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Long-Term Green Renovations for the Printer’s Building of Worcester, Massachusetts

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Long-Term Green Renovations for the Printer’s Building of Worcester, Massachusetts

An Interactive Qualifying Project proposal submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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Abstract

The Worcester Printer’s Building was built in 1923 as a printing and binding facility. It was originally known for its industrial efficiency which it has lost over the past century. To revitalize the Printer’s Building, the project goal was to determine the feasibility of implementing long-term green renovations. The first objective was to analyze and build upon the previously conducted IQP that focused on short-term modifications. Following the analysis, we determined which green technologies were applicable to the building. After identifying these technologies, the final objective was to provide a three and five year feasibility/action plan. With these objectives completed we were able to make recommendations for the Printer’s Building in its pursuit of becoming a sustainable facility.
Acknowledgements

Wyatt Wade
    Building Owner and Project Sponsor

Jim McKeag
    Building Superintendent

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    LEED-Accredited Professional

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D. Snow was mainly responsible for the design and construction of the educational green roof model. He created the sketches and materials list that were used to aid us in the construction. M. Downey was primarily in charge of acquiring outside contacts and scheduling interviews with the necessary professionals in the field of green roofing. P. Galligan primarily contacted and scheduled interviews with LEED-AP and gathered the necessary LEED documents as well as the information about the insulation products. P. Holmes was primarily responsible for documenting and calculating the cost payback information.
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Executive Summary

The Printer’s Building on Portland Street has been a staple of the Worcester’s profile for almost ninety years. Built in the 1920’s, this facility was constructed to be an innovator in efficient publishing by combining both printing and binding within the same facility. Although, state of the art in when erected, the Printer’s Building has become more outdated as time has passed.

Despite its current state, the building has not lost its efficient identity. The current global environmental dilemma, rising utility prices and the desire for a more attractive facility has driven current building owner, Wyatt Wade, to consider long-term, eco-friendly renovations. These renovations should include “green” characteristics, a significant drop in utility costs and a means to attract new tenants. Our Interactive Qualifying Project was a feasibility study to determine which renovations would be best for the Printer’s Building as well as how long each technology would require to pay itself back. We focused on retrofitted concrete insulation and green roof technology in hopes of saving money and attracting new tenants to the Printer’s Building.

Methodology Overview

To complete our sponsor’s expectations, we devised a set of methods that would allow us to make educated and useful conclusions and recommendations for Wyatt Wade. Our first step was to familiarize ourselves with the building and the work that was completed by a previous Interactive Qualifying Project. This knowledge was useful in finding a basis on which we could progress in our project.

Our next task was to identify what could be done to the building, where we could find this information and who could assist us in finding it. We approached these tasks by conducting interviews with professionals familiar with the Worcester area and by conducting our own personal research. Our interviews consisted of discussions with an insulation specialist, a construction manager, two green roof specialists and two LEED Accredited Professionals. We also used product information to learn more about each of the technologies we suggested.
To learn more about the social impact of these renovations, we explored other examples of adaptive reuse within the Worcester community. Two facilities, the Sprinkler Factory and the Lamoureux-Pagano building were chosen because of their similarity in age and floor layouts. We focused on the tenants that occupied the building, renovations done, and the utilization of space. Our tours consisted of walkthroughs with the various tenants that occupied the spaces. From these tours, we were able to project the social impact of renovations to the Printer’s Building.

Lastly, we determined the feasibility of implementing these technologies by conducting a cost/payback analysis. We obtained the building’s basic information, utility bills from the past two years and pertinent information needed from the specified product lines. We inserted these values into a formula that allowed us to see the payback period of each of the technologies both individually and separately.

**Key Findings**

The findings of this project are the result of in-depth independent research as well as the professional opinions of various specialists.

We determined that interior insulation for the Printer’s Building is not applicable. This is due to the fact that the building still utilizes a steam heating system as its main source of heat. The partitions that would hold the insulation would need to be constructed around the steam radiators and the many windows of the facility. By having to make partitions that accommodate both of these features there is a significant amount of material waste and cost increase for additional labor.

As an alternative to the interior insulation there are exterior insulation finishing systems (EIFS) or more commonly referred to as outsulation. Our group researched the EIFS and found two pertinent products for the Printer’s Building. The first is the Versawall® metal paneling system from Centria®. This product is the most effective of the outsulation systems, but also has the highest price tag. The most important aspect of the system that we stressed to our sponsor was the fact that the system will change the appearance of the building to a more contemporary look. The other system that was applicable to the Printer’s Building was the Outsulation® system from Dryvit®. This system is less effective at insulating the building, but is also less
expensive. The benefit of the system is that it is capable of being sculpted to better preserve the historic look of the building.

