Thaddeus Stevens College of Technology

Mellor Building

Energy Survey Report

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Prepared by:
Energy Opportunities, Inc.
1200 East Camping Area Road
Wellsville, PA 17365
717-292-2636

Energy Survey Report

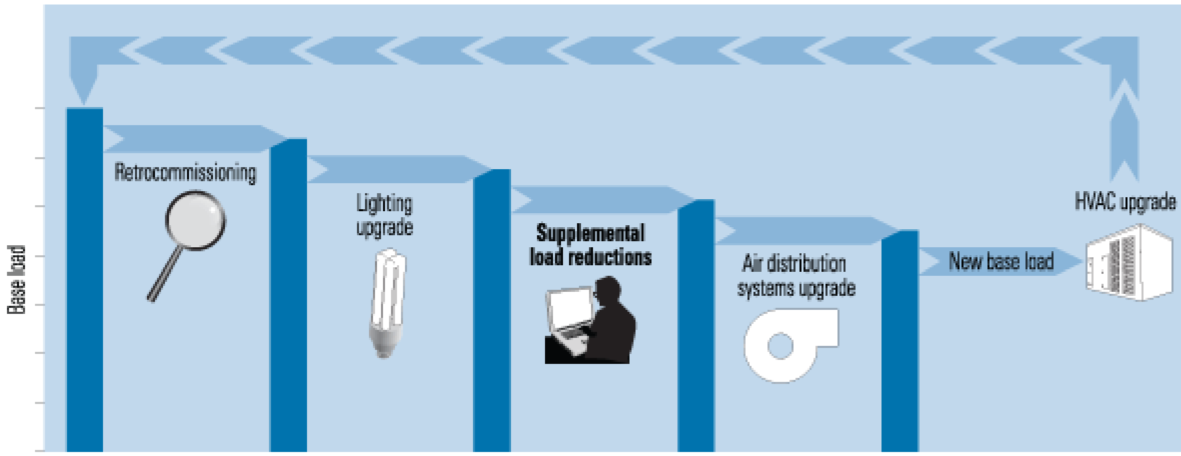
Organization:	Thaddeus Stevens College of Technology	Date of Survey:	June 9, 2009
Address:	750 East King Street	Contact:	Gene Duncan
	Lancaster, PA 17602	Phone:	717-299-7782

Executive Summary

On June 9, 2009 Energy Opportunities, Inc. completed an energy survey of the Mellor Building of Thaddeus Stevens College of Technology. We also obtained a previously completed energy audit report and utility bills to inform our energy analysis and recommendations. The building was originally constructed in 1907, and is currently used for administrative offices and classrooms. The Mellor Building is heated with original steam radiators and cooled with window or ductless split air conditioners. These systems are currently not being controlled in an efficient manner and some are nearing the end of their useful lives. A number of options for replacement systems or retrofits to the existing system are discussed in detail, weighing the pros and cons of each. The lighting system has been partially retrofitted with new technology, but about half of the old fixtures remain and are in need of replacement. Possibly the greatest area in need of a renovation is the building envelope, including windows, insulation, and air sealing. Recommendations have also been provided related to domestic water heating and plug load savings.

When faced with the need to upgrade the building's energy-related systems there is an optimal order to the implementation of the retrofits. Essentially, load reduction strategies should be implemented before major HVAC system upgrades. By reducing the building heating and cooling loads the HVAC upgrade can be sized in an optimal manner. Upgrading the HVAC system before the implementation of load reduction strategies will result in a greater potential for system over-sizing. Over-sized systems cost more up front and will have higher energy use. The figure on page 2 illustrates the proper order of a building retrofit designed to optimize both first and operating cost. For additional information see the *Energy Star Building Upgrade Manual* - http://www.energystar.gov/ia/business/EPA_BUM_Full.pdf

The purpose of this Energy Survey Report is to provide you with recommendations for the most effective energy saving opportunities in your building. Because of its general nature, this report is not intended to be used as a specification for the included recommendations. This report contains general descriptions of several energy saving measures. These opportunities have been analyzed in terms of cost effectiveness. Where possible we have estimated the cost to implement and annual savings generated by the energy saving opportunity. These figures are rough estimates based on your building's characteristics, information provided during the survey, and typical implementation cost data. The assumptions made in the calculations are designed to be conservative, so as not to overestimate potential energy savings.



Stages of an integrated upgrade approach

Courtesy: E SOURCE

The five stages recommended by the Energy Star Building Upgrade Manual are:

■ Retrocommissioning (Chapter 5). Retrocommissioning is the first stage because it provides an understanding of how a facility is operating and how closely it comes to operating as intended. Specifically, it helps to identify improper equipment performance, equipment or systems that need to be replaced, and operational strategies for improving the performance of the various building systems.

■ Lighting (Chapter 6). Lighting upgrades, which may include new light sources, fixtures, and controls, come early in the process because the lighting system has a significant impact on other building systems. Lighting affects heating and cooling loads and power quality.

