Power to the People: Energy Audits

Monika Bubacz[1], Philip T. McCreanor[2], Laura W. Lackey[3]

Abstract – Energy is one of the most fundamental parts of our lives. Energy keeps us comfortable, heats water, preserves food, provides artificial light, and keeps television, computers and other appliances running. All of this requires a lot of energy: households consume nearly one-fifth of the total energy used in the United States each year. Home energy use contributes 20% of the nation's annual CO_2 emissions from fossil fuel combustion. Thus, finding ways to use less energy more efficiently is important to reducing our climate impact. An energy audit is an inspection, survey and analysis of energy flows in a building, focused on reducing the amount of energy input into the system without negatively affecting the outputs. The Mercer University School of Engineering received two grants to support three energy audits performed by engineering faculty members and their students in the neighboring community. The goal of the project was to prepare the faculty for the inclusion of service-learning projects in their courses and to engage students in environment-saving practices. The audit tasks included surveying the: building envelope, HVAC, water, lighting, equipment, landscaping and waste / recycling. The findings of each audit were summarized in a report that included recommendations to make the audited buildings more energy efficient and environmentally friendly. The project facilitated a connection between Mercer' students, faculty, and the community and aimed to improve the quality of life for all affected residents.

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ENERGY AUDITS – THE BASICS

Rising utility costs, growing demand for energy efficiency, concerns about the environment and economic uncertainty have led to billions of dollars in federal, state and local energy efficiency and weatherization programs. An energy audit is an energy assessment performed to evaluate how much energy a building consumes and to evaluate what measures can be taken to make the building more energy efficient. The assessment highlights problems that may, when corrected, save significant amounts of money over time. Energy assessments also determine the efficiency of the building's heating and cooling systems and may identify ways to conserve water and electricity.

A professional auditor uses a variety of techniques and equipment to determine the energy efficiency of a structure. Residential energy auditors are accredited by the Building Performance Institute or the Residential Energy Services Network. Thorough assessments often use equipment such as blower doors, which measure the extent of leaks in the building envelope, and infrared cameras, which reveal hard-to-detect areas of air infiltration and missing insulation [1].

Generally, four levels of analysis can be outlined (following American Society of Heating, Refrigerating and Air-Conditioning Engineers ASHRAE [2]):

[1] Assistant Professor, Department of Mechanical Engineering, Mercer University, 1400 Coleman Avenue, Macon, GA, bubacz_m@mercer.edu

[2] Associate Professor, Department of Environmental Engineering, Mercer University, mccreanor_pt@mercer.edu

[3] Professor, Department of Environmental Engineering, Mercer University, lackey_l@mercer.edu

- Level 0 – Benchmarking: This first analysis consists of a preliminary Whole Building Energy Use analysis based on a review of the historic utility use and comparison of the performance to similar buildings. This benchmarking aid in determining if further analysis is required.

- Level I – Walk-through Audit: Preliminary analysis made to assess building energy efficiency to identify not only simple and low-cost improvements but also a list of energy conservation measures (ECMs) or energy conservation opportunities (ECOs) to orient the future detailed audit. This inspection is based on visual inspections, operating data of installed equipment, and detailed analysis of recorded energy consumption collected during the Benchmarking.

- Level II – Detailed/General Energy Audit: Based on the results of the Benchmarking and Walk-through Audit, this type of energy audit consists of an energy use survey in order to provide a comprehensive analysis of the studied installation, a more detailed analysis of the facility, a breakdown of the energy use and a first quantitative evaluation of the ECOs/ECMs selected to correct the defects or improve the existing installation. This level of analysis can involve advanced on-site measurements and sophisticated computer based simulation tools to evaluate the precise impact of the selected energy retrofits.

- Level III – Investment-Grade Audit: Detailed Analysis of Capital-Intensive Modifications focusing on potential costly ECOs requiring rigorous engineering study.

A home energy audit is often the first step in making a residential building more efficient. A do-it-yourself home energy assessment [3] can be easily conducted. With a simple but diligent walk-through, many problems can be spotted in any type of dwelling. However, the audits alone don't save energy. The recommended improvements need to be implemented. Energy Star provides extensive information about home improvement projects to enhance energy efficiency, lower utility bills, and increase comfort [4].