In regard to the green roof technology, we found that a complete intensive or extensive green roof is not appropriate for the Printer’s Building. The basis of this finding is the current condition of the roof which needs to be repaired and structurally audited. As an alternative, we found a palletized green roof system from GreenGrid® as a viable green roof solution for the building. The palletized systems allowed for easy construction and versatility of placement.

We found that the implementation of either an outsulation system or a green roof system is not a cost effective renovation with the current price of natural gas. Using a cost/payback formula we calculated the years to payback each of the outsulation products at 17 to 18 years. With the same formula, we found that the years to payback the palletized green roof system to be 1 to 3 years, but the current roof should be updated before this technology is implemented.

The social findings of this project are based on the exploration of two facilities in the Worcester community: The Sprinkler Factory and Lamoureux-Pagano. From the examination of both facilities we were able to gather information about the occupants, the renovations done to the buildings, and the utilization of the space. After the tours of the facilities, we were able to pick out which aspects of the buildings we wanted to see incorporated and others that we did not see appropriate for the Printer’s Building.

**Recommendations**

Over the course of our seven week term, we gathered and compiled information that would help us to form our final recommendations to our project sponsor. These recommendations will help our sponsor to make educated decisions regarding the implementation of long-term green renovations to the Worcester Printer’s Building.

1. Display the educational model in a populous area within the building;
2. Use the product binder to learn more about each of the selected technologies;
3. Create a separate account for the sole purpose of budgeting money for long-term renovations;
4. Use Excel templates on Data CD to organize and document utility bills for future years;
5. Focus on one renovation and work toward its implementation;
   a. Be sure to keep updated on any advances within the product technology;
6. Become more aggressive in the pursuit of new tenants;
7. Currently, neither renovation (green roof technology and external insulation) is recommended due to the cost of energy and current state of the facility;
8. Updating/fixing the roof is a larger priority;
9. Invest in an additional IQP for the consolidation of storage space within the facility and to find an appropriate use for each space.

The suggestions that we have provided possess the ability to be implemented within the next five years. These recommendations will be useful and will prove vital in the aspiration of transforming the Worcester Printer’s Building into a sustainable landmark.
Chapter 1: Introduction

Global climate change is evident through more severe storms, the melting of polar ice caps, frequent flooding, and longer droughts. As these events continue to worsen, what will happen if we do not start considering a course of action such as a green changeover? Although there are many interpretations of the definition for “green”, characterized as a concept of a positive impact on the environment by reducing energy consumption, preserving resources and alleviating harmful effects of humans (Basaly, 1997). Green technology is one of the driving forces that push the global movement towards this green changeover. It is the responsibility of those who can make a difference in the environment to find new ways to create a sustainable culture for future generations. In the last decade, green technology has shifted from the backburner of political and social topics to the forefront. It is becoming more evident that there needs to be a change in human policies with regard to climate change.

The design of a sustainable, green building with low energy consumption is one way to combat this global crisis. Green building design not only decreases energy costs and consumption, but it also directly effects the surrounding environment by reducing pollution and alleviating the impact of non-green construction developments.

The implementation of green technology in a building can have a profound effect on society as well. The green concept is applicable to both new and old construction. When starting new developments, it is very important to consider the use of green technologies, which can save money in the long run and help the environment simultaneously. However, it is becoming more imperative to convert old establishments to this new concept of being “green”. Some changes can be simple, such as reducing fuel consumption through means of proper insulation and upgraded windows. Other changes require a larger investment, such as the refurbishing of a roof to become more eco-friendly in terms of runoff and heat loss. This conversion from “old-to-new” can have a significant effect on surrounding buildings. By setting a blueprint for green design, a single building can inspire a community to follow suit.