■ Supplemental Load Reductions (Chapter 7). Supplemental load sources, such as building occupants and electronic equipment, are secondary contributors to energy consumption in buildings. They can affect heating, cooling, and electric loads. With careful analysis of these sources and their interactions with HVAC systems, equipment size and upgrade costs can be reduced.

■ Air Distribution Systems (Chapter 8). Air distribution systems bring conditioned air for heating or cooling to building occupants, and therefore directly affect both energy consumption
and occupant comfort. Fan systems can be upgraded and adjusted to optimize the delivery of air in the most energy-efficient way.

■ Heating and Cooling Systems (Chapter 9). If the steps outlined in the first four stages have been followed, cooling and heating loads are likely to have been reduced. That reduction, coupled with the fact that many existing HVAC systems are oversized to begin with, means that it may be possible to justify replacing an existing system with one that is properly sized or retrofitting a system so that it operates more efficiently. In addition to saving energy, proper sizing will likely reduce noise, lower the first costs for equipment, and optimize equipment operation, often leading to less required maintenance and longer equipment lifetimes.

The HVAC Systems at the Mellor Building

The Mellor Building is heated with steam which is provided via the central campus steam plant. The central plant was upgraded in 2005, which has resulted in significant energy savings. Within the building the steam is distributed to radiators within each space. The building is divided into 3 zones which are each controlled using an old Minneapolis-Honeywell Weatherstat System. This system used to control the heating based on the outside temperature, but this function has apparently been disabled and the system is now controlled only by thermostats within the building. Many of the individual radiators have been outfitted with thermostatic radiator valves to automatically adjust their heat output. As is typical with steam, the system apparently overheats the building often, causing occupants to open windows even in winter to compensate. This wastes a considerable amount of energy which is seen at the central plant. Cooling for the Mellor Building is provided by a combination of window and mini-split air conditioners. In addition to detracting from the aesthetic appeal of this historic building, many of these units are fairly old and are likely nearing the end of their useful lives. Arguably the greatest non-energy downside of the current HVAC system at the Mellor Building is its inability to provide outside air to occupants. Outside air still enters the building through open or leaky windows, but this uncontrolled method of infiltration is certainly not preferred from an energy standpoint. The following HVAC recommendations consider the pros and cons of a number of potential replacement systems or retrofits which intend to improve the energy, comfort, acoustic and aesthetic performance of the current system.

HVAC Recommendations

1. *System Description: Water Source Heat Pumps with Energy Recovery Ventilator*

Relative Cost: $$$ ***Energy Efficiency:*** ***Aesthetic/Acoustic:***

Pros:

- *Utilizes new campus steam plant*
- *Single location of steam control*
- *Energy efficient*
- *Good temperature control*
- *Heat pumps can be placed outside of rooms*
- *Simultaneous heating and cooling*

Cons:

- *Expensive*
- *Need location for cooling tower*
- *Ductwork needed for outside air*
- *Removal of all steam piping and radiators*
- *Many compressors to maintain*

Probably the best HVAC system replacement for the Mellor Building is water source heat pumps. These systems essentially move heat between the building and a water loop, resulting in higher efficiencies than typical heat pumps which move heat between the building and the air outside. In heating mode, the heat pumps extract heat from the water to deliver warm air to the spaces they serve. Campus steam can be used with a steam-to-water heat exchanger to keep the water loop temperatures high during the coldest months, greatly improving the efficiency and output of the heat pumps. This also reduces the number of steam control locations needing maintained to one. In cooling mode, heat from the building is transferred to the water loop, which in turn rejects that heat to the outside air using a cooling tower. The systems could be sized based on the cooling load rather than the heating load, since heating will be supplemented with campus steam. This should allow the systems to be much smaller and therefore less expensive than larger systems sized for the heating load. Outside air for the building would be handled separately from the heat pumps using an energy recovery ventilator, which would recover heat from building exhaust air to precondition outside air before delivering it directly into the occupied spaces.

One key advantage of this system is that each unit can operate in heating or cooling mode as necessary, independent of the heating or cooling requirements of the other systems. Although no spaces in this building are likely to require year round cooling, this feature would likely be useful during the swing seasons when portions of the building will require heating at the same time others will require cooling. Consol heat pump units can be placed inside rooms where the radiators are currently located, or ceiling-mounted units can be placed within the corridors to reduce the noise generated inside the rooms.

This is one of the most expensive system alternatives available. The old steam piping, radiators, and air conditioners would need to first be removed. New piping for the water loop will need to be installed throughout the building as well as the new steam-to-water heat exchanger. Each of the new heat pump units will need to be purchased and installed, along with the energy recovery unit and cooling tower. The energy recovery unit can most likely be located in the existing attic, but a location for the cooling tower will be needed outside. One of the greatest challenges with this, and many replacement system alternatives, will be supplying the outside air to each space. If a centralized energy recovery unit is used and located in the attic, ductwork will need to be run from that unit down to each floor below and into each room. Drop ceilings may need to be added in areas where the only space available to route ductwork is below the existing finished ceiling. This system would also be more involved to maintain, since there is a compressor and more controls in each unit than in centralized systems.

