Chapel Hill Police Station Energy Audit Results & Recommendations

Presentation to Mayor Kevin Foy and Members of the Chapel Hill Town Council

November 19, 2007

Mindstorms Team 2255
Chapel Hill, NC

Connor Bernstein, 13
Jon Rosoff, 13
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Chapel Hill Police Station Energy Audit

Presentation to the Chapel Hill Town Council
November 19, 2007

Mindstorms Team 2255
Marcus Cooper, Robert & James McMahan, Jon Rosoff, Avery Dart, Connor Bernstein, Marlow Durbin

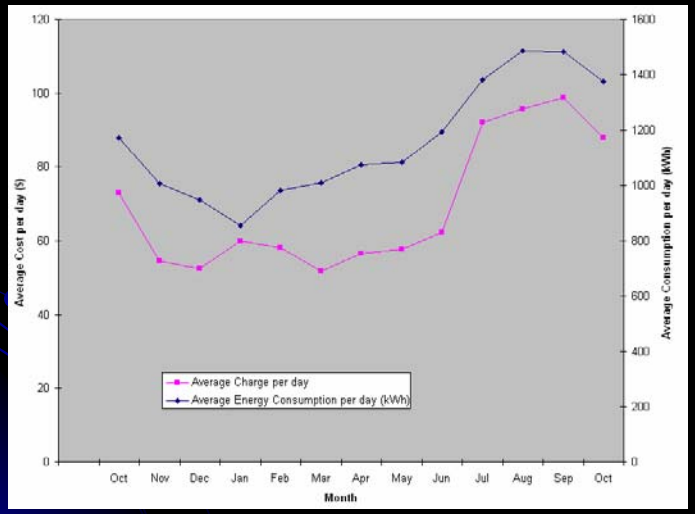
November 9, 2007

- 2 Hour Energy Audit
- Guided by Mr. John Newark
- Major Areas Covered:
  - Overall Energy Use
  - HVAC
  - Lighting
  - Insulation
  - Windows
  - Appliances
  - Electronics
  - Water Heating & Use
  - Solar

Overall Energy Use

- Analyzed 13 Months of Data
  - October 2006 - October 2007
- Annual Power Use: ~ 420,000 kWh
  - Total Cost: $25,061
  - On average:
    - 24% Peak-Time Use
    - 1157 kWh & $69 Per Day
  - Highest in September (1483kWh / $99)
  - Lowest in March (1008kWh / $52)
  - Lighting & HVAC are 2 biggest uses

Energy Use



Lighting

James McMahan

Lighting that meets the building's demand
Energy efficient lighting
Low cost lighting

Fluorescent Lighting

Findings

- We calculated 207 fluorescent fixtures in building.
  - ~1 fixture per 120 ft^2
  - 4-32W bulbs per fixture
  - 128W per fixture + ballast
- Total energy use, fluorescent lighting: 27kW
  - 640 kWh per day
- This is 60% of total building use on average
- Fixtures appear to be original

Fluorescent Lighting

Recommendations

- Install Occupancy Sensing **Light** Switches in all non-essential rooms & areas
  - Turns off all lights in unoccupied areas
  - ~$20 per switch
- If ballasts are old type, replace with energy efficient ballast in each fixture
  - High Performance ballasts can lower energy costs up to 35%-40%
- Reducing lighting use by 20% could save ~$2,700 per year

Incandescent Lighting

- Findings
  - Not many incandescent fixtures in building
  - Each fixture has1bulb
  - Each bulb is 60 watts

- Recommendations
  - Replace incandescent bulbs with LR6 LED downlights
    - LED lamp cost is ~$50
    - Fits in standard fixtures
    - LEDs last for 100,000 hours
    - 650 lumens
    - Uses 5 times less power than incandescent bulbs
    - An excellent demonstration project of new technologies for the community

Windows

Marcus R Cooper

Windows:
- Are an important part of building technology
- Ties in with Insulation

Findings

- Positive
- Windows are double panes
- 73 Total Windows on the south side of the building
- Windows have a reflective material on the exterior
- Negative
- We believe Gas insulation between windows has escaped
  - Typical argon gas windows last 10 years.
  - These windows are 25 yrs old.
- Most of the rooms closest to the windows had space heaters and fans
  - It indicates a possible insulation problem

Suggestions

- Replace old windows with newer, energy efficient models

-or-

- If cost efficient, Pump argon gas between windows

How will you benefit from this?

- Solves the front insulation problems
  - It also solves staff discomfort
- Potentially large energy savings

HVAC

Marlow Durbin

HVAC

- 8 units
  - Direct Exchange (DX) with Heat Strips
  - Resistive induction coil heaters
  - Heat pump A/C
  - All-Electric
- Installed 2002
- About 35% of energy usage
- Almost 50% in summer

Observations

- Thermostats
  - 74° in the winter
  - 72° in the summer
  - accessible to anyone
- Rooms with space heaters, fans
- Some occupants uncomfortable
- Vents
  - Most rooms equal # of supply and return vents
  - Server and technical supply rooms have no returns
- Units are reported to break down frequently
- Maintenance plan?
- Trombe walls intended to heat 2nd floor; reported ineffective
- Ductwork insulated and sealed at time of installation

Recommendations

- Professional HVAC evaluation including
  - Balance return and supply vents
  - Ductwork sealing and insulation
  - Why some rooms require space heaters or fans
  - Maintenance schedule (beyond filter replacement)
- Thermostats
  - Evaluate locations
  - Adjust settings
  - Consider locking devices
- Trombe wall
  - Consider removal
  - Use shades in summer
- HVAC replacement
  - Consider after evaluation of current system
  - Consider geothermal wells

Benefits

- Maintenance
  - Save at least 10% of HVAC cost
  - $950 savings HVAC operating cost per year
  - Thermostats
    - 1° change save at least $300 a year
  - Space heaters
    - ~$1.72 a day for each turned off
  - Ductwork
    - Properly sealed can save 4 - 9% HVAC cost per year.
    - That's $390-$880 per year
  - Geothermal replacement
    - Very low monthly HVAC power charge
    - Savings of nearly $8,000 a year!

