Improving the Energy Efficiency of Fero House
Home of Alpha Delta Phi

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Overview

As our country continues to grow and prosper we are faced with a growing number of environmental issues. While many of these issues were ignored in the pursuit of economic growth, we are now facing the harsh realities of our unmitigated expansion. The continual mining and use of fossil fuels has scarred our landscapes, polluted our air, and contaminated our waterways. Our nation's greenhouse gas emissions are higher than ever and contributing heavily to global warming. With the United States' population constantly on the rise and projected to hit 350 million in little over a decade[1], it appears that our situation will only get worse unless some major changes are carried out.

Unfortunately, change rarely comes when it is not profitable. Both companies and consumers are driven by profits. This is not necessarily a bad thing. Such a mentality has helped sculpt the United States into the most prosperous country in the world. If we did not continually aim to grow and develop we would not have many of the luxuries we have today in western civilization. While this has lead to massive amounts of environmental degradation in the past and to this day, we are now seeing a switch in mentality due to a switch in economics. People are beginning to understand the benefits of efficiency as well as conservation because it saves them money. The latest recession, while highly detrimental to our economy and our citizens, has further illustrated the value of conservation as people are becoming more conscious of their actions such as the food they purchase or the miles they drive.[2]

Increasing the efficiency of our everyday appliances and electronics does a great deal to save energy. Everyday more and more products are being labeled Energy Star, meaning they generally use 20-30% less energy than required by federal standards.[3] These standards for energy efficiency did not come into existence in the United States until the early 1990s but have since been adopted by other countries such as Canada, Australia, and Japan. While Energy Star products typically cost more than their competition, they tend to be cheaper in the long run due to lower rates of energy consumption. The recent rise in energy prices only makes Energy Star products more economically viable in the marketplace.

Besides increasing the efficiency of everyday devices, companies and families are beginning to realize both the economic and environmental benefits of increasing efficiency in their buildings. In 2009, residential buildings accounted for 22% of our nation's total energy consumption while commercial buildings accounted for 19%.[4] Buildings not only require an immense amount of energy and material to build, but after they are built require a constant input of energy in the form of heat and electricity. Using these inputs more efficiently has the potential to save billions of BTUs and thousands of megawatt hours which in turn would significantly curb the amount of greenhouse gases put into our atmosphere.

Our nation has not had much experience with creating efficient housing. In the 1950's after WWII there was a brief call for "solar homes" in the United States to help accommodate the soldiers returning home. These houses utilized south facing windows and tight framework in order to keep power consumption low, an idea sparked by the conserving attitude our nation adopted on the home front during the war. Unfortunately during this time electricity prices were ridiculously cheap and the "solar home" movement quickly died. In their place came large, inefficient houses that consumed much more heat and power. As electricity and heating prices are now rising, we see a call for such energy-efficient houses that were once regarded as unnecessary decades ago. "Solar homes" are a prime example of how the economy drives our development.

Fero House

In 1999, Alpha Delta Phi reached an agreement with Union College to sell our original chapter house to the school for use as offices. What is now known as the Admissions Building belonged to Alpha Delta Phi for over a century.[5] Now our fraternity resides in Fero House on the other side of campus, a three story building that has seen numerous renovations during its existence, yet still remains a major energy consumer on campus. This is due not only to the building's construction, but also the way its internal systems function and the way its residents choose to live.

Union College students living on campus do not incur electrical or heating charges where they live so they have little incentive to try to save energy. This also causes students to push such ideas as conservation to the backs of their minds because it is not something they readily think about every day. When looking at Fero House, we exercise neither conservation nor energy efficient products. We are a mixed group of individuals who collectively consume to our heart's content. Lights, televisions, and computers are left on throughout the day. Showers are left to run until the water is deemed hot enough. Heaters are cranked up in the winter time and air conditioners are cranked down in the summer. While much of the inefficiency of our house stems from the brothers themselves, it is not helped by our house's construction. Our front doors are old and leaky, as are many of our windows. The heating system is sporadic in that it is either on full blast or not at all. Our toilets constantly run, flood, and just flat out stop working. The house is also built to minimize the spread of a fire, so the amount of fresh-air is kept to a minimum, especially in the winter months. In turn, many residents open their windows to allow fresh air in, resulting in more strain on our heating system. This all leads to a less comfortable living environment and a much higher energy consuming building.

While Fero House is presently a picture of inefficiency, there exist large amounts of improvements that can be made. This report will illustrate not only how to make Fero House more "green" by increasing efficiency and environmental consciousness, but also show how it makes sense economically, as so many decisions in our lives are driven by money. After seeing how it is possible to make a fraternity house "green," you will see how it is possible to make nearly any building more efficient and environmentally friendly in order to help contribute to a sustainable society for our generation and future generations to come so that they may enjoy the same quality of life than we enjoy today.

Some of the conclusions I have made regarding house improvements were done with the assistance of eQuest, a free computer program that analyzes a building's energy use.[6] This program has recently been deemed qualified software for calculating commercial building tax deductions that were first enacted under the Energy Policy Act of 2005. eQuest has also been approved by the California Energy Commission as 2008 Title 24 non-residential ACMs. With this software, a model of Fero House was created using specifications exact as possible provided through my own observations and records from Facilities at Union College.

Systems

A house requires numerous systems to create a proper living environment. As humans we've become accustomed to certain atmospheric conditions in order to be comfortable. Making sure these systems work properly not only helps ensure efficiency but also creates a more enjoyable living space. Perhaps most importantly, different systems can affect one another. Heat from electronics can reduce heating demands while less water use can reduce the amount of natural gas needed to heat hot water and also save electricity from less pumping. Making these systems work in harmony, or at least with each other, creates a house that works much more efficiently.

Heating, ventilation, and air-conditioning are systems that work together in order to provide a comfortable environment for a building's inhabitants. The rise of air-conditioning has made it able for our society to expand to areas like Arizona and Florida while advances in heating technology allow people to live comfortably in areas such as northern New York. An HVAC system works best when it is designed for a specific climate.

Fero House at Union College is located in Schenectady, NY. Fairly far north in comparison to the rest of the nation, the climate is cold and as such our house requires only heating during the winter months. In fact, there is no option for cooling during the warmer months because there is no air-conditioning installed in the house. The strain of heating this large, three-story house, falls mainly on an old single-pipe steam heating system. While still functioning, the heating system's age shows through its inconsistency and lack of heating zones.

The strain on Fero House's aging heating system is only worsened by the windows and doors currently installed at Fero House, which provide a less than tight envelope. Many are leaky, allowing numerous areas for drafts and thermal bridging, especially on the first floor. Fero House also has insufficient insulation for the cold climate it resides in, so even in areas where the envelope is tight, it is also quite thin.

The inconsistent heating system and loose envelope has also put more strain on our electrical system in the form of space heaters and personal air-conditioners. These appliances use an enormous amount of electricity. Fero House already uses a large amount of electricity from lighting and other electronic devices. In turn, improvement of our heating system could also lower our electrical use.

Electricity demand in the United States continues to grow every year. This is not only a consequence of an ever increasing population, but of new technologies such as smart phones and high-definition televisions that use an increasing amount of power. This is a problem when you consider that about 45% of our electricity comes from coal, the dirtiest fossil fuel on the planet.[7] Luckily, there is also an increasing amount of Energy Star products on the market that are aiming to reduce electricity use. These product, coupled with smart energy use by consumers can reduce a houses electric consumption by hundreds of kilowatt hours, saving both money and greenhouse gas emissions.

When it comes to conserving energy, plumbing is usually one of the last systems considered. Efficient plumbing can save thousands of gallons of water, as well as reduce natural gas consumption and electricity usage. Fero House's plumbing system works fairly well when compared to the house's other systems, although there have been issues of flooding in the past. Most hot water is used by the showers which have low-flow showerheads installed to conserve water. Wastewater use is fairly high considering all toilets flush with a standard 1.6 gallons per flush, regardless of waste type. Also, the distant between the hot water boiler and the faucets is quite far, resulting in a rather large lag time between cold and hot water.

Indoor air quality, although not directly related to energy-efficiency, greatly impacts the comfort level of the house's living environment. This can subsequently lead to windows and doors propped open for fresh air, which puts more strain on the heating system during the colder months.