2. System Description: Chilled/Hot Water Fan Coil Units with Energy Recovery Ventilator

Relative Cost: $$$ ***Energy Efficiency:*** ***Aesthetic/Acoustic:***

Pros:

- *Utilizes new campus steam plant*
- *Single location of steam control*
- *Moderately efficient*
- *Good temperature control*
- *Single compressor to maintain*

Cons:

- *More expensive than #1 but less efficient*
- *No simultaneous heating and cooling*
- *Need location for air cooled chiller*
- *Chiller noise*
- *Ductwork needed for outside air*
- *Removal of all steam piping and radiators*
- *Fan coil units in rooms and noisy*

Another alternative to the water source heat pump system is a 2-pipe fan coil unit system utilizing chilled water for cooling and hot water for heating. In this system hot or chilled water transfers heat with space conditioning air as the air passes over a finned tube heat exchanger containing the water. Hot water would be provided from the district steam system using a steam-to-water heat exchanger. By using hot water for the space heating rather than steam, more accurate and reliable temperature control can be achieved. As with the previous system, this also reduces the number of steam control locations needing maintained to one. Chilled water would be provided by a packaged air cooled chiller. Outside air for the building would be handled separately from the fan coil units using an energy recovery ventilator, which would recover heat from building exhaust air to precondition outside air before delivering it directly into the occupied spaces.

This system would still allow the building to take advantage of the new and efficient central steam plant. It would still provide much better temperature control than the current system and would eliminate all of the energy waste from open windows during the winter. Its primary advantage over the water source heat pumps is the compressor maintenance would be limited to the single chiller rather than many heat pump units.

This system would require much of the same work as the first system, with some additional disadvantages. Just as with the previous system, the old steam piping, radiators, and air conditioners would need to first be removed. New piping for the hot/chilled water will need to be installed throughout the building as well as the new steam-to-water heat exchanger. Each of the new fan coil units will need to be purchased and installed, along with the energy recovery unit and air cooled chiller. The energy recovery unit can most likely be located in the existing attic, but a location for the chiller will be needed outside. If located close the building, noise from the chiller might be a problem. If a centralized energy recovery unit is used and located in the attic, ductwork will again need to be run from that unit down to each floor below and into each room. Drop ceilings may need to be added in areas where the only space available to route ductwork is below the existing finished ceiling. These fan coil units do not offer the same capability of simultaneous heating and cooling, since the entire building must either be in heating mode or cooling mode with a 2-pipe system. As discussed previously, this may not be a great concern for this building because there will not be much diversity of heating and cooling requiring simultaneous modes operation. It will be most problematic during certain spring and fall days when there is a need for heat in the morning and cooling in the afternoon. The units would also be located within the rooms, making them a noisier and less aesthetically appealing option to the heat pumps. Finally, and most importantly, this system would cost more than the water source heat pumps. It essentially has all of the same components, except replaces the heat pump units with fan coil units and replaces the cooling tower with an air cooled chiller. Any cost savings achieved in the first exchange would probably be offset by the second. This system would appear to have very little advantage over the water source heat pumps and is therefore not recommended.

3. System Description: Variable Refrigerant Flow with Energy Recovery Ventilator

Relative Cost: $$$ ***Energy Efficiency:*** ***Aesthetic/Acoustic:***

Pros:

- *Energy efficient*
- *Good temperature control*
- *Indoor units can vary by application*
- *Simultaneous heating and cooling*
- *Outdoor units are smaller than cooling tower and can be distributed*

Cons:

- *Expensive*
- *Ductwork needed for outside air*
- *Removal of all steam piping and radiators*
- *Many compressors to maintain*
- *Complex, proprietary control system*
- *Does not utilize new campus steam plant*

Another alternative to the water source heat pump system which is more equal in comparison is a variable refrigerant flow (VRF) heat pump system. These systems are relatively new in the U.S. but have been used for many years in Europe and Asia. They are essentially a heat pump system with a single outdoor unit delivering refrigerant to multiple indoor units as needed to meet their needs for heating or cooling. The compressor is variable speed, allowing it to dynamically adjust to the loads experienced by its connected indoor units. This ability gives it superior part-load performance to conventional air source heat pumps. Its energy efficiency is further improved by the fact that indoor units in heating mode can use the heat rejected by other connected indoor units in cooling mode, and vice versa. Therefore part or all of any heating and cooling loads occurring simultaneously can be met by heat recovery rather than the compressor. Outside air for the building would be handled separately from the heat pumps using an energy recovery ventilator, which would recover heat from building exhaust air to precondition outside air before delivering it directly into the occupied spaces.

Unlike the fan coil units, a VRF system would maintain the ability for parts of the building to be in cooling mode while others are in heating mode. A variety of indoor units are available to meet the unique requirements and/or restrictions of each space, and different types of indoor units can be connected to the same outdoor unit. The energy efficiency of this system would likely be comparable to that of the water source heat pumps. The key advantage of a VRF system over the previous two options is the absence of a large cooling tower or chiller to find a location for. The outdoor units have a similar footprint to typical split system heat pumps and can be distributed around the building. This system has an aesthetic and acoustic advantage over both of the previous systems for this reason.