Major Appliances

by Avery Dart

• We did an energy audit of the Chapel Hill Police Station to see if there were any areas they could improve upon.

• Major appliances were considered to be: refrigerators, washing machines, dryers, dishwashers, toaster ovens, microwaves, vending machines, drinking fountains.

•There were not a lot of these major appliances at the Police Station.

Findings

Positive

- 2 refrigerators (type with the freezer on top)
  - Not energy star rated
  - About 470 kWh per year
  - ~$31 to run per year
  - They are about 5 years old
- These are energy efficient refrigerators

Negative

- All major appliances were not energy star rated
- Coke Vending Machine uses energy to keep drinks cold
- The 3 drinking fountains seem to be as old as the building

Suggestions

- Have Coke delivered and put the soft drinks in the 2 refrigerators.
  - If they only need one fridge, and unplug the unused fridge, they could save ~ $31 a year.
  - Use honor system (they are police)
- Replace the water fountains with newer drinking fountains (where the temperature setting can be adjusted)
- Alternatively, instead of using water fountains water coolers use less energy.

How will you benefit from this?

- Not having the Coke Vending Machine and by using more energy efficient drinking fountains or by using water coolers might save a lot of money.
- Will help Chapel Hill cause less pollution
- Will raise awareness in community about pollution and global warming

Insulation for Roof & Exterior Walls

by Jon Rosoff

Observations

- **Roofing**
  - 5 year old white TPO roof with 6 inches polystyrene insulation covering 11,900 sf flat roof area
  - Brown metal roof overhangs
  - Reflective rating of TPO roof in 80s
  - R-value (measuring conduction of insulation) only 19 compared with current code R=31
  - 12-15 year life span for TPO roof
  - Structure strong enough to carry green roof
- **Exterior Walls**
  - Concrete walls with 3 kinds of interior insulation: BATT, raw fiber glass, and spray-in cellulose
  - R-value for walls only 6; current code R=16
  - Waterproofing repair necessary
  - Erosion along bottom edge of wall

Recommendations

- **Roof**
  - Retrofit existing TPO roof with an extensive green roof system to increase the R-value from 19 to 31 or when replacing TPO roof add the green roof
- **Exterior walls**
  - Add foam insulation to interior to increase R-value of insulation from 6 to current code 16
  - Waterproof the exterior surface
  - Consider new products like soy-based foam insulation that seals out moisture & condensation from the interior of the building

Extensive Green Roofing

- **Costs**
- $8.00 sf plus shipping, installation, irrigation & metal edging
- **Benefits**
- Energy savings of up to 25% (that would have saved $3625 last year)
- 2- or 3-fold roofing membrane lifespan extension (from 10-15 to 30-50 years)
- Fire resistant & sound insulator
- Reduce Urban Heat Island Effect
- Reduce ground level ozone
- Reduce & purify stormwater runoff (up to 80% decrease)
- Clean air of green house gases & dirt
- Create habitat for birds & beneficial insects
- It's beautiful! Set an example!

Green Roofs Around The World

More green roofs

Yet More Green Roofs

Adding insulation to interior of exterior concrete walls

- Cellulose
- Benefits
- R-factor 3.8 per inch
- No VOCs, glass fiber
- 85% recycled natural cellulose
- (Absorbs some moisture)
- www.applegateinsulation.com

- Cement Foam
- Benefits
- Lightweight foamed cement
- No glass fiber
- No hazardous chemicals
- Fire resistant without chemicals
- www.airkrete.com

- Soy-Based Foam
- Benefits
- Made from renewable resources
- No VOCs or CFCs
- Creates air tight seal - does not settle
- Air seal means that no moisture or condensation gets through to inside
- R-value 3.8 per inch
- "Outstanding Green Product" 2003 National Association of Home Builders
- www.biobased.com

- COSTS
- Probably comparable but see the dealer/installers

Repairs & Maintenance Exterior Doors

- Weatherstripping:
- Cracks and openings breaking thermal envelope in 7 spots:
- Main entry door – double set of two doors
- Secondary entry – double set of single door
- Single door side front

Hot Water Heating

Connor Bernstein

•Efficient water heating that meets building's demand
•Low Cost

Findings

- Water heater near showers
- Everything insulated
- Two hot water heaters

- Current water heater wastes energy
- Faucets could leak

Suggestions

- Add a tankless water heater when units are replaced
- Motion activated faucets

A tankless water heater

How will you benefit from this?

- Will set an example of power saving technology
- Saves over traditional water heaters

Electronic Devices

Robert K. McMahan III

Findings

Positive

- All computers, printers, etc. appear to be *Energy Star* rated

Negative

- Building transformer installed when building was built
  - May be source of inefficiency
  - Could result in savings of as much as $400/year (@ $0.06 / kWh) if replaced
- ~10% of the station's monitors are CRT monitors
  - Not as energy-efficient as LCD monitors

Recommendations

- Prioritize replacement of non-*Energy Star* devices with *Energy Star* rated ones
- Investigate transformer; consider replacement.
- Consider immediate replacement of CRT monitors with LCD monitors.
  - Will reduce individual monitor energy usage by 17%

Roof Solar Panels

Robert K. McMahan III

Findings

Positive

- Front of building faces south
  - Excellent annual solar exposure
- Long metal fascia directly above front windows
  - Angled and positioned perfectly for solar panel array