The Worcester Printer’s Building is a family owned and maintained establishment, located in downtown Worcester. Constructed in 1922, its initial purpose was a binding and printing facility that was specifically designed for publication efficiency. The aging building is
now being utilized by a variety of local businesses and must be maintained to attract more businesses and meet the demands of the current occupants. While many tenants have come and gone throughout the years, the concept of being an efficient company has never left the founders’ goals. Wyatt Wade, our project sponsor and president of Davis Publications, is striving to maintain that tradition by encouraging the research and implementation of green technology into the building. Our Worcester Community Project Center team has worked with Mr. Wade to attain the goal of a sustainable model for downtown Worcester. A complete renovation of the facility is ideal, but budget and time constraints limit what can be done to revitalize this historic building. The Printer’s Building is not deterred by any alterations in aesthetics, as they are more interested in the functionality of the green technologies they decide to adopt (W. Wade, personal communication, November 12, 2008).

Our goal was to take what has been deemed a historical, energy-inert building and help to transform it into a contemporary model for green building design. Our objective was to formulate a guideline for this institution to follow as it strives to become the model for green building design in the Worcester, MA community. We analyzed energy audits and developed a long-term plan for the building to use in its first efforts in becoming a sustainable facility. This proposal includes three and five year plans that have lists of objectives for our sponsor to follow. We developed a cost and payback analysis of the technologies to be implemented into the building, as well as discussed the social benefits of the renovations.
Chapter 2: Literature Review

This chapter includes the background research relevant to implementing long-term green renovations into the Worcester Printer’s Building. Our research provided an in-depth understanding of the current global energy situation and energy saving techniques. The following sections explore the essential aspects of information that pertained to this project.

2.1 Global Situation and Energy Consumption

The concern for environmental problems is not a new issue but has escalated over time. There has been an increase in anxiety about the current global situation. Much of the probable ecological harm has been associated with the climate and how the change in climate is affected by our everyday actions. Humans are constantly adding harmful gases, called greenhouse gases, to the atmosphere at an alarming rate. While some gases, like carbon dioxide, are released into the atmosphere naturally, man-made gases called chlorofluorocarbons (CFCs) are emitted by human activity and supply the environment with extra greenhouse gases (Desonie, 2002). When in the atmosphere, greenhouse gases do not allow enough heat to escape, which then warms the planet and can introduce a substantial climate change (http://www.epa.gov/, 2008). This global warming can cause possible consequences such as the melting of polar ice caps and a rise in sea level which can lead to flooding and coastline erosions. It can also modify the duration of seasons and create droughts, increase the potential for storms, and bring disease from warmer climates to areas that are usually less susceptible (Desonie, 2002). International agencies such as the Intergovernmental Panel on Climate Change (IPCC) examine the potential causes of human-related climate change and attempt to understand the impacts through national inventories and other findings (http://www.ipcc-nggip.iges.or.jp/, 2008). Figure 1 shows the percentage of human-produced greenhouse gases that contribute to the heating of the atmosphere.
National agencies, such as the U.S. Environmental Protection Agency (EPA), also establish regulations to help reduce the greenhouse gas dilemma. In Figure 2, a comparison is made between regulated and non-regulated amounts of man-made greenhouse gas additions to the atmosphere.
According to the EPA, the average surface temperature of the Earth has increased by about 1.2 to 1.4°F in the last century and experts predict that this average could increase from 3.2 to 7.2°F by approximately the year 2100 (http://www.epa.gov/, 2008).

In order to regulate and make reductions to greenhouse gases as they continue to shape the environment, there must be an investigation into why they are becoming more abundant in the atmosphere. “Many scientists believe that global warming is the most serious threat to our planet. By 2025 the world's energy demand is projected to be 3.5 times greater than in 1990, with annual CO₂ emissions nearly 50 percent higher” (Desonie, 2002).

It is very important for us to understand the negative effects that this energy consumption has on our environment, however, it is also important to identify where the majority of this consumption is coming from. Cars, lighting and heating are all culprits in this issue. However, it is our buildings that contribute most to this global problem.

“In the United States alone, buildings account for 72% of electricity consumption, 39% of energy use, 38% of all carbon dioxide (CO₂) emissions, 40% of raw materials use, 30% of waste output (136 million tons annually), and 14% of potable water consumption” (http://www.usgbc.org/, 2008).

All are important in taking into account the amount of energy that is used. Unfortunately, today’s energy sources are widely taken for granted around the world and need to be greatly reduced. The reduction of energy that is consumed decreases the negative effect upon the environment.

“In the U.S., our energy-related activities account for three-quarters of our human-generated greenhouse gas emissions, mostly in the form of carbon dioxide emissions from burning fossil fuels. More than half the energy-related emissions come from large stationary sources such as power plants, while about a third comes from transportation” (http://www.epa.gov/, 2008).