Being a fraternity house, the air quality in Fero House is quite bad. Our carpets and furniture have accumulated a large amount of dusts and molds over the years of abuse they've been subjected to. There is always some kind of noticeable odor in Fero House and it is a common occurrence to see a mouse scurry across the floor. This is due in part to the low ventilation design of the house but mostly by the lifestyle our residents live.

When Fero House was built, they most likely did not consider the interconnectedness of the house's different systems. With certain changes however, these systems will not only work more efficiently, but also more in harmony with one another. This will save energy, money, and provide a more comfortable living environment for those who inhabit Fero House now and in the future.

Envelope

Fero House's framework is less than tight. There are numerous trouble spots around the house where cold drafts can be felt, signifying thermal bridging between the interior environment and the conditions outside. This is most evident around the first floor doors, two of which are metal, hollow-core doors and another two of which are solid wood doors. The doors themselves are not terrible, but the seal they provide is.

A similar problem can be observed around the south-facing casement style windows in the dining room. Being double-paned, they provide a good insulating value, but the seals they create to the outside weather have become poor over years of wear. This is also the case with some of the double-hung windows found in the rest of Fero House.

The attic is insulated, but very poorly so, resulting in bare patches on the attic floor with no insulation, providing a much easier means for the cold attic air to enter the conditioned house.

Fero House's foundation is composed of concrete and brick approximately 18 inches thick. While the foundation is still fairly solid after all these years, there is a vent installed in the boiler room that lets air from outside flow freely into the basement. There is also a wooden basement door which allows outside air in all around its frame.

Tightening up a house's envelope can save drastically on heating loads and with the recent spikes in heating prices, save a lot of money as well.

<u>Exterior Doors</u>

Entering the front of Fero House you will notice an old wooden double door (Figure 1). Being constructed of solid wood it only offers an estimated R-value of 3.03, a dismal value when compared to a metal door with insulation or an EnergyStar fiberglass door.[8] While beautiful in its own craftsmanship this door has been through years of abuse and its flimsy construction is quite noticeable. This has lead to a less than tight seal around the door, with noticeable drafts at the base of the doors and where the two doors meet. These gaps allow cold air to rush in from the outside, lowering the doors already small insulating value even further. While replacing this weathered wooden door with an EnergyStar fiberglass door would be ideal, it would also cost over a thousand dollars before the cost of installation, which, given the doors unique dimensions, would be quite costly as well.[9]

Figure 1. Front entry doors to Fero House.

Fortunately, this wooden entry door does not lead directly into Fero House, but instead into a small entryway. This entryway is enclosed by a hollow metal door which creates a nice buffer between the outside and inside temperatures (Figure 2).

Figure 2. Metal door leading to the front entryway of Fero House.

Unfortunately, this metal door does not have a tight seal either, with a noticeable gap between the bottom of the door and the floor. This allows a large amount of cold air to enter the house and essentially takes away the benefits of the entryway (Figure 3).

Figure 3. The base of the metal entryway door. A large gap is present between the floor and the base of the door.

The same problem is evident on the entry way doors along the western face of the house. These hollow metal doors also have a gap between the floor and the door base, allowing cold air to rush into the house directly (Figure 4).

Figure 4. The door gap on the left allows cold air to seep directly into the dining room. The door gap on the right allows cold air to flow directly into the kitchen.

These cracks not only allow large amounts of cold air in, which wastes money on heating, but also drastically reduce the comfortable living conditions of these two rooms. While the dining room is often more bearable because it is connected to other heated areas, the kitchen is cut off from the rest of the house by two doors. This makes it near impossible to cook comfortably in the kitchen during the winter time and has helped create other problems such as the frozen pipes we experienced last winter.

In a typical American home, 30% of a house's energy dollars is lost through its doors and windows.[10] This is a highly evident problem in Fero House to which there are a couple solutions. For one, you could replace each door with a more efficient one and have it professionally installed to ensure a tight seal. This would end up costing a few thousand dollars in materials and labor but would minimize loses around the doors. Alternatively, we could try and improve the current doors that are installed. There are products on the market known as draft guards which help create an air tight seal between the door and its frame. As seen on TV, the Twin Draft Guards are easy to use, can be fitted to any door, and most of all, they are cheap.[11] For only forty dollars plus shipping and handling, these draft guards could be applied to every door on the first floor and drastically reduce energy losses. In the spring time they will serve the same purpose, except they'll help keep the warm air out of our non-air-conditioned house. This appears to be the best solution to increase the efficiency of Fero House's doors without spending a large sum of money.

According to the U.S. Department of Energy, excess air leakage in homes can increase heating and cooling bills by 30%.[12] Looking at Table 2 in the **Appendix** section, in the primary heating months from September to March, Fero House consumed 4016 therms of natural gas costing $4,628. If gas consumption is reduced by just 5% by these draft guards, a very modest estimation, it will save $231.40 on the heating bill over this seven month span. This will more than easily cover the cost of the draft guards, resulting in a payback period of just over one month of cold weather.

There is also a basement door which presents a more difficult problem than the first floor doors because a draft can be felt around all the edges of the door (Figure 5).

Figure 5. The picture on the left shows the basement door connected to the boiler room. The picture on the right shows that same door opened, revealing the metal access door which has allowed snow to seep in.

With this door a draft guard will only cover part of the problem and replacing the door will again be quite costly. This door is never used in the winter and only occasionally opened in the fall and spring terms. Considering the low frequency with which this door is used, a sealing tape would be an effective means of preventing drafts around the door in the winter and it can easily be removed if the door needs to be used in the warmer months. A 30ft roll of interior weather sealing tape only costs $4.06,[13] which is enough length to cover the entire frame of the door. Using the same assumptions used for the first floor doors, this tape will easily pay for itself in under a month's time.

Windows

Another area with a large potential for energy losses is windows. While windows provide us with much needed natural light and cool breezes when opened, they are also inherently less insulating than walls or doors.

Immediately noticeable in the first floor dining area of Fero House is a large amount of tall, south-facing windows (Figure 6).

Figure 6. Eight casement-style south facing windows in the dining room of Fero House.

While they do allow a nice area for sun to enter the room, the curtains on these windows are often left closed. Also, the entire south side of Fero house is about 30ft from Union's prestigious Jackson's Gardens, which has very tall trees that block much of the solar radiation. In the spring months the trees' leaves help keep the house cool, when the leaves fall off in autumn, the sun is allowed to heat up this space. Little can be done to maximize this solar exposure besides keeping the curtains open during the day and closing them at night more consistently. Increasing the amount of passive solar energy can greatly help reduce heating loads necessary to keep the house comfortable.

These windows are double-paned and open via a casement style crank that works along the vertical axis of the window. In the winter months these windows let in a noticeable draft, not because the windows themselves are low quality, but because over the years of abuse the frame area between the windows and the walls has become cracked and broken (Figure 7).


Figure 7. Defects along the frames of the south-facing windows in Fero House.

The areas around the cranks of the windows let in a noticeable draft when you put your hand up to them. Also, the cracks in the frames around the windows serve to let cold air seep in. While we could replace these windows with eight double low-e windows with a much higher solar heat gain, it would cost nearly $3,000 plus the cost of installation.[14] It appears to make much more economic sense to invest in fixing the areas around these windows than completely replacing them.

Even with such efficient windows the energy savings would be minimal according to eQuest. This is due in part to the fact that eQuest assumes the original windows are properly installed and sealed, not leaky and somewhat broken like they are currently. If the program were able to take this into account we would see a much higher savings in gas consumption. Unfortunately, eQuest was not very helpful in making a proper analysis on the savings of these new windows. The windows we have now are fine, it is just the frames that are of main concern. Therefore, repairing these windows appears to be the best course of action.

At the cranks themselves is where much of the thermal bridging occurs. Many cranks have been replaced and do not fit correctly, leading to gaps, and one crank is completely absent. Purchasing a new split arm operator for the one window would cost about $31.85[15] along with another $20 for two needed crank handles.[16] After installation, caulking of major cracks and gaps around the windows would help create a much tighter seal than found currently. Considering a 10.1oz tube of caulk is only $3.98,[17] this alternative is much cheaper than replacing all the windows.