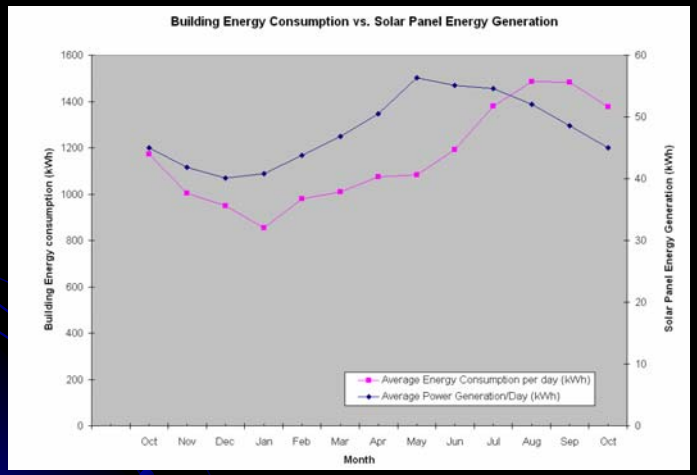
Negative

- Most of this fascia is blocked by trees

Recommendations

- Mount solar panels on fascia above windows
  - ~35 standard 38” x 62” panels
  - 195W Max / 140W typ.
  - With 80% daylight usable
    - On average, 11% of building consumption during usable daylight
    - Power generation highest in summer, when building consumption is highest
  - Excellent Alternative Energy example for community at ~$50,000 cost
- Trim back trees
  - Will give panels access to sun
  - May impact building HVAC requirements

Solar Panel Energy Generation



Thank you!

- Mayor Kevin Foy and Members of the Chapel Hill Town Council
- Mr. Carlo Robustelli
- Mr. John Newark

- Blair Kendall and Dan McFarland, Southern Energy Management
- Clayton Rugh, Ph.D., general manager, Xero Flor Green Roof Systems, Durham NC, for their generous help.

References

- Carter, Joe. "New Insulation Options." This Old House, November 2005. Reproduced in www.thisoldhouse.com/toh/article/0,,1130563,00.html#. Nov. 15, 2007.
- Department of Energy. Insulation Fact Sheet, 2007. Reproduced in www.ornl.gov/sci/roofs+walls/insulation/ins_01.html. Nov. 15, 2007.
- Oberndorfer, Erica et.al. "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services." **BioScience**, November 2007, Vol. 57 No. 10, 823-833. Reproduced in www.bioscience.org. Nov. 13, 2007.
- Peck, Stephen and Monica Kahn. "Design Guidelines for Green Roofs." Reproduced at egov.cityofchicago.org/webportal/COCWebPortal/COC_ATTACH/design_guidelines_for_green_roofs.pdf. Nov. 15, 2007.
- FOAM INSULATION PRODUCT WEBSITES:
- Foam-Tech Supergreen Foam Insulation, www.foam-tech.com.
- Icynene Petrochemical based form blown in by water. www.icynene.com.
- BioBased Soy-Based Foam Insulation. www.biobased.net
- Airkrete Cementious Foam Insulation. www.airkrete.com
- Ecovative Design Mushroom Spore Insulation. www.ecovativedesign.com.
- GREEN ROOF SYSTEM PRODUCT WEBSITES:
- Xero Flor. www.xeroflora.com.
- **Special Thanks** to Blair Kendall and Dan McFarland, Southern Energy Management, and Clayton Rugh, Ph.D., general manager, Xero Flor Green Roof Systems, Durham NC, for their generous help.

References

- http://www.copper.org/applications/electrical/energy/energy_star.html
- http://www.evergreensolar.com/app/en/home/
- http://www.aceee.org/consumerguide/electronics.htm http://www.lipower.org/cei/tips.html
- http://www.consumerreports.org/cro/home-garden/resource-center/energy-saving-guide/energy-saving-guide.htm
- http://www.energysavingtrust.org.uk/energy_saving_products/a_guide_to_choosing_consumer_electronics
- http://ezinearticles.com/?Running-An-Energy-Efficient-Household&id=504470
- http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductCategory&pcw_code=HEF

References

- http://www.greenconsumerguide.com
- www.hugg.com
- www.eartheasy.com
- www.NC live.com

Chapel Hill Police Station
Energy Audit Results

Individual Reports

Mindstorms Team 2255 – Chapel Hill, NC

Lighting – James McMahan

Lighting is one of the 2 major uses of power in the building.

Summary of Findings

During our audit we calculated that there are about 200 fluorescent fixtures in the building. There is approximately 1 fixture for every 120 ft^2 . Each fixture has 4-32W bulbs which use 128W + the ballast. The total energy use by fluorescent lighting in the building is 27kW or 640 kWh per day.

We estimate this is 60% of total building power usage on average. In comparison, there are not many incandescent fixtures in the building with each fixture having only 1-60W bulb.

Recommendations for Improvement

We recommend that you:

- install occupancy sensing light switches in all non-essential rooms & areas.
- check the ballast in each fixture. If the ballasts are an old model replace them with energy efficient ballast.
- replace all incandescent bulbs with LR6 LED downlights, the cost of this is about $50 per module.

Benefits of Improvements

Occupancy switches turn off all lights in unoccupied areas, therefore saving electricity. The cost of a single switch is approximately $20.00.

Replacing old ballasts with high performance ballasts can lower your energy cost up to 35%-40%. LR6 LED downlights use 5 times less power than incandescent bulbs and they fit in standard fixtures, they lasts for 100,000 hours, and they produce 650 lumens (same brightness as the bulb in use). This would be an excellent demonstration project of new technologies for the community.

If you reduced lighting use by 20%, we estimate that you would save $2743 annually.

References

- http://www.greenconsumerguide.com
- www.hugg.com
- www.eartheasy.com
- www.NC live.com

Windows – Marcus Cooper

Summary of Findings

I observed the windows closely as we went through our audit and I found out that the windows had a gas leakage between the two panes that caused a problem with the insulation. The team and I also brainstormed reasons why all the offices closest to the windows had space heaters, yet the offices farthest to the windows near the concrete walls had none. The Reason: Faulty insulation in the windows. This is a quick summary of my findings:

- The windows are double paned.
- Most offices or rooms nearest the windows had space heaters.
- The gas insulation between the windows had leaked out.

