgot anything.

Other notes

- I have counted up lights and windows and noted other appliances for each room. Make sure I did not miss anything!
- Don’t forget to look in the boiler room.
- Energy use of some things (such as refrigerator) can be measured with the Kill-A-Watt meter.

Results of UUCB Energy Audit

The Energy Audit Team

Eileen and John Hamlin Harris and Lynn Thor Doris Reed Tom and Dolores Elliot Wes Ernsberger Gerri Wiley Marta Foster Janet Landow	Chris Sturges Stu McCarty Scott Clark Dick Rehberg Kay Thorp Alan Hochberg Gay Canough

The team conducted an energy audit of the UUCB building on Feb 28, 2007. We looked at the power usage of all the electric appliances, lights, computers, printers, pumps and heaters.

Electric use

The length of time that appliances and lights are on was estimated for many things. The following table shows the approximate kWh usage for each room or set of rooms. For room 11 and 12, items such as the dehumidifier in the closet and the electric heating are the main contributors. The electric use of the addition was greatly underestimated at first, but when the electric heating of the addition is figured in, we get close to the number of kWh shown on the NYSEG summary.

Electric use summary	kWh per month		
fireside	167.01		
halls	255.60		
restrooms	41.14		
kitchen	323.00		
offices library	186.43		
room 1 and 2	162.49		
rooms 3,4,5,9, 10	130.37		
room 11,12	395.94		
sanctuary	190.54		
social hall youth room	172.82		
daycare	128.40		
monthly total kWh	2153.75		
yearly total kWh	25845.03		
addition heating	27666.41	NYSEG	Tons of CO2
TOTAL	53511.44	52880	35.4296

Comments and suggestions regarding electric usage

Converting our lighting to energy efficient lighting is already underway. This is one of the least expensive and easy things to do and should be continued.

Printers and computer monitors are large standby loads. They should be turned off when not in use. This can be done in one of 3 ways.

1. Turn them off by hand
2. Put them on a timer
3. Set the power settings of the computer to turn off monitor and disk after a period of inactivity.

Dehumidifiers are large loads. The downstairs rooms may need to have dehumidifiers, so the best we can do is to get energy efficient ones and put them on timers. It would be worth getting an assessment done on how to reduce moisture without using dehumidifiers. Moisture can often be reduced greatly by repairing or up-grading gutters, installing drainage around the foundation, putting insulation on the walls (which reduces condensation) or sealing up the foundation.

Upgrade all refrigerators to Energy Star models.

Convert the addition heating to some other type (it is electric resistance now), while paying attention to efficiency.

The overhead lights in the Sanctuary can be converted to compact fluorescents. Remove the dimmer, which we don’t use because it causes the filaments to hum.

Natural Gas Use

The heat that must be added to the building is equal to the heat lost. During the audit, we assessed the conduction heat loss. The area of the windows was measured and the areas of the roof and walls were calculated from the building drawings. The R-value of the windows with storms is approximately 2. The R-value of the walls of the main building is 3 to 4, as there is no insulation in those walls. The R-value of the walls in the addition is about 9.5. Those walls have 3" of insulation according to the drawings. The R-value of the addition roof and the main building roof is about 17.5, except for the Sanctuary. The Sanctuary has no insulation in the roof, so its R-value is 3 to 4.

Heat loss summary	**BTUs**	**BTUs**	**fraction of whole**				**1 kWh =**	
fireside windows		15,074,381.52					3412	btus
social hall windows		24,744,377.18						
kitchen windows		11,532,963.61						
offices, library, restroom windows		18,544,812.50						
room11 12 windows		13,659,692.76			**addition windows fraction**	**kWh for HEATING addition**		
classrooms east windows	57,207,182.34	40045027.64			17162154.7	5029.94		
classrooms west windows		20,668,872.00	25%	ALL WINDOWS	20,668,872.00	6057.7		
sanctuary windows and roof		297,778,937.78	36%					
main walls		210,479,302.08	26%					
addition walls	33,054,375.21		4%			9687.683		
main roof		50,448,920.23	6%					
addtion roof	23,512,392.69		3%			6891.088		
TOTAL BTUs	113,773,950.24	**702,977,287.30**	100%					
TOTAL therms		**7029.77**				**27666.41**		
Carbon footprint, tons		**40.07**						

Comments and suggestions regarding gas usage

By far, the most energy lost from our building is through heat loss. The Sanctuary stands out as the biggest loser. The windows in the Sanctuary are insulating glass (double pane), which is good. None of the other rooms have double pane windows. But the Sanctuary roof has no insulation and it is huge in area (over 5000 sf). Its area rivals the area of the walls of the building. The walls of the original building have no insulation either, making them the second largest heat loss. Windows are close in heat loss to walls because they have a lower R-value (even though the area of windows is much smaller).