Like the previous alternatives, this system is relatively expensive. The old steam piping, radiators, and air conditioners would need to first be removed. New refrigerant piping will need to be installed throughout the building. Running refrigerant lines throughout the building typically generates more concern for leaks than hot and chilled water piping. Each of the new indoor and outdoor units will need to be purchased and installed, along with the energy recovery unit. Similar to the previous alternatives, if a centralized energy recovery unit is used and located in the attic, ductwork will need to be run from that unit down to each floor below and into each room. Drop ceilings may need to be added in areas where the only space available to route ductwork is below the existing finished ceiling. This system would also be more involved to maintain, since there is a compressor and more controls in each unit than in centralized systems. The control systems are also very complex and specialized for the installed system, so in-house maintenance or troubleshooting could be problematic. Finally, although this system is relatively energy efficient, it does not take advantage of the new and efficient campus steam plant. This disadvantage should be weighed against the advantages of no longer needing to maintain and control any steam connections in the building.

4. System Description: Steam Radiators and A/C with Energy Recovery Ventilator

Relative Cost: $$ ***Energy Efficiency:***  ***Aesthetic/Acoustic:*** 

Pros:

- *Less expensive than other alternatives*
- *No replacement of piping and radiators*
- *More efficient than current system*
- *Simultaneous heating and cooling*
- *Utilizes new campus steam plant*

Cons:

- *Less energy efficient than other alternatives*
- *Ductwork needed for outside air*
- *Temperature control issues*
- *Steam maintenance*

Another option is to improve upon rather than replace the existing systems. One of the first issues to address is control of the current steam system. The building is currently divided into 3 zones which were set when the Minneapolis-Honeywell control system was installed. These zones may no longer be appropriate for the building's operation, and it is unclear to what degree the original control system is still functioning. This system should be removed, and steam control should be addressed at the building, zone, and individual space levels with a new control system. An intermittent flow control, or heat timer, should be installed at the building level to control the temperature of the entire system. This will allow temperature setback of the entire building during regularly unoccupied periods as well as optimized morning start-up based on outdoor temperature. New zone control valves should be installed, and the building zoning should be reevaluated based on the current use of the facility. This will allow areas with similar schedules and/or heating requirements to be controlled independently. Finally, thermostatic radiator valves (TRVs) should be installed at each radiator to control the temperature of each individual space. These can be self-contained or operated with a remote thermostat. Self-contained TRVs are less expensive but remotely-operated thermostats could allow for programmable temperature control. Some of the radiators already have TRVs installed, so they may not need to be replaced if they are operating properly. Another critical component for proper steam system operation is steam traps. These should be inspected annually, as a malfunctioning steam trap will either cause a reduced radiator capacity or a loss of steam (and therefore energy).

Another issue to address is the current cooling systems. The window air conditioners diminish the aesthetic appeal of this historic building, are noisy for the occupants, create large penetrations in the thermal envelope of the building, and many are old and relatively inefficient. The ductless split systems lack many of the disadvantages of the window units, but some of these systems may also be approaching the end of their useful lives. The best replacement for all of these systems may be new ductless split systems. These are available with high efficiencies and programmable thermostats to allow unoccupied temperature setback. The indoor units can be wall mounted, under ceiling mounted, or ceiling cassettes depending on the needs of each space.

The final issue to address is the lack of outside air being delivered to building occupants, assuming that proper control of the heating and cooling systems would enable the windows to remain closed while these systems are running. Just as with the previous alternatives, outside air would be handled separately using an energy recovery ventilator, which would recover heat from building exhaust air to precondition outside air before delivering it directly into the occupied spaces.

The primary advantage of this option of improving upon the existing systems is its low cost relative to a complete replacement. The steam system would remain largely intact with the addition of new controls, and would utilize the new and efficient central plant. New air conditioning units would need to be installed in each space, but these units would cost significantly less than any of the previously discussed new systems. This option also maintains the ability of simultaneous heating and cooling in different areas of the building, while improving the aesthetics and acoustics. Even with the added energy use of conditioning and delivering the outside air, this system would most likely save energy relative to the current system because the amount of outside air is controlled and the heating and cooling systems will operate with improved efficiency.

Despite an improved efficiency relative to the current system, this option is less efficient than the other alternatives. Each of the new indoor and outdoor air conditioning units will need to be purchased and installed, along with the energy recovery unit. Similar to the previous alternatives, if a centralized energy recovery unit is used and located in the attic, ductwork will need to be run from that unit down to each floor below and into each room. Drop ceilings may need to be added in areas where the only space available to route ductwork is below the existing finished ceiling. The primary disadvantage of this option relative to other alternatives is the need to maintain and control the steam connections throughout the building. Even with the new control system installed, steam traps will still require regular maintenance and replacement, and temperature control problems may still arise.