Recommendations for Improvement

The windows at the police station are an expensive thing to replace with the two ways you could replace them. You could either refill the gas layer in between the window panes or replace the windows entirely. It is Very expensive and would take a long time to replace *73 windows!* You could either:

- Replace windows entirely and refill them with argon gas
- Refill the argon gas, keeping the original windows

Benefits of Improvement

The benefits of doing one of the two above is that it will cut your HVAC bill in half! It's also being energy efficient by keeping warm air in, and cold air out and vice versa. The windows also prevent any mold and condensation from forming in unwanted areas.

HVAC – Marlow Durbin

The HVAC system in the Chapel Hill Police Headquarters uses 8 Trane units, each are combination heating and cooling units. The heating element is a resistive induction coil, and the cooling element uses heat pumps. These units were installed in 2002 and currently use about 35% of the building's energy. In the summer this number jumps to nearly 50% of the energy use of the building. An energy efficient HVAC system is a critical component towards using less power in the building.

Summary of Findings

We observed in the energy audit that the thermostats were set at 74 degrees in the winter heating season and at 72 degrees in the summer cooling season. We also observed that the thermostats were located in prominent areas where anyone could access them and adjust the settings.

One of our observations was that in many of the rooms, especially ones with outside windows, there were space heaters in use. The occupants of the rooms said that they were uncomfortable despite the fact the thermostats were set for maximum comfort. 74 degrees for a thermostat heat setting is 6 degrees above the recommended setting for a building and yet the occupants were still cold. In the summer, these same offices often need fans to be comfortably cool despite the fact the thermostat is set at 72 degrees in the summer. Again, that is 6 degrees below the recommended cooling setting for a building. The HVAC system is not heating or cooling some rooms well enough.

The vents in most of the rooms had a balance of supply and returns, which means that the pressure in most of the rooms was even. However, some rooms, including the technical supply room and the server room had no return vents at all. In these rooms, there is positive air pressure which forces the warm air produced by the machines to blow out into the hall causing it to be drafty.

Occupants of the building reported the HVAC system breaks down frequently. This seems very odd, because the units are only five years old. The building engineer indicated that there was no regular maintenance to the system beyond replacing the filters every 90 days.

On the second floor, there is a large vertical concrete slab or wall along the side of a row of windows. Called a Trombe wall, it was designed to absorb sunlight in the daytime and to radiate heat into the building and warm it in the nighttime. According to the building engineer, this works fairly well in the winter and warms that area of the building. However, the Trombe wall also warms the building in the summer as it radiates heat. In the summertime the HVAC system is working to cool down the building while the Trombe wall is working to heat up the building. This adds more stress to the HVAC unit at a time when it is requiring as much as 50% of the buildings energy usage during the highest kilowatt per hour rates.

The building engineer reported that the ductwork in the building was insulated and sealed at installation.

Recommendations for Improvement

Because HVAC systems are very complicated, we recommend the Town have a professional inspection of the entire system to determine several things. We suggest that the balance of supply and return vents is investigated and return vents be added where they are needed. The inspection would help determine if the system is working at full potential. We also recommend an inspection of the ductwork insulation and sealing. We further recommend a maintenance plan of the HVAC units per the Trane manuals.

The location of the thermostats should be evaluated, and we strongly recommend that the thermostat's temperature setting be lowered in the winter and raised in the summer. We also recommend locks be installed on the thermostats so that they are not accessible to everyone in the building.

Removing the Trombe wall is one option but it is going to be expensive and messy. We recommend you consider custom-made energy efficient shades that can be lowered in the summertime but raised in the winter.

According to Trane, the average HVAC system lasts from twelve to twenty years before needing to be replaced. Because this system is only five years old, it should not need to be replaced. It may just need to be maintained, repaired, evaluated and adjusted for better performance.

However, if a professional inspector determines the HVAC system cannot be improved, consider replacing it with one that uses geothermal wells. Since there is so much surrounding land and on the building's property, a very large geothermal system may be possible and practical. A geothermal system uses no electricity, is constantly pumping out comfortable air, and will keep a building warm in a power outage and an ice storm.

Benefits of Improvements

A proper HVAC maintenance plan can save at least 10% of the operating cost of the system because it improves performance and efficiency and will help prevent breakdowns. This could save the Town about $950 a year in energy costs.

According to the Energy Ideas Clearinghouse and ComEd, if the temperature setting of the thermostat in a commercial building is lowered one degree in the winter, and raised one degree in the summer the building can expect a 2-4% energy savings. For every degree of thermostat change, the Town will save a minimum of $300 a year.

We calculated the cost of running one space heater to be $1.72 a day. For each space heater the Town is able to turn off, we will not burn 233 pounds coal a year.

An American Society of Heating and Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE) journal states, "...improved duct sealing reduces heating and cooling energy consumption in air-based systems by at least 4% - 9%" If the ductwork has worn down, it is leaking conditioned air and the system is not working at optimum efficiency. If the ducts are in need of re-sealing, doing so could save the Town about $390-$880 per year.

If it is decided to replace the current HVAC units with geothermal wells, there will be an extremely low monthly power charge, and the building will be cooled and heated from temperature of the earth. The building will stay cool in the summer, and warm in the winter. The electrical bill for the Police Headquarters would be nearly $8,000 lower yearly with the most efficient geothermal system available.

Bibliography

Brewer, Robert. HVAC system Filter types; email interview. Monday, November 12th, 2007. The Filtration Group, Inc.