So, how can the energy problem be resolved? Since the environmental dilemma is directly related to the amount of energy that humans consume on a daily basis, it becomes more imperative that changes must be made to conserve energy and produce less waste. To make these alterations and alleviate our damaging global impact on the environment, it is important for people to explore sustainable living and implement green technology before any permanent, detrimental transformations occur to the places in which we live.
2.1.1 Green Technology and Sustainability

Green technology can be defined as any application that can be utilized to diminish the expenditure of energy or reduce negative environmental impacts. Sustainable living is the practice of these applications in society. Green technologies have been innovated and designed for a variety of functions, which range from energy efficient light fixtures to green rooftop gardens, in order to make sustainability easier to accomplish. With the use of these technologies, society can meet the needs of the present without compromising future generations (Watts, 2008).

As research into sustainable building progresses, it is more evident that green technology must be a feasible option for all. These technologies are capable of being used individually, for those on a strict budget or who look to apply new tools over time, or simultaneously to obtain a decline in energy consumption and waste production. After all, the cost of some of the larger implementations is higher than their traditional counterparts, but the benefits far outweigh the price over time. The energy efficient and green products are also increasingly accessible and are not an uncommon commodity at the present time. In addition, the diversity of these products has the ability to range widely from small applications like energy efficient light bulbs and other household appliances, to large structural alterations such as solar panels or green rooftop gardens (http://www.epa.gov/, 2008).

Certain areas of the globe that are reliant on foreign energy sources are looking to the future of green technology and sustainability, the United States being one of these regions. Around the U.S., sustainable living has been receiving more attention and is gaining more momentum as time goes on and oil prices go up. Nationally, professionals are finding ways to make their areas of expertise more sustainable. For example, mechanical engineers are finding ways to optimize HVAC unit performance while simultaneously using minimal energy (A. Green, personal communication, February 3, 2009). On a local level, cities see sustainability initiatives as a means to simultaneously invest in the infrastructure, conserve energy, save money, and create a better situation for our ecosystem. Located in central Massachusetts, Worcester has an Energy Task Force that has been attempting to assess the opportunities to build a more sustainable community. Their objectives are to “create a step-by-step plan to reduce
energy consumption, reduce greenhouse gas emissions and increase the use of clean, renewable energy in a cost effective manner” (http://www.ci.worcester.ma.us/, 2008).

### 2.2 Worcester, Massachusetts and the Printer’s Building

The city of Worcester, known as the “Heart of the Commonwealth”, is located in central Massachusetts about 45 miles west of Boston. It was founded as a town in 1722 and later incorporated as a city in 1848. The city is the second largest in New England, with a population of just over 175,000. The Worcester area is attempting to rejuvenate itself from an old industrial state. Like many cities, it is difficult to ensure a trouble-free environment and maintain a high standard of living for every citizen. Despite some hardships that the city endures, it is a cultural community that is home to colleges and universities, businesses, and many historical sites. The downtown Worcester area has maintained its commercial stature over the years and many businesses, new and old, are located on or just off of Main Street that runs through the heart of Worcester. One of these buildings, just one block off of Main Street, is the Printer’s Building (http://www.davis-art.com/Portal/Home/HomeDefault.aspx, 2008).

#### 2.2.1 History of the Printer’s Building

The Printer’s Building is a seven story, concrete structure that is wrapped with large windows around all sides of the building. It is located on Portland Street in the Worcester downtown area, and was built in the early 1920’s, by Davis Press; a partnership of three printing companies founded in Worcester at the turn of the 20th century. Gilbert Gates Davis and the founding members of the Applied Arts Guild; Fred Daniels, James Hall, and Henry Bailey, started Davis Press with intentions of creating and publishing a document that would help guide art teachers in their development of a curriculum. The Printer’s Building was constructed in a way to create a system where both the printing and binding of their publications could be incorporated into the same facility. The building immediately became a model for industrial efficiency. Rather than printing in one building and then shipping it off to another company for binding, the product would stay within the single Printer’s Building. The products would be transported from floor to floor, going from the printing presses down to the binding equipment. This system allowed the product to move quicker from process to process. The Printer’s Building is one of two buildings that were built to withstand the loads that heavy printing and
binding equipment would put on the structure. As the tenants and the technologies changed over the years, the uses for the building have changed as well. Only one of the original printing presses still stands in the building today, but creativity and the idea of efficiency that these men used to create the Printer’s Building are still alive and growing (http://www.davis-art.com/Portal/Home/HomeDefault.aspx, 2008).