This is a common dilemma found when trying to renovate a house. When making changes you have to work within the existing framework of the house unless you want your changes to be very expensive. In the case of Fero House, it makes sense to try and fix-up these windows rather than buy all new ones not only because of the cost, but because of the destructive environment which these windows are subjected to. Windows are constantly broken in fraternity houses, I heard of one being broken in Sigma Chi just this past weekend. Sealing up these windows is efficient, low cost, low risk, and could result in high energy savings, especially considering that the hot water baseboards in the dining room run right underneath these windows.

The rest of the windows in the house are double-paned, double-hung windows. They are all the same style, with larger ones on the first and second floors and smaller ones found on the third floor. Most of these windows are fine and do their job well, but a couple have grown leaky and imbalanced after years of use (Figure 8).

Figure 8. The window on the left has cracks in its frame, allowing cold air to seep in. The window on the right fails to close completely, creating a noticeable gap through which air can flow.

Aside from a couple minor defects these windows work fine, but these little problems can add up to big losses. Replacing the windows themselves initially appears unnecessary, as it is the frames that are primarily the problem. However, these windows are old, from the late 1980's, and parts for these windows are pretty much impossible to find since they are an obsolete version. Also, repairing the frames would require patchwork and still would not provide the greatest seal. An in-home consultation from a local Mr. Handyman employee said the best course of action to take with these two windows would be to replace them completely. Each window would cost about $400 including the cost of installation and come with a lifetime guarantee, something crucial for a fraternity house. Although somewhat costly, these new windows will provide an air-tight seal while will cut down drastically on thermal bridging and make for much more comfortable living spaces.

Skylights

The skylights in Fero House are one of the few aspects of Fero House that work superbly. They all operate correctly, provide a good seal, and allow nice natural lighting during the day time. Replacing any of them with a double-paned, Low-e coating alternative skylight would cost $547 before installation costs.[18] The energy saving benefits of these skylights would be minimal when compared to their price. Overall the current skylights are fine and should only be replaced if broken.

Walls

Unfortunately, Facilities at Union College were unable to provide me with an answer on exactly what Fero House's walls are composed of. From what could be deduced based on external and internal observations, as well as old renovation notes, the walls of Fero House are primarily built of concrete blocks and/or brick (Figure 9).

Figure 9. A hole made in one of the external walls on the 2nd floor of Fero House during a party. It has since been fixed.

From Figure 9 you can see there is no additional insulation to be found in this part of the wall. Based on the 1992 renovation blueprints of Fero House, 6 inches of insulation was added to the walls on the third floor, but no insulation was recorded as being added to the second floor. I can only assume that most of the external walls of Fero House are composed of stucco, concrete/brick, framing, and drywall, resulting in a relatively low R-value for the climate we live in. Once a building is constructed, little can be done to alter the insulation in the walls without extremely expensive renovations.

Using eQuest, the current second floor walls were compared to better insulated walls showing little savings in terms of gas consumption. However, eQuest also showed yielded some inconsistent results with this comparison, making it unhelpful with this analysis. Given the high cost of blow-in insulation it is not recommended unless a larger project is taken on that involves opening the walls also (i.e. installing new piping, see Boilers in the **HVAC** section). The most immediately cost effective and efficient option is thus to fix damaged areas as best as possible and live with the under-insulated walls we have.

In the basement there are noticeable damaged places that are allowing for large amounts of thermal bridging. Figure 10 shows such a place.

Figure 10. A large hole in the wall of the basement of Fero House.

This hole only seems to be a problem for aesthetic and structural reasons, but as you can see in Figure 11, it also creates a major thermal bridge between the unconditioned basement and the rest of the house.

Figure 11. A hole in the basement wall of Fero House. The picture on the left shows a limp piece of paper. The picture on the right shows that same piece of paper being straightened out by an upward draft from the basement when it is placed inside the hole.

This gap in the wall can be quite costly in energy loses as it is potentially opening the heating envelope of the rest of the house to the unconditioned basement. It could not be deduced exactly where this hole leads to, regardless it is a problem. This hole can easily be fixed with the installation of new drywall, a relatively cheap solution considering an 8' by 4' piece of ½ inch drywall is only $9.24.[19]

A similar hole can be found in the same basement room in Fero House (Figure 12).

Figure 12. A large hole in the basement of Fero House.

This hole in the wall also creates a draft between the unconditioned basement and other areas of the house. Again, it could not be deduced where exactly this hole in the wall leads to, only that it could create thermal bridging between other conditioned areas of the house. Another 8' by 4' piece of ½ inch drywall would effectively cover this hole and stop this draft.

It is unclear just how much energy could be saved by covering up these holes. Considering two pieces of drywall will cost less than $20, this seems like a worthy renovation to stop two large sources of thermal bridging with unknown destinations.

Attic & Roof

The current third floor of Fero House used to be considered an attic according to the house's 1992 blueprints. These renovation blueprints also state that nine inches of fiberglass insulation with a radiant barrier was added to the actual attic floor. Upon inspecting the attic floor, I found this insulation to be less than well-installed (Figure 13).

Figure 13. Insulation on the attic floor of Fero House.

On many areas of the attic floor there is no insulation present. This makes for many gaps where thermal bridging can occur between the attic air and the floors below. In the areas where there is insulation, it is often scrunched or folded, completely altering the effectiveness of the insulation. The insulation was most likely moved in this way to make room for new communication and electricity lines, which can be observed in Figure 13. However, these lines can still be present with properly installed insulation, in the case of Fero House this was just sloppy work. This illustrates how future renovations need to be properly installed and supervised so they do not undo previous improvements.

Most of this insulation is still very useful, it just needs to be arranged properly. Still, there does not appear to be enough insulation to currently cover the entire attic floor. To cover the bare spots I recommend using R-38 attic insulation with a vapor retarder that is thirteen inches thick. According to the Department of Energy, for our climate zone we should install R-49 insulation on our attic floor,[20] but I have been unable to find any local stores that sells insulation with a value higher than R-38. However, R-38 is a much higher R-value than the insulation found currently in the attic and will definitely benefit the heating envelope in such a cold climate. At $67.05 per roll (64 ft^2)[21] it is not exactly cheap, but should drastically reduce heating loads as well as help the third floor from being so cold during the winter months. About three rolls or $201.15 worth of this insulation are necessary to create a continuous layer of insulation on the attic floor.

Fixing this insulation will also provide the opportunity to fix the vents leading from the bathrooms below, a problem described later in the **Air Quality** section.

As for the roof, the boards are structurally sound and there are no apparent leaks from the outside. Insulating the entire underside of the roof would be quite an investment of time and money. It appears best to just fix the insulation on the attic floor, ensuring complete coverage with no thermal bridging. If this does not seem sufficient the roof can be insulated at a later date. I would recommend slag wool, cotton, or cellulose insulation as they are high in recycled content while still providing a high R-value per thickness.[22] However, proper insulation on the attic floor should be sufficient.

Foundation

The 18 inch concrete foundation in Fero House has withstood the test of time very well. There are no apparent leaks to the outside in the foundation itself and no signs of flooding that are typically seen in older basements. There is however an opening installed in the boiler room which allows a large amount of outside air to flow directly into the basement (Figure 14).

Figure 14. A vent in the basement which allows air to flow in from outside.

This opening was installed for some purpose, most likely to ventilate the basement in order to allow the main boiler to function. Since the steam boiler relies on natural draft, this constant influx of outside air is necessary for it to function properly. More modern heating systems utilize forced draft via fans and ductwork, making the need for influxes of outside air unnecessary. This makes forced draft systems much more economical due to the lack of such large amounts of thermal bridging.

If this vent is not needed for natural draft or if a new system is installed that utilizes forced draft, this vent should be plugged up. With dimensions of approximately 8 inches high, 18 inches wide, and 18 inches thick, this is a fairly large gap in the foundation. Four solid concrete blocks would fill most of this area for just $5.36.[23] The remaining gaps could easily be filled with an insulating foam sealant for just $3.88,[24] turning this unnecessary thermal gap into a well insulated block for just under $10. Considering the amount of cold air this vent lets in currently, this renovation should pay for itself very quickly.