5. System Description: Steam Control System

Relative Cost: $ ***Energy Efficiency:*** ***Aesthetic/Acoustic:***

Pros:

- *Least expensive alternative*
- *No replacement of piping and radiators*
- *More efficient than current system*
- *Simultaneous heating and cooling*
- *Utilizes new campus steam plant*

Cons:

- *Least efficient alternative*
- *Does not address outside air issues*
- *Does not address cooling issues*
- *Temperature control issues*
- *Steam maintenance*

At a minimum the building's steam control system should be updated, even if this is only seen as a temporary fix until a major system replacement can be completed. The building is currently divided into 3 zones which were set when the Minneapolis-Honeywell control system was installed. These zones may no longer be appropriate for the building's operation, and it is unclear to what degree the original control system is still functioning. This system should be removed, and steam control should be addressed at the building, zone, and individual space levels with a new control system. An intermittent flow control, or heat timer, should be installed at the building level to control the temperature of the entire system. This will allow temperature setback of the entire building during regularly unoccupied periods as well as optimized morning start-up based on outdoor temperature. New zone control valves should be installed, and the building zoning should be reevaluated based on the current use of the facility. This will allow areas with similar schedules and/or heating requirements to be controlled independently. Finally, thermostatic radiator valves (TRVs) should be installed at each radiator to control the temperature of each individual space. These can be self-contained or operated with a remote thermostat. Self-contained TRVs are less expensive but remotely-operated thermostats could allow for programmable temperature control. Some of the radiators already have TRVs installed, so they may not need to be replaced if they are operating properly. Another critical component for proper steam system operation is steam traps. These should be inspected annually, as a malfunctioning steam trap will either cause a reduced radiator capacity or a loss of steam (and therefore energy).

Although this solution does not address many of the issues with the current system, including the lack of outdoor air and problems with the cooling system (inefficiency, aesthetics and acoustics), it does offer a relatively inexpensive means to get the steam system under control which will likely offer a very short payback. This solution will likely reduce or eliminate the current overheating and temperature control problems with the steam system, in addition to allowing temperature setback during unoccupied periods. Offices and classrooms should be maintained at a maximum occupied temperature of 70°F during the heating season, and set back to 55°F during unoccupied periods. This temperature setback alone will save approximately 18.4% of the annual energy used to heat the building. Assuming the Mellor Building uses 50,000 Btu/sf/year for heating, the campus boilers are 85% efficient, and the cost of natural gas is $1.30 per CCF, the annual energy cost savings would be approximately $4,800. Significant additional savings will be achieved due to the improved operating efficiency of the system during occupied hours, since less overheating will occur and less heat will be wasted through the opening of windows to control temperature.

The Lighting System at the Mellor Building

The lighting system at the Mellor building consists of a combination of old and newly replaced or retrofitted fixtures. Old fixtures include troffer, wrap, and strip luminaires with 4-foot T12 fluorescent lamps and magnetic ballasts. Most of these fixtures contain four or even six lamps, often resulting in higher light levels than necessary in the space. About half of these old fixtures have been retrofitted with new T8 lamps and electronic ballasts. There are also a number of fixtures using a variety of incandescent bulbs. Most exit signs contain two incandescent bulbs, although a few have been replaced with LED exit signs.

Although the new lighting utilizes new and relatively efficient lamps, in most areas the lights are controlled rather inefficiently with manual wall switches. The lighting systems which were not upgraded suffer from inefficiency in both of these areas. For these reasons there are significant opportunities to improve the efficiency and effectiveness of your lighting, making it one of the most cost-effective areas of energy conservation available in your facility.

This study assumes all standard 40 Watt fluorescent tubes have been replaced with "energy saver" 34 watt tubes as a result of the National Energy Policy Act. The lighting fixture count was obtained from the lighting retrofit proposal prepared by Global Energy Services. Savings figures were calculated based on $0.0722/kWh, your average cost for electricity between September 2008 and May 2009. Estimated hours of operation are assumed to be 45 hours per week for the majority of spaces, 24/7 for corridors and stairs, and 10 hours per week for storage rooms.

Energy efficient lighting systems will also yield savings in other areas. Longer life lamps will reduce maintenance costs. More efficient lamps operate cooler, resulting in a reduction in air-conditioning costs. These side effects can add significantly to your savings. However, in order to present conservative estimates of savings they have not been included in the calculated savings in this report.

The estimated costs of the lighting retrofits are rough estimates only, and include labor. If installation can be completed by students, the payback of each retrofit will be significantly improved.

The specific recommendations and associated savings contained in this report are to serve as a guide to the potential for implementing energy efficient lighting in your facility. The purpose of this report is to give you an idea of the magnitude of the project. The cost and savings figures are rough estimates based on generalizations about your lighting system. The actual retrofits that are implemented in your facility will vary based upon a more complete lighting study and/or the recommendations of another lighting professional. This report should not be used as a specification for obtaining cost estimates.

All recommendations should maintain recommended quality, lighting levels and uniformity in compliance with IESNA standards.