2.2.2 The Printer’s Building Today

The current Printer’s Building is home to a diverse group of companies. Davis Publications, the owner of the building, WICN (a public jazz radio station), an up-and-coming film company, and the non-profit Worcester Community Project Center (WCPC) are among the present occupants of the building. Davis Publication occupies a majority of the buildings space but supplies ample room for their tenants to effectively run their businesses. The radio station is located on the first floor, the film company is on the fifth and the WCPC is on the top floor. These operations do not occupy all of the space on the floors in which they are located. Davis uses one floor for office space and an ever-changing art gallery, one for their printing and binding operation, and another three floors for product storage. They use approximately 60% of their space for product storage (W. Wade, personal communication, November 12, 2008).

The WCPC was occupied by previous Worcester Polytechnic Institute students that were working on their Interactive Qualifying Projects towards the economic development of the Worcester community and the surrounding areas (http://www.davis-art.com/Portal/Home/HomeDefault.aspx, 2008). One project team was assigned to the advancement of the Printer’s Building’s electrical efficiency. This group focused on an energy audit of the building and created an existing conditions report of the facility. With this information, they were able to offer the owner of the Printer’s building information regarding short-term renovations or products that would improve the overall efficiency of the building.
2.2.3 Structural Considerations for the Printer’s Building

The building’s design and construction has long been outdated and is in desperate need of renovations. In order for the owner to get a better idea of where to begin renovations on the Printer’s building, an energy audit was proposed by the previous IQP group. This audit has given them information regarding the energy loss of different aspects of the building, such as the windows, roof, and masonry. With this information the previous team was able to formulate some feasible short-term ideas for products and renovations that the owner’s of the Printer’s Building could apply to their building within the next year or so. The large windows that cover all sides of the building are one of the main sources for the building’s heat loss. These windows are single paned, reinforced by a metal wire crosshatch and by modern standards are obsolete and provide no form of insulation for the building. Since most of the building’s exterior is covered by these windows, replacing them with state-of-the-art windows is one possibility. They will insulate the building from the outside conditions, whether it may be cold or hot. The owner has recently experimented with the idea of new windows. The owner has replaced one of the windows on the second floor of the building with a new high efficiency pilot window, which has been subjected to thermal tests by the previous IQP team. These tests examined the insulating properties of the new window versus the old. The team used an infrared thermal imager to find the temperature difference on either side of the window. From the team’s audit, they were able to find that there was a drastic change in temperature and consequent energy loss or savings (J. McKeag, personal communication, November 12, 2008).
The windows, although poor, are not the only problem that the building faces in terms of insulation. The masonry, generally over 80 years old, is also a problem. The concrete walls have been weathered and the owner has noticed small gaps, cracks and other small issues within the masonry. The walls were scanned and a masonry evaluation was done in 2006 that provided a cost estimate for the repairs of all flaws. The research team also recorded some thermal image readings of the area of the walls that surround the windows. It was determined that the seals around the windows are the weakest with regard to insulating the building. The team also looked at the thermal imaging results of the roof to determine how well the roof is insulating the building (J. McKeag, personal communication, November 12, 2008).

Davis Publications uses a majority of their space for product storage. This space is well organized and the products are spaced apart in a way that makes them accessible and easy to move. The only disadvantage of this setup is that it creates a lot of empty, unused space. The product storage has the potential to be consolidated to a smaller area, by looking into the feasibility of stacking the products, or organizing the product in a manner that allows them to be placed directly adjacent to one another rather than spread apart. This would give them the option of closing off one or more floors of the building. In addition to consolidation, if the building could be equipped with the proper heating, ventilation, and air conditioning (HVAC) system, they would have the capabilities to use what is called “zone” heating. Zone heating would allow the owner to set an appropriate temperature for those floors that are occupied by people or offices while reducing heat to floors that are unoccupied (P. Clay, personal communication, November 19, 2008). They would also have greater flexibility in finding new tenants to fill the space. The addition of a new tenant would add to their diversity and not only help the building flourish economically and socially, but help them financially.