HVAC

According to Energy Star, Fero House falls into the Northern climate zone of the United States, an area in which most of the energy consumed is for heating.[25]

Boilers

There are two different boilers used to heat Fero House. The primary boiler is a single-pipe steam boiler that runs on natural gas. This boiler was manufactured by Weil McLain and produces about 300,000 BTUs of heat. Fero House relies on this single boiler to heat most of the first floor as well as the second and third floors. Being a rather old heating system, there are no heating controls for this boiler on the second and third floors, only a single thermostat on the first floor. This makes it difficult to provide proper heating levels on the upper floors as heating demand is based on the temperature of the first floor, which is often cold due to the draftiness of its doors and windows.

In a single-pipe steam heating system, each heating unit or radiator is connected to the boiler through a single pipe connection. With this pipe, the heating unit receives steam and also releases condensate at the same time. All the heating units and the end of the supply main are sufficiently above the boiler water line so that condensate flows back to the boiler via gravity.[26] This explains why there is no heating in the basement because with the single-pipe steam system the condensate could not use gravity to re-enter the boiler. Such a system requires no pumps or fans, making it very easy to maintain and long-lasting.[27] Unfortunately, you cannot separate a single-pipe system into different heating zones, something more modern systems can easily accommodate. Over time, single-pipe steam systems have died out in favor of more efficient and easier to install forced air systems which are in most homes today. However, there still exist ways to improve the efficiency of a single-pipe steam system, but it means changing the system altogether.

One potential means of improving efficiency would be to create a two-pipe system. A two-pipe system has a separate return pipe for the condensate (steam system) or water (hot water system). In a hot water system pumps are utilized, making the need for natural draft unnecessary. A two-pipe hot water heating system is one of the most common systems found in homes today and is much more efficient than older steam systems.

Converting this single-pipe steam system to a two-pipe hot water heating system would require the installation of a second set of piping throughout the house. This would be quite an expensive process, especially with the number of radiators present on the three different floors of Fero House. For this reason, it is generally more cost-effective to convert a two-pipe steam-distribution system than a single-pipe system. Converting a single-pipe system to a two-pipe system can reduce heating costs by approximately 13 to 27 percent. [28] Furthermore, replacing steam boilers with hot water boilers can reduce heating costs approximately 16 to 39 percent because it takes much less energy to heat up water than it does to convert it to steam.

Given the unknown costs of adding new piping, replacing the old piping, and potentially replacing the current boiler, converting Fero House's single-pipe steam system has many unknown costs when compared to its potential benefits. Converting this heating system is however a very viable option, especially when considering the ever increasing fuel prices in this country. Further research is necessary to determine if these large renovations costs are warranted.

The second boiler is a domestic hot water boiler manufactured by Burnham that produces about 96,000 BTUs of heat. Utilizing natural gas and an 80 gallon storage tank, this boiler provides hot water for the whole house as well as heating for the dining room. Three separate pumps are used to transport hot water to the three separate floors, all of which are located on the boiler in the basement.

The hot water boiler efficiency could easily be improved through more pipe insulation. The pipes closest to the boilers themselves are left exposed which can result in unnecessary heat loses (Figure 15).

Figure 15. Un-insulated piping coming from the hot water boiler.

Approximately 40 feet of ¾ inch pipe insulation is needed to cover the exposed piping seen in Figure P. This should cut down on heat loses, especially considering the basement is unconditioned. 42 feet of insulation will cost only $8.26[29] and should be very easy to install. The payback period of this insulation is unknown, but given its low cost and potential benefits it should be fairly short.

Kitchen Vent

The hood above the stove in Fero House is meant to suck out the smoke and steam caused by cooking so the fire alarm does not go off (Figure 16).

Figure 16. Hood vent above the stove in the kitchen of Fero House.

This kitchen vent does its job well; the problem is that it is commonly left on when people are done cooking. This results in large quantities of warm air being sucked outside for no reason. While this could simply be remedied by a change in people's habits, Fero House's residents are very stubborn to change. Installation of a timer switch on this vent would allow people to still cook and then shut off the vent automatically after a maximum of fifteen minutes. For longer cook times, like when Fero House hosts dinners on Thursday nights, there is an option on this switch to keep the vent on until the user deems it time to turn off the vent.[30] Given the typical brevity with which meals are cooked in Fero House, the option to keep the fan on should not be consistently utilized. For only $19.50 this switch would save hours of unnecessary runtime by this vent which wastes electricity and removes a lot of warm air from the house, putting more strain on the heating system.

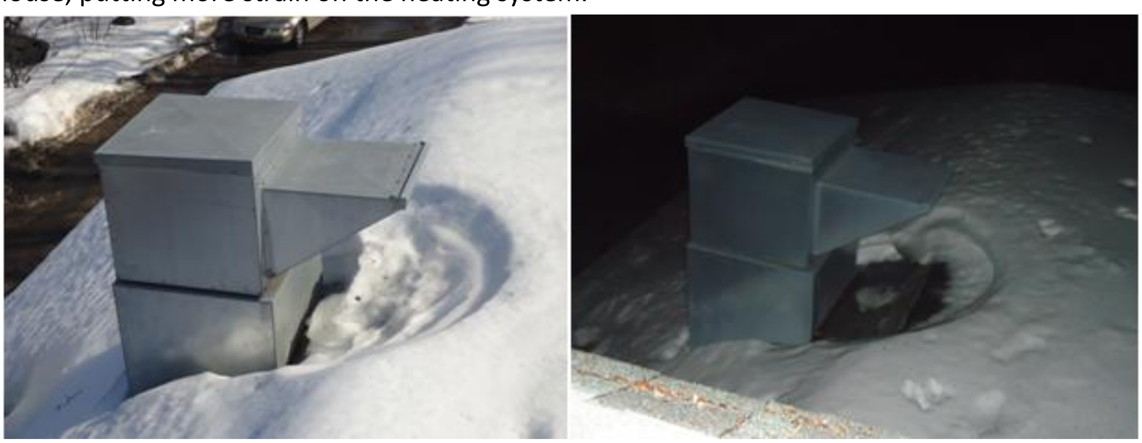

Figure 17. Image of vent being left on from the late afternoon (left) until night time (right) for one day.

The impact of this vent is very hard to measure but can easily be seen by looking at Figure 17. All the warm air being exhausted by the vent easily melted a patch of snow on the second floor roof in just a few hours. The timer switch should pay for itself in just a term with all the electricity and natural gas it will save.

Electricity

Table 1 illustrates the primary electricity loads in Fero House as well as estimates their usage for a typical term.

Lighting

When you walk into Fero House you will notice something immediately, it's bright. This is because nearly every hour of every day, the lights in the main rooms of the first floor remain on. With only one resident living on the first floor, who primarily stays in his room, this is an enormous waste of energy.

Most of the lights in Fero House are the typical fluorescent tube lamps you see in office buildings or schools. These lights create a great deal of direct light but also use up a lot of electricity. Even though these bulbs are labeled "ECO," they still use 32 watts of electricity per tube.[31] In the kitchen, this amounts to 320 watts of lighting which is basically left on twenty-four hours a day. Over the course of a term this adds up to 537.5 kWhrs of electricity for a room that is maybe occupied an average of two hours a day. With electricity costing about 18 cents per kilowatt-hour,[32] the cost of lighting just the kitchen adds up to $96.75 a term. If it were to only be lit up when it was in use for a typical two hours a day, it would only cost $8.06 a term, a savings of nearly $90.

As it has been evident that our residents cannot seem to turn off the lights when done in the kitchen, installation of a motion sensor would be a great means of reducing wasted light energy. Costing only $37.25 before shipping, handling, and installation, a Leviton ODS10-IDI infrared occupancy sensor would keep the lights on only when the kitchen is occupied. Over the course of a term this motion sensor would more than easily pay for itself, especially with the continual increase of energy prices.

The same wasted light energy that plagues the kitchen plagues the dining room and living room. Each of these rooms' lights stay on basically all day even when no one is occupying them. However, these rooms do not have the bright fluorescent lights like the kitchen, so their electricity demand is lower. In the dining room, continual lighting adds up to 124.32 kilowatt-hours a term and in the living room it adds up to 218.4 kilowatt-hours a term. In total, it typically costs $61.69 to light the living and dining room in the current wasteful fashion. Installing the same motion sensor used for the kitchen in both rooms would lower lighting use based on occupancy time, which is about 6 hours a day. This would effectively lower lighting costs in these two rooms to approximately $15.42 a term. With each motion sensor costing $37.25, it would take about two terms to payback the costs of the motion sensors with the added electrical savings.