ComEd (2002) *Common Edison, Controlling Building Temperatures Technical Brief* Retrieved Tuesday, November 13th, 2007 http://www.exeloncorp.com/NR/rdonlyres/8EC3C4BE-8A4E-42A4-8837-73D7E20CD16B/0/ce_controlling_temperatures.pdf

Energy Ideas Clearinghouse (11/12/2007) *ENERGYIDEAS CLEARINGHOUSE Q&A* Retrieved Tuesday, November 13th, 2007 www.energyideas.org/default.cfm?o=h,g,ds&c=z,z,3998

Flex Your Power (2007) *California Energy Efficiency and Conservation* Retrieved Monday, November 12th, 2007 http://www.fypower.org/com/tools/energy_tips_results.html?tips=hvac

GreenNC Tradeshow, attended tradeshow and spoke with vendors, September 6, 2007, Jane S. McKimmon Center, NC State University Directory of Exhibitors online at http://www.greennctradeshow.com/3/miscellaneous1.htm

Hamilton, S.D, Roth, Kurt W. PhD, Brodrick, James PhD, (May 2003), ASHRAE Journal, *Emerging Technologies, Improved Duct Sealing*, Pg 64-65. Also available online at: http://www.tiax.biz/aboutus/pdfs/ashrae_0501-03.pdf

Kendall, Blair and McFarland, Daniel. *Energy Audit Training*, Tuesday, October 16th, 2007. Southern Energy Management

Latham, Steven; Klein, Larry: Schwartz, Evan I., (Producers), *Saved by the Sun*, NOVA, NOVA/WGBH Educational Foundation, WUNC, aired April 2007

North Carolina Division of Pollution Prevention and Environmental Assistance (September 2002) *Energy Efficiency in Industrial HVAC Systems*, Pages 1-10. Available online at http://www.p2pays.org/energy/HVAC/index.asp

Trane, Commercial HVAC Building Services, (2007) *Operate and Maintain, Restore and Modernize*, Retrieved November 13, 2007, http://www.trane.com/Commercial/BuildingServices/Default.aspx?i=867

U. S. Department of Energy, Office of Energy Efficiency and Renewable Energy [EERE], Federal Energy Management Program (May 2001) *Greening Federal Facilities*, DOE/GO-102001-1165, NREL/BK-710-29267. Section 5.2 HVAC Systems, Pages 56-57. Available online at http://www.nrel.gov/docs/fy01osti/29267.pdf

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy [EERE], (02/05/07) Federal Energy Management Program, *Energy Efficient Products, How to buy an Energy Efficient Ground Source Heat Pump* Retrieved Wednesday, November 14th, http://www1.eere.energy.gov/femp/procurement/eep_groundsource_heatpumps.html

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy [EERE], (2007), *Industrial Technologies Programs, Industrial Energy Systems*, Retrieved on November 10, 2007 http://www1.eere.energy.gov/industry/energy_systems/

U.S. Environmental Protection, U.S. Department of Energy, (2007), *Air Source Heat Pumps*, Retrieved on November 11, 2007 http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_as_heat_pumps

Major Appliances – Avery Dart

Summary of Findings: Even though the police station is 25 years old, it was relatively energy efficient with their major appliances.

Details

Major appliances were considered to be: refrigerators, washing machines, dryers, dishwashers, toaster ovens, microwaves, vending machines, drinking fountains.

There were not a lot of these major appliances at the Police Station.

Water fountains – 3 of them in the building. Newer more energy efficient drinking fountains could be used (fountains where the water temperature is adjustable). This could save $9 per year. If energy efficient water coolers were used instead of water fountains $60 per year could be saved.

They have 2 workout machines that are plugged in. If the machines use power while plugged in, it would be possible to save energy by putting the machines on timers to turn off the energy overnight (assuming police don't workout overnight).

There are 2 refrigerators and both have freezers on the top. The refrigerators were not that old (about 5 years), but they were not energy star rated. If you unplug one of the fridges they can save 28.20 per year. If they replaced the fridges they have currently have with compact fridges because they don't need that much space they could save $22.20 a year.

They have 2 microwaves and 1 toaster oven. Both are not energy star rated.

There is 1 soft drink vending machine and 1 snack vending machine. They can save about $50 a year if they get rid of the Coke vending machine.

California Energy Commission
www.energy.ca.gov/appliance

Energy star products (water cooler)
www.energystar.gov/index.cfm?c=water_coolers.pr_water_coolers

Water fountains and water cooler
http://www.energync.net/resources/docs/pubs/drinking.pdf

Info on vending machine energy
http://www.michigan.gov/documents/CIS_EO_Inside_school_iee_39276_7.pdf

Insulation – Jon Rosoff

SUMMARY OF FINDINGS

1. Roofing System

We climbed to the roof area. Most of the roofing is white TPO. TPO stands for thermoplastic polyolefin and is a type of synthetic material often used in the construction of commercial roofs. A roof system consists of three things: the deck underneath, a layer of insulation and a waterproofing membrane.

TPO is the membrane. Membranes are asphalt, rubber, polymer or metal. TPO is a new polymer-based membrane that supposedly are naturally UV (ultra-violet) and heat resistant, environmentally friendly, and recyclable. The white TPO has a reflective value in the high 80s.

There is 5-6 inches of an insulation called polystyrene. The R-value for the polystyrene was reported to be 19. This is less than the current energy conservation code for ceilings of 31. The building was built in 1971, and that was probably the code at the time.

The structural deck is strong enough to support a green roofing system, which adds up to 30 pounds per square foot weight, depending on the depth of the plantings.

While we don't yet know how long TPO roofing membranes will really last (since they are new), the main problem with our roofing system is not enough insulation.

There is a measure of heat resistance called R factor. The R factor measures conduction of the materials that make up the roofing system. There are three kinds of heat transfer: conduction, convection and radiation. The high reflective factor for the TPO roofing membrane measures its ability to reflect the sun's radiation. This high is important because a lot of the sun's radiation isn't transferred through the roof to the inside of the building.

2. Exterior Walls

The exterior walls are concrete.

There are three kinds of insulation used in the building: BATT, raw fiberglass, and cellulose fibers. The R-value of the insulation (which reflects the depth of the insulation materials) was reported to be 6. The current code is 16.

The exterior wall needs to be resurfaced and water proofed.

RECOMMENDATIONS FOR IMPROVEMENT

1. Roofing System

We would recommend that the Town add an extensive green roof over the existing TPO membrane basically to add insulation to the existing insulation.

There are many kinds of green roof systems. The extensive green roofing system seems most appropriate for the Police Headquarters.