2.2.4 Future of the Printer's Building

The owner’s vision for the future of the building is for it to become a contemporary “green” demonstration site for the Worcester community. They are focusing their efforts on the necessary aspects of the building that need to be renovated. This hard work is not just to reduce maintenance and utility costs, but to take that first step towards going “green”. They have a vision to continue the building’s reputation of being efficient by updating the building’s technology with state of the art systems. These products will update their building to modern
building standards and allow their company to be more efficient and economically sound. Furthermore, this decision is also in direct response to the global crisis that we face – and updating these technologies will be one small step toward slowing the building’s impact on the environment (W. Wade, personal communication, November 12, 2008). The Printer’s Building will not be the first of its kind to attempt a changeover to a sustainable, green building. There are many buildings around the nation that have successfully converted, and are reaping the benefits of going green.

2.3 Case Studies: Conversion of Old Buildings to Green Buildings

The new frontier of sustainable facilities has begun as large companies have invested substantial efforts into the construction of new, sustainable structures. Companies such as Hunter Industries and Testa/JAB are investing millions of dollars into the construction of new green headquarters for their corporations. These state-of-the-art facilities are trademarks of their respective companies and have many cutting edge technologies that have led to global recognition (http://www.bdcnetwork.com/article/CA6613459.html, 2008).

It is great to have a vision of a completely green society. However, it is also important to look at the buildings that exist in our city profiles and the feasibility of introducing green technology within them. Existing buildings today use an overwhelming amount of electricity and other forms of energy (http://www.usgbc.org, 2008). We have an obligation and opportunity to reduce these numbers through the implementation of sustainable technologies. With this responsibility comes the necessity of examining the advantages of green renovations and previous buildings similar to the Printer’s Building that have successfully made their buildings into LEED (Leadership in Energy and Environmental Design) certified facilities (http://www.usgbc.org, 2008). Whether or not a building is salvageable is a judgment call by the owner based upon their goals and objectives. No project is too large for renovations; it is a matter of how much capital the owner is willing to invest into the project. Many large renovations can be changed or aborted based on the actual construction of the project.

There are many incentives that make the renovation of a green building appealing to a property owner. First and foremost, the ability to save money on utilities and other energy costs is one of the best rewards offered to owners as it decreases expenditures. Also, a LEED certified
sustainable facility increases property value and improves the area it is situated in by minimizing its impact on the surrounding environment (O'Keefe, Babaian & Louis, 2007).

Another appealing incentive for owners is the ability to have control over the status of the building. LEED-EB (LEED-Existing Buildings) provides explicit measurements and standards in checklist form that an existing building must meet in order to obtain its LEED certification. This checklist includes action items that deal with sustainability, water efficiency, energy and atmosphere, material and resources and indoor environmental quality. Each of these categories has credits that are worth a point value. Although there are many credits that can be earned, there are some that are particularly applicable to the Printer’s Building such as storm water management, heat island reduction (roof), and optimization of energy efficiency (refer to Appendix A for the full LEED checklist). The building’s point value is summed and is then placed in a category. The categories, certified, silver, gold and platinum, dictate the level of sustainability that the building has attained (http://www.usgbc.org, 2008). By looking over this list and deciding what items they would like to implement, property owners can dictate the level of certification that is available and logical for their facility.

2.3.1 RiverEast Center

The RiverEast Center, located in Portland, Oregon on Portland’s Willamette River, is the redevelopment of a former warehouse into what is now an award winning office complex. This forty year old facility, bought by two companies (Group MacKenzie and Coaxis) was completely renovated into a sustainable structure that serves as a model to the area of Portland. One can draw many comparisons of this building to the Printer’s Building. In particular, the present storage space of the Printer’s Building can be made into an extension of office space to allow for new tenants. Also, the RiverEast Center is located near Portland’s mass-transit system and can easily be accessed by public transportation. Because of the Printer’s Building’s proximity to Main Street, one can expect an increase in the number of employees using public transportation to travel to work every day.

What makes this facility such an excellent example for the Printer’s Building are the actual appliances and procedures that are within the RiverEast Center’s walls. Due to the temperate climate and extensive rainfall in the Portland area, rainwater is collected and used for
toilet refill and flushing. This process, called gray-water because it can be treated and reused, saves water and money. Additionally, dual flush toilets, motion sensor faucets and low flow fixtures were installed to decrease water usage. Special motion-sensor light fixtures make sure that lights that do not need to be used are not in use. One interesting feature that may be of particular use to the Printer’s Building is the use of windows with a light glazing on the surface that keeps the inside of the building at the temperature dictated by the HVAC system. The facility uses glass panels to utilize natural light in conjunction with the structure’s heating system to capture solar heat and disperse it through the facility (http://www.jetsongreen.com/2008/02/old-warehouse-c.html, 2008).