The lights in the library are surprising only on for about half the time as the other lights, so about 12 hours a day. The lighting level is actually absurdly low considering it is a room where people typically read, only 65 watts light the whole room from a central chandelier. Over the course of a term this adds up to about 54.6 kilo-watt hours, costing only $9.83 to light the library for the whole term. Even this number can be reduced as typical occupancy time in the library is 2 hours a day. Since the library is significantly smaller than the kitchen, dining room, or the living room, it would not require a motion sensor with as much range. A Leviton PR180-1LW infrared occupancy sensor costing just $15.17 before shipping, handling, and installation, would suffice in reducing the amount of time the lights are on. Based on current estimated occupancy time, it would reduce the cost of lighting the library to just $1.64 a term and would pay for itself in just two terms.

The same motion sensor could be installed in the corridors on the first, second, and third floors, areas where the lights are on continually. Assuming these motion sensors would cut the time these corridor lights are on in half, to twelve hours, it would save 420 kilo-watt hours of electricity. This would save $75.60 in just a single term, covering for the cost of the three motion sensors ($45.51) in one term easily.

Exterior Lighting

The lights on the front and back porches of Fero House, much like the first floor lights, are always on. While to some extent this is for safety reasons, having the lights on during the day does little to help thwart theft and only serves to waste electricity. Since no one in the house is conscious of these lights even being on during the day, putting a timer control on the front and back porch lights would effectively reduce this electricity waste and turn the lights on at night without any action from the residents.

The Aube TI003/U by Honeywell programmable timer switch would be ideal for controlling the on/off times of the porch lights. This timer switch allows up to 7 days of different programmable on and off times as well as a manual override. The current usage of lighting on the porch adds up to about 188.16 kilowatt-hours per term, costing about $33.87. Each timer costs $26.81 before shipping and handling.[33]

With Schenectady located at a latitude of approximately 42.5º,[34] we receive on average of 12 hours of sunlight per day over the course of the year.[35] However, Fero House is occupied more during the darker parts of the year than the lighter parts, so while inhabited, Fero House experiences an average of about 11 hours of sunlight during Union College's calendar year. With the timers installed, this would reduce the time the lights are on and lower the cost of lighting the porches to $18.35 a term. Since these timers are somewhat more expensive compared to the amount of electricity they are saving, it will take about 3 and a half terms to payback the price of the timers.

While these lights could also be on motion sensors to reduce electricity consumption even further, Union College's campus safety has routinely visited Fero House when they observe the outside lights off at night. They like to have these lights on continuously during the night so when they do their drive-bys they can observe any suspicious activity outside of Fero House without leaving their cars. Although somewhat wasteful in terms of energy, it is also somewhat worth it in terms of safety, as Fero House has been broken into before.

Electronic Devices

Another large electrical drain in Fero House is the various electronic devices that every college student deems as a necessity. It is common at today's universities for a student to have a television, stereo, a video game system, multiple computers, a refrigerator, and chargers for their multiple handheld devices. All these electronics drain a large amount of electricity when in use and seem to draw even more when not in use. It is a common occurrence in Fero House to hear music blasting or a movie playing in someone's room when no one is around. Since no one in the house is paying for electricity nobody pays any mind to such wasteful practices. One of my friends will purposely leave his music on before he goes to class so he has something to listen to as he leaves the building, sort of like his theme music for the day. Typically I'm the one who has to turn it off. He, like many other residents, also falls asleep with the television on. Personally, I cannot fall asleep without my fan running.

Of the 50,293 kilo-watt hours used by Fero House in 2009-2010 (Table 2 in the **Appendix**), approximately a third of this comes from electronic devices. About half the time these devices are on they are not even being utilized. This adds up to 8,382 kilo-watt hours of wasted electricity every year, amounting to over $1,500 dollars of wasted energy every year!

When it comes to the various electronics our residents use, there is little than can be done to curb their use aside from informing them they are being wasteful. I have tried such education with little success and instead end up turning off devices myself when no one is around. It is hard to convince people to change their habits when there exists no immediate incentives for them to do so.

Space Heaters and Air Conditioners

Due to the discontinuous nature of our heating system, especially during the end of the fall term and the beginning of the winter term when temperatures drop significantly, many of the residents of Fero House have invested in electronic space heaters (Figure 18). These are used primarily when our heat is not responding but also sometimes when the heat is active.

Figure 18. Electric space heaters used in various bedrooms around Fero House.

Three of the four space heaters pictured are located on the third floor of Fero House because this is typically the coldest floor in the house. This is due in part to the shoddy attic insulation which I touched on earlier as well as a couple leaky windows and inconsistent heating.

While electric space heating is said to be 100 percent efficient,[36] it is also the most expensive to run as it draws a huge amount of electricity. The manual for the space heater in the top left of Figure 7 says that particular heating unit uses 1000 watts on its low setting and 1,500 watts on its high setting, which adds up to a huge amount of power being drawn during extended usage. Even though these electric units are frowned upon by Union College due to their fire hazard, they are still prevalent in numerous buildings around campus. A more efficient heating system in Fero House could make such space heaters obsolete and save hundreds of kilo-watt hours.

One resident's heat fails to work, even after placing a work order and inspecting the heating unit it still does not function, so he utilizes one of these space heaters. Measuring its electricity usage over a twelve hour period, the typical amount of time and settings for which the heater is on, found the space heater to draw 8.85 kilo-watt hours of electricity. For an entire term this adds up to 619.5 kilo-watt hours, costing around $100 worth of electricity ($86.73 at .14 cents per kilo-watt hour and $111.51 at .18 cents per kilo-watt hour). Other residents use their space heaters much less frequently. Estimating all other space heater usage adds up to 1032.5 kilo-watt hours in a term, costing over $150 for a term ($144.55 at .14 cents per kilo-watt hour and $185.85 at .18 cents per kilo-watt hour). Use of space heaters contributes greatly to electricity costs, which is probably the prime reason they are not allowed at Union College. A tighter envelope and a more reliable central heating system would make these electric space heaters unnecessary and save the school hundreds of dollars.

Alternatively, air conditioners are a large electrical drain in the early fall and late spring terms. This is due in part to the lack of central air-conditioning in Fero House. There appears no need for air-conditioning in such a commonly cold environment, but the current draftiness of Fero House allows the constant flow of warm air into the house during warmer months. Looking at Table 1 in the Appendix, we see that the two air conditioning units in Fero House during the fall term were only on for the first four weeks yet still were some of the top users of electricity for the entire term. A better sealed house will help prevent such energy use from air conditioners.

A tighter house will also allow for cooling via the process of night-flushing. This is where the windows of the house are opened at night, allowing the cool air in, and then closed during the day to keep the warm air out. This works best with a whole-house fan that can move a large amount of cool air into the house, but given the current construction of the house being aimed at keeping air change low due to fire hazards, such a fan would only be somewhat effective.

Phantom Loads

Another significant drawer of electricity is from phantom loads. A Phantom load is electrical power consumed by an electronic device when they are switched off or in standby mode. According to the U.S. Department of Energy, 75% of the electricity used to power home electronics in the average home is consumed while the products are turned off.[37] This is a staggering statistic given the amount of electricity we already use with our electronic appliances on. Such waste is most evident when looking at cable boxes. Cable boxes use just was much energy off as when on because they are constantly receiving information in the form of guide information and updates even when you are not watching television.[38]

One way to combat this waste of electricity is to use power strips. When you are done using your electronics you not only turn them off but switch off the power strip as well. This ensures no electricity is being consumed by electronic devices that are "off." There are a couple of problems with this approach. In Fero House, pretty much every outlet on a power strip is utilized, meaning that if you want to turn one specific electronic off for good you also have to turn off everything else. This is a nuisance for those who have a refrigerator or clock plugged into the same power strip. Also, when our residents are done with one appliance they are often not done using several other ones. Furthermore, our power strips are often jammed behind desks or under tables, making them less than easy to access.