Summary of Lighting Retrofit Savings and Costs

Total estimated retrofit costs:	**$16,284**
Total annual retrofit savings:	**$5,820**
Estimated payback:	**2.8 years**

Detailed Lighting Recommendations

1. ***Current luminaires:*** Various fixtures with T12 lamps and magnetic ballasts
Recommendation: Retrofit/replace with high performance T8 lamps and electronic ballasts
Estimated Cost: $15,314 ***Annual Savings:*** $4,180 ***Payback:*** 3.7 years

There are approximately 241 remaining fixtures with T12 lamps and magnetic ballasts throughout the building. Of these 53 have six lamps, 143 have four lamps, 15 have two lamps and 30 have one lamp. These remaining T12 fixtures should be retrofitted or replaced if necessary with high performance T8 ("Super T8") lamps and electronic ballasts. Many of the spaces with four- and six-lamp fixtures were over-lit and can likely be reduced to two and four lamps, respectively, and paired with ballasts with an appropriate ballast factor. The one and two lamp fixtures can be retrofitted on a one-to-one basis with low ballast factor electronic ballasts. A single four-tube ballast could be used for every 2 two-lamp fixtures to reduce the number of new ballasts needed. Any retrofits should include a reflector kit to improve the efficiency of the fixture.

2. ***Current luminaires:*** Various fixtures with incandescent lamps
Recommendation: Replace lamps with equivalent compact fluorescent lamps (CFLs)
Estimated Cost: $410 ***Annual Savings:*** $933 ***Payback:*** 0.4 years

There are a total of 82 fixtures with incandescent lamps installed inside and outside the building. These lamps range from 50 to 150 W A-lamps to 65 W PAR-30 reflectors. These should all be replaced with equivalent compact fluorescent lamps (CFLs) unless a different light output is acceptable or required. 50 and 60 W bulbs can be replaced with 13 W CFLs, 100 W bulbs can be replaced with 23 W CFLs, 150 W bulbs can be replaced with 42 W CFLs, and 65 W PAR-30 reflectors can be replaced with 22 W PAR-30 CFLs. Additional savings will be achieved from reduced lamp replacement and associated maintenance costs due to the CFLs lasting approximately 5 times longer than the incandescent lamps.

3. ***Current luminaires:*** Incandescent exit signs
Recommendation: LED exit signs
Estimated Cost: $360 ***Annual Savings:*** $312 ***Payback:*** 1.2 years

The exit signs should be replaced or retrofitted with LED lamps. Energy use will decrease from 50 watts to 3 watts. Since the LED signs are rated for over 10 years this will eliminate the current lamp (every 1 to 2 years) and replacement costs associated with the current signs. Lamp replacement and labor savings have not been included in the annual savings value above.

4. ***Current luminaires:*** Wall-mounted exterior light with 400 W mercury vapor lamp
Recommendation: Replace fixture with 250 W metal halide lamp
Estimated Cost: $200 ***Annual Savings:*** $91 ***Payback:*** 3.8 years

Consider replacing the 400 W mercury vapor wall-mounted exterior fixture with a new fixture which uses a 250 W metal halide lamp. At the very least the lamp should be replaced with a 250 W metal halide lamp. This will reduce the energy consumption by 150 W which is especially significant since this light operates for approximately 12 hours each day. If replacing, the new fixture should have a photocell to automatically turn it off during periods of daylight.

5. ***Current luminaires:*** 1000 W metal halide tower lights hidden by bushes
Recommendation: Disconnect
Estimated Cost: $0 ***Annual Savings:*** $342 ***Payback:*** 0 years

Consider disconnecting the two 1000 W metal halide lights which are meant to illuminate the bell tower but are currently covered by bushes, which is significantly reducing the amount of light that actually reaches the building. If illuminating the tower is necessary, a more effective method would be to mount flood lights directly on the building in order to reduce the required light output, and therefore energy input, of the lamps.

General Notes

In spaces where the lights will be turned on and stay on for extended periods, instant-start ballasts may be used. In spaces that are intermittently occupied and the lights will cycle frequently, rapid-start ballasts are recommended to extend the lamp life; these ballasts should also be used in spaces with occupancy sensor or other lighting controls.

When purchasing new fluorescent lamps, an important factor to consider is color quality. Color Rendering Index (CRI) is a measure of the quality of color light ranging from 0 (monochromatic) to 100 (full spectrum). A light source with a higher CRI improves the appearance of people and objects in a space compared to a light source with a lower CRI. Using lamps with a higher CRI actually allows lighting levels (and therefore lighting energy) to be reduced while still providing the same light quality for visual tasks as a higher lighting level and a lower CRI. For this reason we recommend purchasing 85 CRI fluorescent lamps rather than the standard 75 CRI lamps for these retrofits and the replacement lamps to be used thereafter.

The recommendations for fluorescent lamps also specified high performance T8s, or "Super" T8s. These all have a higher CRI than standard T8s, in addition to higher initial lumens (3,100+), higher lumen maintenance (>90%), and extended lamp life. The higher light output of these lamps allows them to be paired with lower ballast factor electronic ballasts than standard T8s while producing equivalent luminance levels. This reduces the energy consumption by about 5 W per lamp. Although these lamps cost more than standard T8s, the energy savings achieved will pay for the cost difference 4-5 times over the life of the lamp. Additional lamp replacement and maintenance costs will be realized through their extended life.