The main components of a Level I audit are:

- **Locating Air Leaks** - The potential energy savings from reducing drafts in a home can range from 5% to 30% per year. A visual inspection may be sufficient to locate many leaks. If light can be observed through a joint, it is not well sealed. Possible locations for air leaks include but are not limited to:
  - gaps along the baseboard or edge of the flooring and at junctures of the walls and ceiling,
  - electrical outlets and switch plates,
  - window frames,
  - baseboards,
  - weather stripping around doors,
  - fireplace dampers,
  - attic hatches,
  - wall- or window-mounted air conditioners,
  - gaps around pipes and wires,
  - mail slots,
  - all exterior corners,
  - where siding and chimneys meet, and
  - areas where the foundation and the bottom of exterior brick or siding meet.

- **Insulation** - Heat loss through the ceiling and walls can be large if the insulation levels are less than the recommended minimum. When a building is being constructed, the builder installs the amount of insulation recommended at that time. Given today's energy prices (and future prices that will probably be higher), the level of insulation might be inadequate, especially in case of an older buildings. Possible locations to be inspected include but are not limited to:
  - attic hatch, if located above a conditioned space, should be at least as heavily insulated as the attic, weather stripped, and closed tightly,
  - openings for pipes, ductwork, and chimneys should be sealed,

- vapor barrier under the attic insulation - it reduces the amount of water vapor that can pass through the ceiling (large amounts of moisture can reduce the effectiveness of insulation and promote structural damage),
- attic vents should not blocked by insulation,
- electrical boxes in the ceiling should be sealed,
- walls' insulation level can be determined through thermographic inspection,
- insulation under the living area flooring in the basement and crawl space, and
- water heater, hot water pipes, and furnace ducts should all be insulated as well.

- **Heating/Cooling Equipment** - Heating and cooling equipment needs to be inspected annually, or as recommended by the manufacturer; filters replaced about once every month or two, especially during periods of high usage. If the unit is more than 15 years old, it should be replaced with an energy-efficient unit. Ductwork should be checked for dirt streaks, especially near seams. These indicate air leaks that should be sealed.

- **Lighting** - Energy for lighting accounts for about 10% of the typical residential electric bill. The wattage size of the light bulbs should be examined and changed to lower values when suitable. Compact fluorescent lamps for areas where lights are on for hours at a time should be considered. The electric utility provider may offer rebates or other incentives for purchasing energy-efficient lamps.

ENERGY AUDITS IN EDUCATION

Renewable energy technologies are important on a global basis due to pressures on conventional fossil-fuel energy resources used to power the majority of today's societal needs. This dramatic shift means that there is a new need for sustainability engineers who are proficient in the broad portfolio of technologies and analytic techniques required to evaluate renewable and alternative energy. To meet the need for developing sustainability engineers many universities[5,6] are bringing together professionals, faculty, and both undergraduate and graduate students to work on projects directly related to sustainability engineering. Designing new systems as well as evaluating the financial attributes of new and current systems are both equally important in the success of sustainability engineering.

In many cases the undergraduate engineering curriculum does not incorporate sustainability fundamentals including energy management, architecture design, sales, equipment management and alternative energy training. Finding a way to incorporate these additional topics into existing curricula is a challenge. However, a building energy audit provides a perfect hands-on experience in a project-based setting. In these projects, faculty or students lead a building audit focused on analyzing the energy utilization of a building and make recommendations for methods to reduce energy consumption and increase the overall efficiency. The audit activity provides experiential learning activity that covers the properties of energy, insulation, air leakage, the building envelope, windows and doors, heating and cooling systems, water heating systems, and more. The audit report contains the building's past and current energy consumption, an inventory of all portable and stationary equipment, lighting, and HVAC energy use on a room by room basis. Based on the collected data, seasonal patterns of energy usage are developed and used to guide modeling for possible energy efficiency improvements.

As an added benefit, these improvements can result in better lighting conditions, better indoor and outdoor air quality and better controlled indoor temperature – all of which can improve the productivity and general well-being of the occupants[7]. Having that in mind, energy audits provide a wonderful service learning opportunity and provide productive and gratifying community involvement for the students. Students are also given the opportunity to interact with an off-campus client, which provides an additional unique experience that is not typically found in the classroom. This interaction allows students to further develop their project management and communication skills.

Most people hardly notice details about buildings, such as how they are designed, how they are built, and how well they are maintained. These details have a strong effect on how comfortable a building is and how much it costs to operate. In the energy audit activity the students learn science and mathematical concepts in a hands-on, minds-on way. They become empowered to research their environment and make recommendations for changes.