TABLE: COMPARISON OF EXTENSIVE & INTENSIVE GREEN ROOF SYSTEMS

Extensive Green Roof	Intensive Green Roof
Thin growing medium; little or no irrigation; stressful conditions for plants; low plant diversity.	*Deep soil; irrigation system; more favorable conditions for plants; high plat diversity; accessible.*
Advantages: • Lightweight; reinforcement unneeded. • Good insulation -not as good as intensive. • Suitable for large areas. • Suitable for roofs with a little slope. • Low maintenance & long life. • No need for irrigation. • No need for specialized drainage systems. • Less technical expertise needed. • Often suitable for retrofit projects. • Can leave vegetation to grow. • RELATIVELY INEXPENSIVE. • Looks more natural.	*Advantages*: • Greater diversity of plants & habitats. • Good insulation properties. • Can simulate wildlife garden. • Often accessible for recreation, etc. • More energy efficiency than extensive. • More storm water retention than ext. • Less technical expertise needed. • Longer membrane life.
Disadvantages: • Less energy efficiency than intensive. • Less storm water retention benefits. • More limited choice of plants. • Limited access for recreation. • Unattractive to some.	*Disadvantages:* • Greater weight. • Need irrigation & drainage systems. • Greater capital & maintenance costs. • More complex systems & expertise.

Source: adapted from Design Guidelines for Green Roof

a. Benefits of the Extensive Green Roof System

Green roofs protect the roof membrane from UV rays and temperature changes, and result in reported a 2- to 3-fold increase in the life span of the roofing membrane. In the case of the TPO roofing membrane that could mean an increase from 15 to 45 years. This would mean that the roofing membrane does not have to be replaced as often and that will also mean less garbage in our landfills.

Green roofs can mean an energy savings from 5% to 25% depending on the depth of the growing medium. Less heat is conducted through the plant materials and cooler air goes into the air conditioning systems. We have estimated (report on HVAC by Marlow) that 35% to 50% of the energy consumed by the Police Headquarters comes from heating and air conditioning. That means that the green roof could save up to $1400 from the annual bill. Over 30 years, that would mean $42,000.

Green roofs reduce storm water runoff by capturing the rainwater and using it to grow the plants. There may be up to an 80% annual decrease in storm water runoff. Green roofs also filter out hazardous substances from rainwater, like heavy metals, acid rain, and airborne viruses and bacteria. Green roofs also clean the air of green house gases and dirt, and decrease the Urban Heat Island Effect that leads to higher air temperatures. All this means that there is less smog, and less distress for very young and very old people and people with respiratory problems like asthma.

Last but not least, green roofs create habit for birds and beneficial insects like butterflies, bees and other pollinators.

b. Costs of Green Roofs

The costs for the Xero Flor system is $8.00 per square foot, plus installation, shipping, and any irrigation and metal edging costs. For about 11,500 square feet, that would be $92,000, plus.

2. Exterior Wall and Ceiling Insulation

There are many kinds of insulation that can be added. We only list several of the newer, environmentally friendly products that can be added without taking out the sheetrock. We don't know what where and how much insulation is currently there, and that will be an important consideration in what new kinds can be used. (There is a mushroom spore grown insulation from Ecovative Designs but that insulation cannot be added without taking down interior walls.)

a. Cellulose

There is cellulose in the building now. Cellulose is made from natural fibers treated to make them fire resistant. The benefits of cellulose is that (at least certain brands like Applegate) are made from recycled, natural cellulose, with no volatile organic chemicals (VOCs), and no glass fibers. The R factor is 3.8 per inch depth against the wall. A disadvantage in the Police Headquarters is that cellulose absorbs some moisture, and there is a dampness problem.

b. Icynene

This is polystyrene. Although it is made from non-renewable oil resources, this foam is blown in with water, not gases that might deplete the ozone.

c. Cement Foam

This foam is basically foamed concrete. The air bubbles in the foamed concrete form the insulation. The manufacturer points out that concrete lasts thousands of years. Concrete is naturally fire resistant so there is no need for chemicals to make the foam fire resistant, and there are no glass fibers.

d. Soy-based Foam

BioBased has made a soy-based foam; we aren't using up oil for insulation, with no VOCs. BioBased claims that it is different from cellulose because it does not settle,

and creates a tight air seal that keeps out moisture and condensation. Given the water problems, this might be important to keep in mind.

BIBLIOGRAPHY

Carter, Joe. "New Insulation Options." This Old House, November 2005. Reproduced in www.thisoldhouse.com/toh/article/0,,1130563,00.html#. Nov. 15, 2007.

Department of Energy. Insulation Fact Sheet, 2007. Reproduced in www.ornl.gov/sci/roofs+walls/insulation/ins_01.html. Nov. 15, 2007.

Oberndorfer, Erica et.al. "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services." **BioScience**, November 2007, Vol. 57 No. 10, 823-833. Reproduced in www.bioscience.org. Nov. 13, 2007.

Peck, Stephen and Monica Kahn. "Design Guidelines for Green Roofs." Reproduced at egov.cityofchicago.org/webportal/COCWebPortal/COC_ATTACH/design_guidelines_for_green_roofs.pdf. Nov. 15, 2007.

FOAM INSULATION PRODUCT WEBSITES:

Foam-Tech Supergreen Foam Insulation, www.foam-tech.com.

Icynene Petrochemical based form blown in by water. www.icynene.com.

BioBased Soy-Based Foam Insulation. www.biobased.net

Airkrete Cementious Foam Insulation. www.airkrete.com

Ecovative Design Mushroom Spore Insulation. www.ecovativedesign.com.

GREEN ROOF SYSTEM PRODUCT WEBSITES:

Xero Flor. www.xeroflora.com.

Special Thanks to Blair Kendall and Dan McFarland, Southern Energy Management, www.southern-energy.com, and Clayton Rugh, Ph.D., general manager, Xero Flor Green Roof Systems, Durham NC, www.xeroflora.com, for their generous help.

Water Heating - Connor Bernstein

Summary of Findings

I was in charge of hot water heating, and here are some of my findings:

The water heater was already by the showers, which is the buildings major draw of ho water, and all of the pipes and the water heater itself were very well insulated (the pipes right above the heater aren't insulated because of maintenance).