Lighting Controls – *Motion Sensors*

Motion sensors detect when an area is occupied. Most sensors are also equipped with a sensitivity adjustment. Sensors can be mounted on the wall (replacing a wall switch), or on the ceiling to cover a larger area. When the area is vacated the lights turn off after an adjustable time delay. These controls are most valuable in spaces where the lights may be left on, either intentionally or by mistake, for any significant amount of time without any occupants in the space. In spaces such as offices which are occupied on a consistent basis, motion sensors might not make sense as long as the occupants always turn the lights off when they leave for the day. However, there are many spaces throughout your facility which are likely to be occupied infrequently or intermittently, creating the potential for significant savings by automatically turning the lights off. These include classrooms, restrooms, mechanical and storage rooms, and corridors.

Domestic Water Heating Recommendations

Install low-flow aerators

Most of the lavatory faucets throughout the building had flow rates of 2.2 gallons per minute (gpm). Others had no aerators so their flow rate could not be determined. All of these faucets should be retrofitted with low-flow aerators to reduce their flow rate to 0.5 gpm. This will reduce water consumption by 77%, which in turn saves hot water and the energy needed to heat it. The aerators cost between $5 and $10 and will have a very short payback when the cost savings of water and energy are considered.

Envelope Recommendations

The attic in the facility is nominally insulated with fiberglass batt insulation of various thicknesses. Many areas of the attic floor are un-insulated and numerous bypasses are present. When the building was originally designed the "cooling" system was comprised of a

series of ventilation shafts tied to ductwork in the attic. The system worked via natural convection with hot air rising up through the building and being ventilated through vents in the roof and gable ends of the building.

The existing walls do not appear to be insulated. *To evaluate the need for and opportunities to reduce air infiltration and improve insulation values an envelope analysis should be performed including an infrared scan of the facility.* This evaluation should be able to assess the opportunities for improving the performance of the exterior envelope.

The existing windows consist of single pane clear glass along encased in double-hung wood frames. The windows are original to the facility and are in need of repair in many cases.

Many of the exterior doors do not seal well and are therefore leaky. Make sure weather-stripping is installed on all exterior doors and that it is in good condition. Small cracks add up and can have a large impact on heating and cooling energy.

The greatest potential for energy savings related to envelope improvements is likely in air sealing and better insulating the building's attic.

Detailed Envelope Recommendations

Air Seal and Reinsulated the Attic

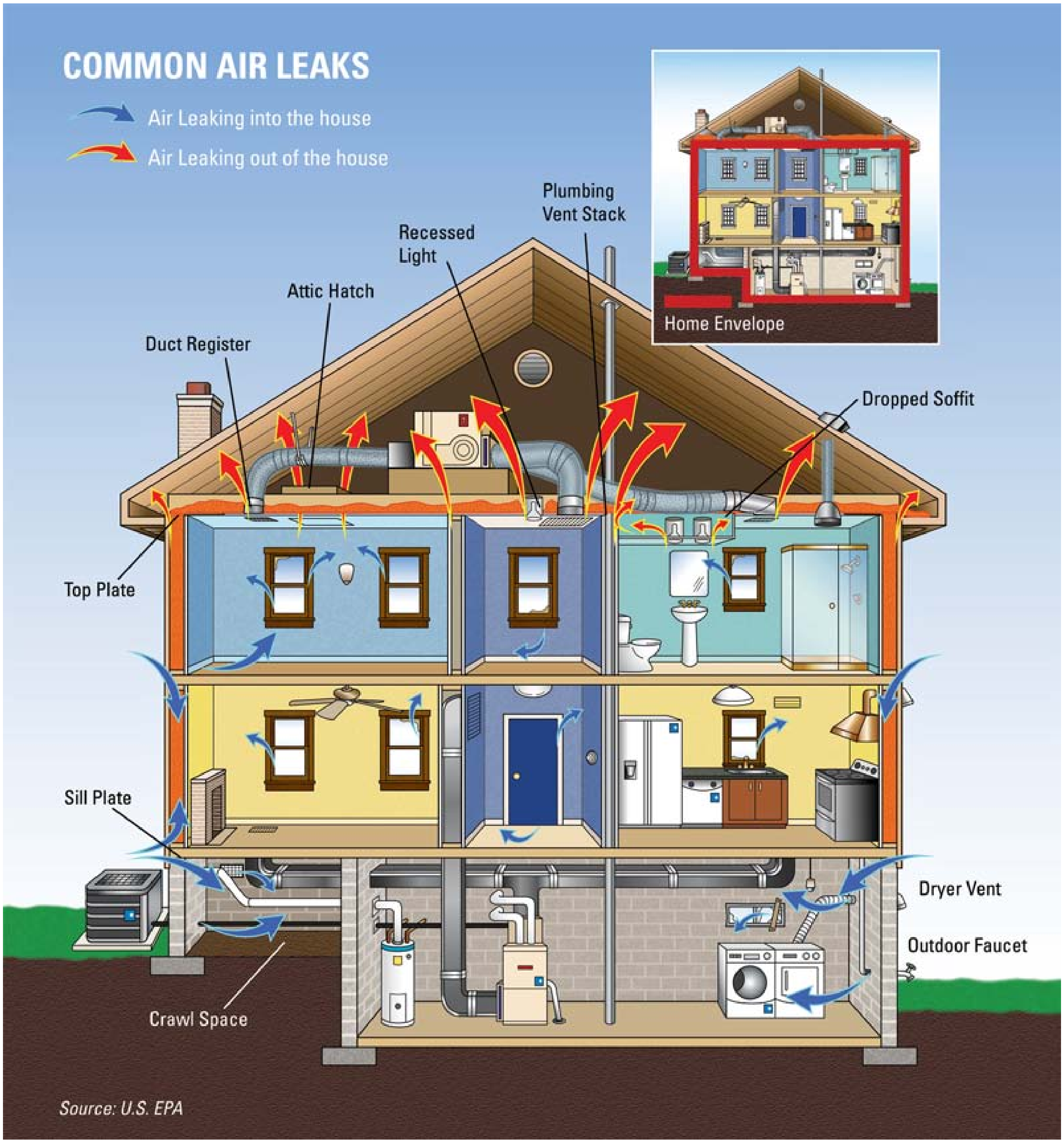
Initial Cost:	To be determined by contractor
Annual Energy Savings:	Difficult to estimate given the large areas in need of air sealing and the uneven level of the current insulation; savings should be substantial
Simple Payback:	should be less than 3 years