ENERGY AUDITS AT MERCER

The energy audits performed by students and faculty of Mercer University School of Engineering (MUSE) have been made possible thanks to two grants from John S. and James L. Knight Foundation obtained through the Knight Neighborhood Challenge. The goal of the Knight Neighborhood Challenge is to invest in ideas to restore the land use and social fabric of the College Hill neighborhood in Macon, GA, to reawaken the soul of the community through active participation in a wide array of community arts, cultural and sports activities, and to connect to one another through digital and traditional information gathering/sharing channels[8].

The goal of the first funded project was to prepare MUSE faculty for the inclusion of service-learning projects in their courses, to involve students, and to develop a plan for the reduction of the environmental footprint of a Victorian Style house built in 1855, recently remodeled as office space. The antebellum structure is commonly referred to as the “Bell House,” located at 315 College Street and is currently vacant. The project was expected to create a stronger connection between Mercer students, faculty, and the community and aimed at improving the quality of life of the College Hill neighborhood residents. The grant allowed training of three faculty members by another faculty who has been previously involved in performing energy audits with Georgia Interfaith Power and Light (GIPL). The trained faculty would then use the acquired knowledge in their classrooms and to involve and instruct groups of students performing future energy audits in the neighborhoods surrounding Mercer University.

Funding from the second grant was used to procure equipment and supplies required to conduct Level I energy audits. Teams of engineering students would work with their clients, trained faculty advisors, and evaluators to perform energy audits for buildings, streets, and parks in the College Hill neighborhood. Audit recommendations could be implemented by students as Senior Design Projects after receiving additional funding from either specific clients or funding agencies. Again, the project was designed to create a stronger connection between Mercer’s students, faculty, and the community and aimed at improving the quality of life for the residents.

The grant allowed purchase of the following equipment:

- power meters (Energy Mizer),
- tape measures,
- flashlights,
- thermometers (cooking and surface),
- stopwatches,
- plastic graduated beakers,
- screwdrivers,
- safety glasses,
- face masks,
- knee pads,
- disposable gloves,
- storage bags,
- portable collapsible ladders.

The Bell House was audited in September 2011, by four faculty members and eleven students. Students’ participation was voluntary and the group consisted of juniors and seniors from Mechanical and Environmental Engineering Departments. The building history, energy and water usage data, and square footage were evaluated prior to visually inspecting the dwelling. The following outline was used to guide the audit:

1. Building Envelope
    a. Danger spots for solar gain in summer
    b. Ceilings, walls – major cracks, holes
    c. Attics – insulation, tightness of energy barrier
    d. Basements, crawl spaces – insulation, water infiltration
    e. Doors – seals, frame
    f. Windows – seals, double paned glass, damaged

2. HVAC Systems
    a. Controls – programmable thermostats, proper placement, settings

b. Ductwork – damage, insulation
c. Individual room units – insulation, are they turned off when not used
d. Maintenance – proper maintenance contract
e. If replacement is needed – get an engineer

3. Water
   a. Leaks, aerators on faucets
   b. Low-flush toilets
   c. Water heaters – insulated, temperature of output, properly sized

4. Equipment
   a. Kitchen – over-capacity of freezers and frigs, ice-making machines, Energy Star
   b. Office – computers, copiers off when not in use, Energy Star
   c. Water coolers, vending machines – are they necessary?

5. Lighting
   a. Fluorescents – T-5 or T-8, all tubes working, compact fluorescents
   b. Incandescent – necessary? off when not in use?
   c. Sanctuary lighting – off when not in use?
   d. Exit signs – LED?
   e. Controls – timers or motion switches where necessary

6. Outside Watering
   a. Cisterns or rain barrels
   b. Proper drainage away from buildings
   c. Gutters and downspouts – damage, clean

7. Recycling and Precycling (not using in first place)
   a. office paper
   b. composting
   c. cans and bottles

It has been decided to use the same protocol for residential and commercial buildings as the energy audit process is rather similar with the exception of room occupancy scheduling. This is especially true for community structures (churches) where some rooms many only be used a few times per week.

An 11-page energy audit report was prepared by the faculty members in training using a template created by Georgia Interfaith Power & Light[9]. The report provides a basic energy assessment consisting of a summary of findings and a prioritized outline of actions that will make the building more energy efficient. This report also provides a rough estimate of the cost of the recommendations. The report was evaluated and revised by the instructing faculty and submitted to the owners of the audited building. Summary of the most important findings included: incandescent bulbs, exposed outdoor wiring, open crawl space, inadequate and damaged subfloor and attic insulation, internal and external water damage, single pane windows painted shut, gaps between doors and frames, attic ladder broken, sinking foundation. It is hoped that the report will be turned over to the new occupants of the building. The auditors will be available to re-audit the property if requested.