The current hot water heater wastes energy, because it's on and heating water 24/7, and although it's in use for short times throughout the day, it's still wasting energy heating water that's not going to be used. Also, the faucets in the bathrooms are old-style, and they can be accidentally left on for longer than needed, or not turned off fully, along with the fact that they are very prone to leaks.

I would recommend that you replace the hot water heater with a tankless one, which can provide endless amounts of hot water 24/7, but isn't heating any water when not in use. I would also recommend that you replace all of the faucets with motion activated ones, to eliminate any possible leaks or people laving the water on longer than they need to.

By doing this, you'll probably save around 15-20% on your electric bill, which is about $16 a day! It will also serve as a good example of some new energy saving technologies.

Electronics – Robert McMahan

Summary of Findings

During our audit, my section was gathering information on the station's small electronic devices and evaluating their energy use. Here are our findings:

- Mr. John Newark informed us that all the station's computers are *Energy Star* rated
- The building's transformer was installed when the building was built
    - May be source of inefficiency

- ~10% of the station's monitors are CRT monitors
    - These are not as energy-efficient as LCD monitors

Recommendations for Improvement

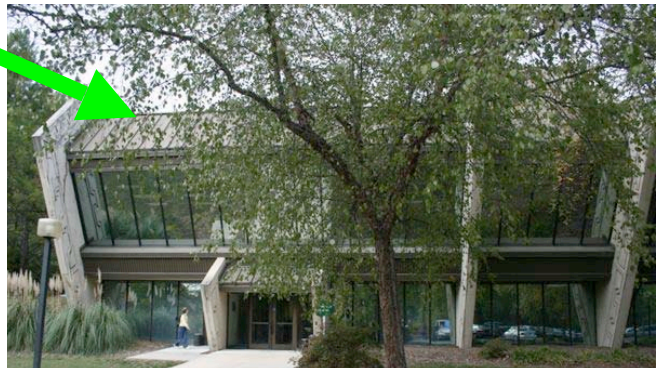
To their credit, this building's staff has done a lot to make sure that the electronic devices use as little energy as possible. However, there are still some areas to improve upon. These are:

- Prioritize replacement of non-*Energy Star* devices with *Energy Star* rated ones
- Investigate transformer; consider replacement.
- Consider immediate replacement of CRT monitors with LCD monitors.
    - This will reduce individual monitor energy usage by 17%

Solar Energy

Summary of Findings

I also have taken on the assignment of working out the placing of solar panels on the building. I'm told that you have recently commissioned the building of a bus stop powered entirely by solar energy, in order to set an example of alternate energy technology to the city and surrounding communities. With that in mind, here are our findings in Solar Energy:



- The building has excellent annual solar exposure
- Long metal fascia directly above front windows
  - Angled and positioned perfectly for solar panel array
  - Most of this fascia is blocked by trees

Recommendations for Improvement

Though solar panels would not seriously impact the building's energy bill, they would serve as a great demonstration to the city on alternative energy technology. Here are our recommendations:

- Mount solar panels on fascia above windows
  - ~35 standard 38" x 62" panels
  - 195W Max / 140W typical.
  - With 80% daylight usable
    - On average, 11% of building consumption generated by panels during usable daylight
    - Power generation highest in summer, when building consumption is highest
- Trim back trees
  - Will give panels access to sun
  - May impact building HVAC requirements

Benefits of Improvements

These improvements could greatly impact the community, both in saving money and in providing an example of alternative energy technology. Here are the benefits of these improvements:

- Solar Panels: Excellent Alternative Energy example for community at ~$50,000 cost
- Transformer could result in savings of as much as $400/year (at $0.06 / kWh) if replaced

References

http://www.copper.org/applications/electrical/energy/energy_star.html
http://www.evergreensolar.com/app/en/home/
http://www.aceee.org/consumerguide/electronics.htm
http://www.lipower.org/cei/tips.html
http://www.consumerreports.org/cro/home-garden/resource-center/energy-saving-guide/energy-saving-guide.htm
http://www.energysavingtrust.org.uk/energy_saving_products/a_guide_to_choosing_consumer_electronics
http://ezinearticles.com/?Running-An-Energy-Efficient-Household&id=504470
http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductCategory&pcw_code=HEF

Chapel Hill Police Station
Energy Audit Results

Analyses

Mindstorms Team 2255 – Chapel Hill, NC

Index	Month	Month	Year	On Peak (kWh)	Off Peak (kWh)	Total (kWh)	% On Peak	Total Charges	Days in Billling Cycle	Average Charge per day	Average Energy Consumption per day (kWh)
1	10	Oct	2006	8310	22158	30468	27%	$ 1,899	26	$ 73	1172
2	11	Nov	2006	6987	22156	29143	24%	$ 1,580	29	$ 54	1005
3	12	Dec	2006	6123	21388	27511	22%	$ 1,516	29	$ 52	949
4	1	Jan	2007	7056	23726	30782	23%	$ 2,164	36	$ 60	855
5	2	Feb	2007	6995	19466	26461	26%	$ 1,568	27	$ 58	980
6	3	Mar	2007	7659	25613	33272	23%	$ 1,709	33	$ 52	1008
7	4	Apr	2007	7083	24080	31163	23%	$ 1,642	29	$ 57	1075
8	5	May	2007	6891	23408	30299	23%	$ 1,614	28	$ 58	1082
9	6	Jun	2007	8895	31665	40560	22%	$ 2,119	34	$ 62	1193
10	7	Jul	2007	11037	28987	40024	28%	$ 2,672	29	$ 92	1380
11	8	Aug	2007	13055	34463	47518	27%	$ 3,062	32	$ 96	1485
12	9	Sep	2007	10367	32637	43004	24%	$ 2,863	29	$ 99	1483
13	10	Oct	2007	8052	31865	39917	20%	$ 2,552	29	$ 88	1376
		Totals		100,200	319,454	419,654		$ 25,061			