The remnants of the old ventilation system in the building are drawing conditioned air from the building to a significant degree. Registers on interior walls in rooms throughout the facility are connected to ventilation shafts which are open to the attic. These shafts pull air to the attic with the chimney effect and are a major source of heat loss in the facility. Numerous other bypasses were noted around electrical and plumbing penetrations, chimneys (see below) and drop ceiling areas.

A contractor with a specialty in air sealing, not just insulation, should be hired to air seal all areas first. Once the air sealing has been completed the entire attic should be insulated with blown insulation to a minimum total R-value of 38. This additional insulation can be installed directly over the existing fiberglass batts.

Recommended local contractors:

Zerodraft of Pennsylvania - http://www.zerodraftpa.com/index2.html - Laurie Johnson, 717-241-4201
Comfort Home - http://www.comforthome.com/ - Ed Carr, 800-367-7223
Weaver Weatherization – John Gehman, 717-866-1665 or cell is 717-821-6873



Install Storm Windows

Initial Cost:	Overall to be determined by contractor, typical - \$7.00 - \$8.00/sf
Annual Energy Savings:	\$1.50 to \$2.00 per sf
Simple Payback:	7 to 9 years

The single pane windows should be fitted with exterior glass storm windows. Consider using low-e glass, especially on the south and west orientations.

Repair Leaking Windows

Loose and leaking windows should be re-hung and repaired as needed for a tighter fit where applicable.

Window Air Conditioners

Either remove the window air conditioners during the heating season or cover them to reduce air infiltration. The installation of some of the window air conditioners is somewhat permanent, while some have been placed in the window with little regard to infiltration and heat loss through or around the unit. Covers should be applied seasonally to prevent air flow through the unit.

Plug Load Recommendations

In addition to the direct energy use associated with the variety of plug loads in the facility, they can add significantly to the building's cooling load. Every 3 to 4 watts of internal load requires 1 watt of cooling to address it. When considering the replacement of the HVAC system every effort should be made to reduce the tonnage of air conditioning required. This will enable a downsizing of the HVAC equipment which can reduce first cost.

Purchasing New Equipment

When purchasing new equipment such as computers, printers, copiers, refrigerators, kitchen equipment, etc. be sure to purchase Energy Star rated equipment - http://www.energystar.gov/
County purchasing policy should require the selection of Energy Star equipment for all facilities.

Computer Monitors

Where possible consider replacing the CRT monitors with LCD monitors. The annual energy savings per monitor is approximately $34 (426 kWh). At a price differential of $78 to simple payback is 2.3 years.

Computer Operations

During our visit it was observed that the printers in the computer lab were on when the space was unoccupied. All computer equipment should be turned off when not in use with the exception of servers which must be accessed remotely. Power management software can be installed to maximize energy savings. For more information -
http://www.energystar.gov/index.cfm?c=power_mgt.pr_power_management

Vending Equipment

Install VendingMiser on your beverage vending machines -
http://www.usatech.com/energy_management/energy_vm.php
The cost is approximately $200 per machine and the payback is generally under two years. Also consider disconnecting any unnecessary lighting within the vending machines.

Personal Equipment

Stevens should consider a policy of prohibiting the use of personal electrical consuming equipment such as space heaters, fans, coffee makers, refrigerator, microwave, etc. within an individual's office or cubicle. The cost to operate a single electric space heater is approximately $50/year.

Conclusion

Thank you for the opportunity to assist you in reducing your energy costs. The recommendations above should serve as a guide when implementing energy saving retrofits at the Mellor Building. Energy Opportunities is available to assist you in implementing all or any of these recommendations. We would be happy to recommend contractors, review proposals, and assist you in overseeing the work necessary to reduce your energy costs. We will be in contact with you in the near future to discuss our findings. If you have any questions or comments, please do not hesitate to contact us.