A vacant rental property located approximately two blocks from the Mercer University campus was selected for the second audit. The audit was conducted in December 2011, by five students supervised by the same four faculty members that audited the Bell House. Once again, the students' participation was voluntary and the group consisted of juniors and seniors from Mechanical and Environmental Engineering Departments. Two of the students had participated in the previous energy audit at the Bell House. The building history, square footage and water usage data were collected before the physical inspection. The audit followed the same plan as detailed above for the Bell House. One of the students that had participated in the Bell House Audit prepared the report for this property. The report was evaluated and revised by the faculty and submitted to the owners of the audited property. Summary of the most important findings included: incandescent bulbs, polybutylene pipes, AC and rain water drainage issues, exposed AC unit located on south side of the house, loose power and telephone lines, gaps between garage door and its frame, leaking sewer vent pipe in attic, animal (bird) access to attic, sinking foundation. It is hoped that the report will be used to improve the condition of the house. The auditors will be available to re-audit the property if requested.

The Woodruff House, 988 Bond St., Macon, GA, has been identified as the third location for audit by the student and faculty team. The Woodruff House is an antebellum mansion built in 1836 that is open during festivals for public tours and used to host special events. This audit is scheduled for March 2012, and will be conducted by five or more students and supervised by the four faculty members.

Both projects enhanced faculty and students' interest in future energy audits, community service, and environmental sustainability. An assessment tool needs to be developed to evaluate students learning and a pre- and post-audit survey has been suggested. It is hoped that energy audits will be added to engineering curriculum as a lab activity or lecture topic and student projects in selected energy and environmental sustainability related courses. There is also a prospect of possible weatherization projects conducted in cooperation with Macon Area Habitat for Humanity.

A motion to offer no-cost or low-cost audits to the Macon community has been made.

CONCLUSIONS

The goal of this project was to prepare Mercer Engineering faculty for the inclusion of service-learning projects in their courses, involve students, and develop a plan for the reduction of the environmental footprint of buildings in the Mercer University neighborhoods. The energy audits performed by students, as service-learning ventures, provide a unique learning environment and certainly should help with developing new skills. The energy audit reports produced can be used to make the buildings more energy efficient and environmentally friendly. These projects should foster students' engagement and motivation, which may improve learning. The project itself creates a stronger connection among students, faculty, and the community and will ultimately reduce the environmental impact of the College Hill neighborhood while reducing the utility bills associated with these buildings.

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Monika Bubacz

Dr. Monika Bubacz is an Assistant Professor in the Department of Mechanical Engineering at Mercer University. She received both her B.S. and M.S. in Mechanical Engineering from Poznan University of Technology in Poland, and the Ph.D. in Engineering and Applied Science from the University of New Orleans (UNO). Before her appointment at Mercer she has worked for the Metal Forming Institute in Poznan, Poland, and the Center for NanoComposites and Multifunctional Materials at Pittsburg State University in Pittsburg, Kansas. While at UNO, Dr. Bubacz did summer research at the Oak Ridge National Laboratory and the Indiana University Cyclotron Facility. Her teaching and research interest areas include materials science, polymers and composites for aerospace applications, nanotechnology, and environmental sustainability.

Laura W. Lackey

Dr. Laura W. Lackey is the Chair of the Department of Environmental Engineering and a Professor at the Mercer University School of Engineering. She earned B.S., M.S., and Ph.D. degrees in Chemical Engineering from the University of Tennessee. The terminal degree was awarded in 1992. She has six years of industrial experience at the Tennessee Valley Authority as an Environmental/Chemical Engineer where she conducted both basic and applied research with emphasis on the mitigation of organic wastes through bioremediation. In the 12 years since Dr. Lackey began her career at Mercer, she has taught 14 different courses, ranging from a freshman-level Introduction to Problem Solving course to a senior-level Process Chemistry course, which she developed. She is a registered professional engineer.

Philip T. McCreanor

Philip T. McCreanor is an Associate Professor in the Environmental Engineering Program and Director of the Engineering Honors Program at Mercer University in Macon, GA. Dr. McCreanor possesses a Ph.D. in Environmental Engineering and a M.S. in Environmental Science from the University of Central Florida and a B.S. in Mechanical Engineering from the University of Miami. His research interests include bioreactor landfills, remote sensing, instrumentation, and unsaturated groundwater flow.