Perhaps most importantly, once again, residents are not paying the electric bill, so have little incentive to worry about such things as phantom loads. Looking at Table 1 in the **Appendix,** about one third of Fero House's electricity use is from lighting and laundry. Looking at Table 2 in the **Appendix,** Fero House consumed 50,293 kilo-watt hours of electricity in 2009-2010. Assuming one-third of this was from home electronics, 16,764 kilo-watt hours were used for electronic devices. Based on the DEA's estimate that 75% of electricity used to power home electronics is from phantom loads, 12,573 kilo-watt hours were consumed by electronics that were "off." This equates to $1,760 from phantom loads, in just one year! (Assuming .14 cents per kilo-watt hour due to mostly off-peak usage) That is a huge amount of power and money wasted but again, Fero House's residents have little concern for such costs because they are not paying for them. Educating our residents on the existence and impact of phantom loads would be a good start to curbing this energy wasted. However, my efforts thus far have proven futile, which are further explored later in **The Consumers** section.

Plumbing

Conserving water is something that falls by the wayside when people typically think of environmental efficiency. This is most likely attributed to the fact that our country is fairly abundant in fresh water sources and people can easily stroll to the super-market to buy bottled water. In other countries around the world however, people are not nearly as lucky. With global average temperatures rising, certain areas are getting dryer while others are getting wetter. Unfortunately, the areas that are becoming dryer are the areas in which water is needed most.

While here in America we have a plentiful supply of water and a known reliable reserve of water in Canada, we should aim to be as efficient as possible with it to ensure it is here for future generations. It also seems morally wrong to take our clean, on-demand water for granted when so many other areas of the world suffer from lack of clean drinking water. If these reasons weren't good enough, there is also an economic incentive to saving water, especially in warmer parts of the nation. According to a survey by Black and Veatch, water and wastewater bills for residential use have been increasing at a steady rate across the country since 2001.[39]

Toilets

Every toilet in Fero House flushes with the same 1.6 gallons per flush, which is standard. Four flushes, per person, per day are an average number of flushes.[40] Seeing as the residents of Fero House most likely ingest more liquids than the standard person, five flushes per person, per day is a more accurate estimation. This amounts to 11,550 flushes or 18,480 gallons of clean water used simply for flushing over a school year. Considering the number of guests Fero House typically has, this number could easily be doubled.

Much of this water being flushed is not for solid waste either, meaning most of these flushes use 1.6 gallons simply for urine, which is overkill. Installation of higher efficiency toilets would save thousands of gallons of water and money. The Stealth Ultra High Efficiency Toilet uses only 0.8gpf regardless of waste type.[41] This is achieved by the toilet's unique flushing system, in which the energy generated by water filling the tank is harnessed and an air transfer system is used to pressurize the bowl's trapway. Based on FEMP numbers and a national average water and wastewater combined rate, this toilet saves up to 20,000 gallons and $101 per year with regular use, and up to 200,000 gallons and $1,013 in its lifetime.[42]

At $308 a piece, these toilets are only slightly more expensive than a typical toilet but save much more in terms of water and utility bills than a standard toilet. Replacing all four of Fero House's toilets with an Ultra High Efficiency Toilet would cost $1,232 and based on the numbers presented by their website, should pay for themselves in three years. Considering the large household size of Fero House and the number of guests typically present, this payback period could be considerably less than estimated.

Showers

All the showers in Fero House are already equipped with low-flow showerheads. Together they each average a flow of 2 gallons per minute, which is about as efficient as they come. Any flow lower than currently available would most likely be met with numerous complaints by our residents.

With showers it is not the equipment that is the problem, but instead the people using them. Since it takes time for the water to heat up, people will leave the showers running for minutes on end until the water has reached a desirable temperature. This leads to hundreds of gallons of water being wasted every week. This is a significant amount of energy when you consider the fuel that is used to heat up the water, the electricity required to pump the water to the showers, and the heating loses experienced during the water's transportation through the pipes.

On the third floor it takes approximately a minute and a half for the water to reach an acceptable shower temperature. So even if you are testing the water waiting to jump in the shower, at least three gallons of water will be wasted in the process. This can be combated by the installation of a hot water recirculation pump.

The pump is installed under the sink furthest from the water heater, in the case of Fero House this would be the third floor bathroom but a pump could also be installed in the second floor bathroom where showers are most frequent. A built-in temperature sensor automatically turns the recirculation pump on when the temperature of the water in the hot water supply line cools to 85°F. This cool water in the hot water supply line is then pumped into the cold water line and back into the water heater.[43] The pump turns off again when the water in the hot water supply line reaches 95°F, creating an instant availability of warm water to use for showering and hotter water supplies being delivered only seconds later.

At $254 a piece these recirculation pumps are not cheap, but they have a large potential for future savings. This particular water pump is said to save the average family of four up to 17,000 gallons annually.[44] Extrapolating this number to 11 people, the current number of residents in Fero House, and shortening the time from one year to 30 weeks, Fero House could save almost 27,000 gallons of water per school year. Economically, this can result in a large savings from reduced gas use by the hot water heater (Figure 19).

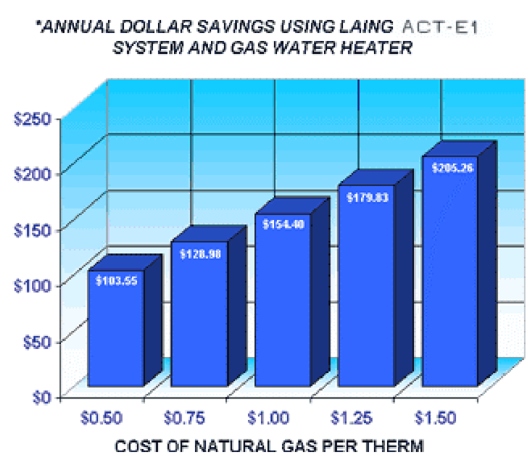

Figure 19. Graph showing potential savings with the proposed recirculation pump and different gas prices.

From the 2009-2010 energy cost data found in Table 2 in the **Appendix**, the average cost per therm throughout the year was \$1.49, or approximately \$1.50. Assuming the chart in Figure 19 also applies to a family of four, the potential savings for eleven residents in Fero House would be \$564.47 for a whole year or \$325.65 for a school year. Therefore, the two recirculation pumps should pay for themselves in just under five terms. These recirculation pumps will also reduce the lag time between cold and hot water on the sinks, saving even more water and money.

Indoor Air Quality

While increasing energy efficiency is the primary goal when it comes to making these renovations, we must also consider other modifications aimed strictly at improving living conditions. As Americans spend 90 percent or more of their time indoors, establishing a clean and healthy indoor environment is crucial.[45] Indoor levels of pollutants may be two to five times higher, and occasionally more than 100 times higher, than outdoor levels.

This air pollution can come from combustion sources, certain building materials and furnishings, central heating and cooling systems, as wells as outdoor sources such as radon, pesticides, and outdoor air pollution. Many homes built before 1978 have lead-based paint, which can be exposed to people through paint chips, dust, and contaminated soil. [46] Such pollutants can lead to adverse health effects such as asthma[47] and even cancer.[48]

There are many steps which can be taken to increase indoor air quality and provide a more comfortable living environment. One of the simplest ways of doing so is preventing the contaminants from entering the house in the first place. This can be accomplished by installing a dirt catcher in the front entry way between the entry door and the inside door. Such a dirt catcher will drastically reduce the amount of dirt and pollen entering the house from the outside and hold it in a non-living space instead of having it spread throughout the house on the soles of people's shoes. Dirt catchers can also easily be cleaned periodically with a broom and dustpan.

Carpets

The first floor of Fero House is comprised of wood and tile flooring, a necessity for a house that throws social events. The second and third floors however are nearly all covered in carpet. These carpets have been experiencing the abuse of a fraternity house for years, and as such have become quite disgusting. Soaking up spills, dirt, food, dust, and various other small particulates, these carpets are housing some terrible air pollutants that we breathe every day. Removing all the carpeted flooring and replacing it with wood or tile would be very expensive. A more viable option is to hire a carpet cleaning service to do some professional work on these carpets, as standard vacuuming appears to have little effect anymore. The cost of cleaning approximately 2,000 square feet of carpet would be about $500.[49] Although there is no payback from cleaning carpets, it should drastically improve the air Fero House's residents breathe every day, especially in rooms where mold has been found.