Dealing with heat loss is difficult and costly. The traditional way to deal with it is to get quotes for upgrades, run a capital campaign and have everything done at once. Often, the cost of doing that rivals the cost of tearing down the structure and building something new.

But perhaps there is an alternative. Let’s take a lesson from Europe and Japan on this. The way that improved efficiencies are accomplished in new products by innovators in Europe and Japan is via incremental improvements. Americans often see this as wimpy and unglamorous, but the fact is that incremental improvements add up over time to grand and wonderful improvements in efficiency. Two great examples of this strategy are the Toyota Prius car and the European refrigerator. The European way of improving refrigerator efficiency is so clever, that US manufacturers now use it to give us Energy Star refrigerators.

So we could make a plan for incremental improvements and then simply stay on task over time. Here is a rough draft of the flow of such a plan, to be tuned up as needed.

Tomorrow, we can insulate all the heating pipes that go from the boiler to the heating units. This costs a few dollars and perhaps a couple of hours of volunteer time to accomplish. While heat loss from those pipes is a small percentage of the whole (less than 1%), there’s nothing like action immediately to get us in the habit.

The Environmental Task Force Endowment grant application was approved, so we will have the blower door test and IR camera test done. This will tell us where the air leaks are. We can then seal up leaks using caulk. Again, this costs a few bucks and maybe a day’s work for a couple of volunteers.

With the storms in, the windows are almost as good as double-pane windows. Instead of replacing windows initially, we could install Window Quilts (R-value of 5). Window Quilts are easy to install by volunteers. Window Quilts can be kept closed unless the room is in use during the day. We might want to experiment with motorized Window Quilts on timers. Windows could gradually be upgraded to insulating glass. Eliminating many of the operable windows will reduce heat leaks.

Putting insulation in the roof of the Sanctuary might seem to be an impossible task at first. However, the roofing shingles are due for replacement (being almost 30 years old). When this is done, insulation can be added to the exterior of the Sanctuary roof. There are a variety of ways to do that. The reason the rest of the building’s roof has insulation is because it was added when the roof was re-done. Roofing work is something that we probably will have to hire a contractor to do simply because it has to be done quickly. So we need to plan for that.

Insulating the building walls is another thing that can be done incrementally. One way to do this without disrupting use of the building, is to take off the exterior siding, install insulation and then put the siding back on.

UUCB Energy Audit   4/7/2007

The heating system for the building is old, but it has been kept in good repair. We have not measured its efficiency, but based on its age and type, it is probably about 75 % efficient. While replacing the heating system seems appealing, stemming the heat loss from the building should be done first.

The addition is heated with electric resistance heating. Replacing that system would reduce cost, but we would have to look into which types of replacements will reduce the carbon footprint. For example, we might consider a ground-source heat pump system (uses 1/3 the electricity of an electric resistance heating system) or a hydronic heating system such as a radiant floor fed by a high-efficiency boiler.

Next steps

1. Presentation of energy data to
    a. UUCB Energy Audit Team (April 8)
    b. UUCB Board (at April or May Board meeting)
    c. UUCB Members (highlights during Matters of Our Lives)
2. Get the blower door and IR camera measurements done (DONE 3-31-2007)
3. Get the NYSERDA Energy audit done so we have their recommendations (4 to 6 weeks)
4. Home Energy Auditing class for UUCB members (Tentatively planned for Saturday May 5)
5. Gather cost data ((4 to 6 weeks)
    a. Pipe insulation
    b. Window Quilt cost
    c. Insulating glass pricing
    d. Sanctuary roof quotes
    e. Cost of insulation for walls
    f. Changing addition heating system