		In Month
Max	$ 99	Sep
Min	$ 52	March
Average	$ 69	

	Building Area (sq ft)	Area per Fixture (sq ft)	Number of Fixtures	Power Use per Fixture(W)	Load (kW)	Daily Use (kWh)
Lighting Use	23800	115	207	128	26.5	636

Usable Daylight	80%
Average Panel Generation	140
# of Panels	35

If we Reduced Lighting by: 20%

Lighting	Other	HVAC (est)	Average Daily Charge with Savings	Average Daily Savings	Average Monthly Savings		Daylight Hours (decimal)	Solar Energy Hours	Average Power Generation/ Day (kWh)	Fraction of Daylight during 24 hour period	Fraction of Average Building Consumption during Usable daylight (kWh)	% of Daily Building Consumption	% of Building Consumption during Usable daylight
54%	46%	37%	$ 65	$ 8	$ 206	Oct	11.47	9.17	44.95	0.38	448	4%	10%
63%	37%	29%	$ 48	$ 7	$ 200	Nov	10.67	8.53	41.81	0.36	357	4%	12%
67%	33%	26%	$ 45	$ 7	$ 203	Dec	10.23	8.19	40.11	0.34	324	4%	12%
74%	26%	21%	$ 51	$ 9	$ 322	Jan	10.40	8.32	40.77	0.35	296	5%	14%
65%	35%	28%	$ 51	$ 8	$ 203	Feb	11.17	8.93	43.77	0.37	365	4%	12%
63%	37%	30%	$ 45	$ 7	$ 216	Mar	11.95	9.56	46.84	0.40	402	5%	12%
59%	41%	33%	$ 50	$ 7	$ 194	Apr	12.88	10.31	50.50	0.43	461	5%	11%
59%	41%	33%	$ 51	$ 7	$ 190	May	14.37	11.49	56.32	0.48	518	5%	11%
53%	47%	37%	$ 56	$ 7	$ 226	Jun	14.07	11.25	55.14	0.47	559	5%	10%
46%	54%	43%	$ 84	$ 8	$ 246	Jul	13.93	11.15	54.62	0.46	641	4%	9%
43%	57%	46%	$ 87	$ 8	$ 262	Aug	13.27	10.61	52.01	0.44	657	4%	8%
43%	57%	46%	$ 90	$ 8	$ 245	Sep	12.38	9.91	48.54	0.41	612	3%	8%
46%	54%	43%	$ 80	$ 8	$ 236	Oct	11.47	9.17	44.95	0.38	526	3%	9%
				Total	$ 2,743								

Lighting	In Month					
74%	Jan	Max	56.3		5%	14%
43%	Sep	Min	40.1		3%	8%
57%		Average	47.9		4%	11%

Total Amount of Daylight (30 deg. Latitude)

Month	Hours	Minutes	Hours (decimal)	
January	10	24	10.40	October
February	11	10	11.17	November
March	11	57	11.95	December
April	12	53	12.88	January
May	14	22	14.37	February
June	14	4	14.07	March
July	13	56	13.93	April
August	13	16	13.27	May
September	12	23	12.38	June
October	11	28	11.47	July
November	10	40	10.67	August
December	10	14	10.23	September
				October

Index	Month	Month	Year	On Peak (kWh)	Off Peak (kWh)	Total (kWh)	% On Peak	Total Charges	Days in Billling Cycle	Average Charge per day	Average Energy Consumption per day (kWh)
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11	8	Aug	2007	13055	34463	47518	27%	$ 3,062	32	$ 96	1485
12	9	Sep	2007	10367	32637	43004	24%	$ 2,863	29	$ 99	1483
13	10	Oct	2007	8052	31865	39917	20%	$ 2,552	29	$ 88	1376
		Totals		108,510	341,612	450,122		$ 26,960	390		

		In Month
Max	$ 99	Sep
Min	$ 52	March
Average	$ 69	

	Building Area (sq ft)	Area per Fixture (sq ft)	Number of Fixtures	Power Use per Fixture(W)	Load (kW)	Daily Use (kWh)
Lighting Use	23800	115	207	128	26.5	636

If we Reduced Lighting by:	20%

Lighting	Other	HVAC (est)	Average Daily Charge with Savings	Average Daily Savings	Average Monthly Savings	Charge $ per kWh	Monthly HVAC Energy Usage (kWh)	HVAC $ Cost per month
54%	46%	36.6%	$ 65	$ 8	$ 206	0.06	11,150.37	$ 694.98
63%	37%	29.4%	$ 48	$ 7	$ 200	0.05	8,564.53	$ 464.33
67%	33%	26.4%	$ 45	$ 7	$ 203	0.06	7,258.93	$ 400.00
74%	26%	20.5%	$ 51	$ 9	$ 322	0.07	6,315.41	$ 443.98
65%	35%	28.1%	$ 51	$ 8	$ 203	0.06	7,436.16	$ 440.64
63%	37%	29.6%	$ 45	$ 7	$ 216	0.05	9,833.26	$ 505.08
59%	41%	32.7%	$ 50	$ 7	$ 194	0.05	10,180.53	$ 536.42
59%	41%	33.0%	$ 51	$ 7	$ 190	0.05	9,997.94	$ 532.58
53%	47%	37.4%	$ 56	$ 7	$ 226	0.05	15,155.04	$ 791.75
46%	54%	43.1%	$ 84	$ 8	$ 246	0.07	17,269.33	$ 1,152.90
43%	57%	45.7%	$ 87	$ 8	$ 262	0.06	21,738.68	$ 1,400.81
43%	57%	45.7%	$ 90	$ 8	$ 245	0.07	19,653.33	$ 1,308.42
46%	54%	43.0%	$ 80	$ 8	$ 236	0.06	17,183.73	$ 1,098.60
				Total	$ 2,949		Total	$ 9,770.51

Lighting	In Month			
74%	Jan		4%	$ 390.82
43%	Sep	$ 7,870.51	9%	$ 879.35
57%			10%	$ 977.05