Furniture

Air pollutants can also be held in old furniture, which is the only kind of furniture found in Fero House (Figure 20).

Figure 20. A couch found in the main living room of Fero House.

Being subjected to spills, food, and constant abuse without ever being properly cleaned, most of the furniture in Fero House resembles the couch in Figure 20. This results in furniture that houses large amounts of dust mites and mold spores which can negatively affect the respiratory system. However, cleaning of this furniture will be quite costly, at approximately $100 per piece of furniture.[50] Considering the amount of furniture there is, the condition it's in, and the future abuse it will also be subjected to, cleaning of the furniture does not appear to be a viable option economically.

Bathroom Vents

Keeping air quality high in a house also has a great deal to do with ACPH or Air Change per Hour, a measure of how many times the air within a house is replaced with fresh air. If ACPH is low, moisture can become trapped, allowing molds to feed and other allergens to build up. In Fero House, this is most noticeably a problem in the bathrooms where the vents have essentially stopped functioning (Figure V).

Figure 21. Picture of vents in the second floor (left) and third floor (right) bathrooms.

Both the bathroom vents shown above turn on when the light is turned on, but they fail to provide any sufficient suction to ventilate the stale air. This is most likely due to clogged vents as well as damage to the ventilation tubes themselves from the altered attic insulation seen in Figure 13. The lack of properly functioning vents leads to windows being left open in the second floor bathrooms in an effort to remove the foul-smelling air. Subsequently, these windows are often left open for extended periods of time, resulting in large amounts of cool air coming in and thus higher heating loads. These vents can easily be fixed when the new attic insulation is installed, resulting in better air quality and less heating loses.

The Consumer

Efficiency can only take us so far. Ultimately, it comes down to personal consumption and the importance of being conscious about your everyday energy usage. Here in the United States we average just over 12,000kWhrs per person, 9^{th} worldwide.[51] That is a tremendous amount of electricity, especially considering there are over 300 million of us. The best way to lower this number is to curb our consumption through conservation.

Lowering consumption is much easier said than done, especially considering the amount of electronics the typical college student relies on every day (Figure 22).

Figure 22. One of Fero House's more wasteful residents' room. Three monitors are on, along with two computers and a refrigerator. A printer, Xbox 360, and GameCube are also present but off.

While Figure 22 is not indicative of all of Fero House's residents, it is not too out of place. Being a fairly costly school, Union College students are typically very well-off and can afford the latest electronic gadgets. In turn, we have many rooms, such as the one in Figure 22, where multiple electronics are on at once, with many devices not being used at all. This leads to wasted energy and wasted money.

Habits are hard to change, especially when there is no incentive to do so. Union has tried to remind its residence to save money by putting "Conserve, U can help save energy" on almost every light switch, but this has done little to remind people to turn their lights off. Personally, I have tried to tell Fero House's residents about the impacts of their wasteful use, but have had very little success. Most of my friends argue that they have enough to worry about as it is besides saving the school a few extra bucks on their electricity bill. Considering the high workload and intensity of the trimester system, this is a somewhat valid point.

Since we do not pay for our electricity, we do not have to worry about our wasteful use. Perhaps rewards for less use would have a larger impact. An idea for reducing electricity across Union College campus would be to enter every residence building into a competition in which the building with the largest reduction in its energy use would receive a prize. This would provide some incentive for people campus-wide to reduce their own energy usage and perhaps put the idea of conservation more at the front of people's minds. Such a competition could be run every term in an effort to continually remind student's of their personal impacts.

Alternatively, the building with the least amount of improvement in energy reduction could be subjected to a talk on the impacts of such wasteful practices. Such a talk could illustrate the impacts fossil fuels have on the environment, our world's dwindling natural resources, global climate change, how to reduce one's own personal consumption and the benefits associated with such reductions. This could hopefully cause a few people to change their personal habits and encourage others to do so as well.

Ultimately, energy-efficiency comes down to you and me. All the other proposed changes would be far less necessary if everyone was conscious of their own personal environmental footprint and changed their habits accordingly.

Conclusions/Recommendations

The following recommendations are based on my knowledge of building systems as well as my own personal experiences in Fero House. For each change, cost was considered as well as the subsequent benefits, both short and long term. With each change proposed there exist numerous other alternatives, yet I feel these are the best renovations available for Fero House (Table 3).

Table 3. Proposed Improvements for Fero House. The costs of each renovation do not include tax or shipping charges needed for some products or the cost of installation.

System	Area of Concern	Change/Renovation	Cost of Change	Payback Period
Envelope	1st Floor Exterior Doors	Draft Guards	$40.00	~1 month
	Basement Exterior Door	Sealing Tape	$4.06	<1 month
	First Floor Casement Windows	New Split Arm Operator, Crank Handles, and Sealant	$55.83	N/A
	3rd Floor Windows	New Windows (x2)	~$800.00	N/A
	Holes in Basement Walls	Drywall	$18.48	N/A
	Attic Insulation	More Insulation w/ Proper Installation	$201.15	N/A
HVAC	Exposed Hot Water Piping	Pipe Insulation	$8.26	N/A
	Kitchen Vent	Timer Switch	$19.50	~1 term
Electricity	Lighting	Kitchen Motion Sensor	$37.25	≤1 term
	Lighting	Dining and Living Room Motion Sensors	$74.50	~2 terms
	Lighting	Library Motion Sensor	$15.17	~2 terms
	Lighting	Corridor Motion Sensors	$45.51	≤1 term
	Lighting	Porch Programmable Timer Switches	$53.62	~3.5 terms
Plumbing	Toilets	New High-Efficiency Toilets	$1,232	~3 years
	Hot Water Lag Time	Recirculation Pumps	$508	≤5 terms
Air Quality	Carpets	Carpet Cleaning	$500	N/A
	Bathroom Vents	Fix During Attic Insulation Installation	N/A	N/A

In total, my recommended renovations amount to $3,613.33 in changes. Up front this seems like a large sum of money, yet many of the proposed changes have a payback period of less than one school year. Also, once a change meets its payback period time, it will begin saving money in the form of less electricity and gas consumption. With increasing energy prices, these savings can only increase over time.

Most of my proposed renovations are cheaper alternatives to bigger renovations, favoring fixing what we have over complete replacement of some of Fero House's components. One aspect I failed to fully understand in terms of costs and benefits was the aged single-pipe steam heating system currently installed. Transitioning this system to a two-pipe hot water heating system should create more consistent heating, reduction in gas consumption, more comfortable living environments, and less electrical demand from space heaters. Further research is needed on the overall cost of purchasing and installing new piping, a new boiler, and thermostats zoned for each floor. If such a project is undertaken in the future to convert to this kind of system, I would recommend installing more wall insulation during the process of replacing the piping as well as plugging up the vent found in the boiler room in order to reduce any unnecessary thermal bridging. More modern heating has great potential to reduce Fero House's overall gas consumption, saving money and a dwindling natural resource.

Considering $13,540 was spent on gas and electricity for Fero House in 2009-2010 (Table 2), there is large room for improving our house's efficiency. If my proposed renovations lower Fero House's total energy consumption by an ambitious 30%, they will pay for themselves in just one year. Using a much less bold reduction of 10%, my renovations will pay for themselves in about three years, which is still a relatively short time period. Rising energy prices only serve to make these energy reductions more economically viable.

While these changes are fueled by economics, they will also help the environment. Lower natural gas demand will help reduce our reliance on a dwindling natural resource which is being harvested in more and more delicate areas. Lower electricity demand will reduce the demand for energy from coal, America's primary electric resource which degrades the environment more than any other fossil fuel. Increasing efficiency coupled with better conservation will help reduce our use of fossil fuels, helping to better the health of our environment and allowing us more time to transition to renewable sources of energy such as wind and solar power.

These changes illustrate how Fero House, a picture of inefficiency and over-indulgence, can drastically reduce its environmental impact with just a few minor changes.

Appendix

Table 1. Chart of the major electrical usages in Fero House during the fall term of 2010.

	Room	Appliance/Electronic	Wattage	Citation	Average Usage (hrs per day)	Average Usage per day (Watts)	Qualifiers	Total (for term)	
--------------------------	Tim's Room	Regular Lighting	128	~	10	1280		89.6	kWhrs
I		Task Lighting	160	~	6	960		67.2	kWhrs
I		Television	120	*	6	720		50.4	kWhrs
I		Refridgerator	.032kWhr	*	24	.768kWhr		53.76	kWhrs
I		Laptop	33	*	6	198		13.86	kWhrs
I		Xbox 360	187	~	2	374		26.18	kWhrs
I	Library	Regular Lighting	65	"	12	780		54.6	kWhrs
1st Floor	Kitchen	Regular Lighting	320	~	24	7680		537.6	kWhrs
I		Refridgerator	.075kWhr	*	24	1.8kWhr		126	kWhrs
I		Freezer	.58kWhr	*	24	13.95kWhr		976.6	kWhrs
I	Closet	Regular Lighting	64	~	1	64		4.48	kWhrs
I	Dining Room	Regular Lighting	74	~	24	1776		124.32	kWhrs
I	Bathroom	Regular Lighting	67	~	12	804		56.28	kWhrs
I	Living Room	Regular Lighting	130	~	24	3120		218.4	kWhrs
I		Tuner	110	*	4	440		30.8	kWhrs
I		Television	80	*	4	320		22.4	kWhrs
--------------------------	Corridor	Regular Lighting	39	~	24	936		65.52	kWhrs
--------------------------	Tayyab's Room	Regular Lighting	256	~	0	0		0	kWhrs
I		Task Lighting	113	~	7	791		55.37	kWhrs
I		Subwoofer	250	~	3	750		52.5	kWhrs
I		Speakers	24.3	~	5	121.5		8.505	kWhrs
I		Xbox 360	187	~	2	374		26.18	kWhrs
I		Laptop	40		24	960		67.2	kWhrs
I		A/C Unit	560	"	24	13440	4 weeks	537.6	kWhrs
I		Television	110	*	8	880		35.2	kWhrs
I	Corridor	Regular Lighting	269	~	24	6456		451.92	kWhrs
I	Cox's Room	Lighting	256	~	0	0		0	kWhrs
I		Task Lighting	115	"	12	1380		96.6	kWhrs
I		Fan	40	*	2	80		5.6	kWhrs
I		Gamecube	39	~	1	39		2.73	kWhrs
I		Xbox 360	187	~	3	561		39.27	kWhrs
I		Television	100	*	5	500		35	kWhrs
I		Computer (x2)	150	*	10	1500		105	kWhrs
I		Router	7	"	24	168		11.76	kWhrs
2nd Floor	Landing Bathroom	Regular Lighting	13	"	12	156		10.92	kWhrs
I	Main Bathroom	Regular Lighting	59	"	24	1416		99.12	kWhrs
I	Doyle + Kaplan's Room	Regular Lighting	256	~	10	2560		179.2	kWhrs
I		Task Lighting	112	"	2	224		15.68	kWhrs
I		A/C Unit	740	"	24	17760	4 weeks	1243.2	kWhrs
I		Speakers	150	"	6	900		63	kWhrs
I		Laptop Computer	40	*	8	320		22.4	kWhrs
I		Desktop Computer	120	*	24	2880		201.6	kWhrs
I		Television	80	*	8	640		44.8	kWhrs
I		Cable Box	26.5	*	24	636		44.52	kWhrs
I		Xbox 360	187	~	3	561		39.27	kWhrs
I	Infante + Colby's Room	Regular Lighting	256	~	12	3072		215.04	kWhrs
I		Task Lighting	40	"	4	160		11.2	kWhrs
I		N64	19	"	4	76		5.32	kWhrs
I		Television	175	"	6	1050		73.5	kWhrs
I		Refridgerator	90	"	24	2160		151.2	kWhrs
--------------------------		Infante's Laptop	22	*	10	220		15.4	kWhrs
--------------------------	Reshad's Room	Regular Lighting	128	~	8	1024		71.68	kWhrs
I		Task Lighting	204	"	4	816		57.12	kWhrs
I		Fan (x2)	95.6	*	8	764.8	4 weeks	30.592	kWhrs
I		Television	100	*	4	400		28	kWhrs
I		Speakers	62	"	4	248		17.36	kWhrs
I		Refridgerator	60	*	24	1440		100.8	kWhrs
I	Corridor	Regular Lighting	192	~	24	4608		322.56	kWhrs
I	Guerra's Room	Regular Lighting	128	~	12	1536		107.52	kWhrs
I		Television	185	"	10	1850		129.5	kWhrs
I		Xbox 360	187	~	2	374		26.18	kWhrs
I		Laptop	33	*	24	792		55.44	kWhrs
I		Speakers	62	"	8	496		34.72	kWhrs
I		Cable Box	26.5	*	24	636		44.52	kWhrs
I		Refridgerator	-	*	24	0.88	kW/hr	1478.4	kWhrs
I		Fan	43.3	*	24	1039.2		72.744	kWhrs
I	Bathroom	Regular Lighting	15	"	24	360		25.2	kWhrs
I		Task Lighting	44	"	24	1056		73.92	kWhrs
3rd Floor	Jared's Room	Regular Lighting	192	~	12	2304		161.28	kWhrs
I		Task Lighting	15	"	6	90		6.3	kWhrs
I		Television	101	*	10	1010		70.7	kWhrs
I		PS3 Slim	96	~	10	960		67.2	kWhrs
I		Cable Box	26.5	*	24	636		44.52	kWhrs
I		Laptop	40	*	12	480		33.6	kWhrs
I		Refridgerator	-	~	24	340 kwh/yr		71	kWhrs
I		Fan	45	*	12	540	4 weeks	21.6	kWhrs
I	My Room	Regular Lighting	128	~	10	1280		89.6	kWhrs
I		Task Lighting	20	"	1	20		1.4	kWhrs
I		Blacklight (x2)	30	~	2	60		4.2	kWhrs
I		Fan	85	~	12	1020		71.4	kWhrs
I		Television	150	~	4	600		42	kWhrs
I		Laptop	65	*	12	780		54.6	kWhrs
I		Speakers	23	*	6	138		9.66	kWhrs
I		PS3	197	~	1	197		13.79	kWhrs
I		Phone Charger	6.5	*	10	65		4.55	kWhrs
--------------------------		Refridgerator	-	~	24	0.5kWh/24hr		35	kWhrs
--------------------------	Basement	Main Lighting	55	"	12	660		46.2	kWhrs
I		Storage Lighting	13	"	2	26		1.82	kWhrs
Basement		Washer	.07 kWhr per load	*	1 load/person/week		11 people	7.7	kWhrs
--------------------------		Dryer	.32 kWhr per load	*	1 load/person/week		11 people	35.2	kWhrs
Outside	Front Porch	Lighting	67	~	24	1608		112.56	kWhrs
--------------------------	Back Porch	Lighting	45	~	24	1080		75.6	kWhrs
			*Found using P3 Kill-A-Watt Electricity Usage Monitor						
			~Found using the internet						
			"Found using personal observation						
			Assume 70 days for a 10 week term						

Table 2. Usage and costs of electricity and gas for Fero House during 2009 and 2010.

	2009						2010						
	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	TOTAL 09-10
Fero (33 Ter. La. No.)	0	0	1	30	73	106	146	120	0	0	146	0	
KWH	1653	1324	3271	5490	6131	2769	5181	6343	4797	4711	4531	4092	50293
Total Cost Elect.	243	223	396	624	657	421	772	862	603	619	608	547	6575
Electric Delivery	153	147	227	284	314	226	347	388	329	307	308	276	3305
Electricity	90	76	169	340	343	196	425	474	274	312	300	271	3270
DEMAND	6	6	10	12	13	10	14	14	13	10	12	11	130.1
DEMAND COST	60	63	98	116	135	103	0				0		574.69
THERMS	75	61	121	478	291	786	849	966	525	306	189	33	4680
TOTAL COST	83	72	116	504	382	1245	1239	1528	909	588	240	60	6965
TRANS. COST	48	43	63	153	130	232	252	269	196	143	96	35	1661
GAS COST	35	29	52	350	252	1014	988	1259	713	445	144	24	5305

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