These green components contributed to the awards won by the facility. The RiverEast Center is classified as a Gold Level Certification by LEED and was named the “Best Green Renovation of 2007” by Northwest Construction, a popular construction magazine published in the Northwestern United States. The facility completed its upgrade at a cost of $17 million for a usable square footage of 99,000. The RiverEast Center has similar structural elements to the Worcester Printer’s Building and now serves the same purpose that is the goal of our project’s sponsor (http://www.portlandonline.com/OSD, 2008).

2.3.2 Center for Neighborhood Technology

Another project that has successfully transformed an existing structure into a sustainable facility is the Center for Neighborhood Technology located in downtown North-side Chicago. This facility is an eighty-year old former textile mill that has now been recreated into a “Platinum” level certified green building. The occupant company, CNT, outgrew its floor space and was forced to either move or renovate. They decided to renovate and make their facility one of the most efficient green buildings in the United States. Because of the CNT’s green technological implementations, the building was able to cut its energy use by 50% and its water consumption by 30% (O'Keefe, Babaian & Louis, 2007).
This facility is remarkably similar to the Printer’s Building in many ways. Both buildings were industrial facilities before they were converted to office space. Also, both facilities were built in a similar time periods and in similar climates. This makes us believe that the structures can support the same green technologies because of the similarities in the original design of the buildings (http://building.cnt.org/, 2008).

There are a multitude of technologies that were implemented that could be of interest to the owner’s of the Printer’s Building as they select the technologies that they wish to include in their facility. One green aspect of the building that may interest the Printer’s Building’s owners is the use of a reflective roof. This lightly colored surface deflects the sun’s heat away from the structure instead of absorbing the rays and “accidentally” heating the building. If the owners of the Printer’s Building decide to incorporate the use of a green roof into their renovation, it is strongly suggested that they use the extra space as a reflective roof in order to gain further control over the ambient temperature of the facility. Additionally, because of the climate of Chicago, it was important for the CNT to insulate their building. This complete insulation reduces unneeded energy and oil costs that are a result of heat loss due to poor insulation. Another initiative that the Center for Neighborhood Technology undertakes is the composting of food that is discarded by the building’s employees. They use this composted food as fertilizer.
for the outdoor gardens. We believe that the Printer’s Building could use a similar process to fertilize their green roof (O’Keefe, Babaian & Louis, 2007).

These similar facilities were a great use for the Worcester Printer’s Building as it examines its renovation. We hope the Printer’s Building will serve as a model for other sustainable facilities, similar to the way that the RiverEast Center and the Center for Neighborhood Technology have served our proposal. We used these two case studies to give us an idea of places to start. It is evident that there are an abundance of technologies out there for buildings like the Printer’s Building to implement, but these replacement technologies do not come cheap. In our efforts to help the building take its first big step to converting to a green facility, our focus is on long-term technologies that increase the building efficiency as well as giving the building noticeably “green” qualities.

2.4 Evaluating Green Technologies

There are many technologies available that can help transform the Printer’s Building into a more efficient structure. The previous IQP team’s audit provided information regarding which short-term technologies would benefit the building immediately, such as high efficiency light bulbs, motion sensor lighting, and so forth. After discussing the possibilities with our project sponsor, we focused our research on two of the more significant and long term possibilities: retrofitted concrete insulation and the implementation of green roof technology. These two technologies are large renovations that will improve the sustainable status of the building. The green roof will also allow the Printers Building to take the first step towards their “green” changeover.

2.4.1 Retrofitted Concrete Insulation

In response to the current energy situation, one of the best ways to reduce energy costs and consumption of a facility is to have a building sufficiently insulated. There are numerous advantages to insulation including retention of warmth and cool air, decreased dependence upon fossil fuels, and general comfort of the building’s inhabitants. Old buildings, such as the Printer’s Building, are particularly susceptible to poor insulation due to their aged concrete walls. Due to this lack of adequate insulation, heat loss in the winter months is a direct factor of the elevated energy consumption and fuel costs of the Printer’s Building. Additionally, the loss of
cool air and gain of radiant heat during the summer months dramatically increases electricity usage – the driving force behind the building’s cooling system.

The previous IQP team conducted an energy audit of the Printer’s Building. This team identified the major flaws in the energy usage of the facility. During their audit of heat loss through walls and windows, they arrived at a surprising conclusion. Using a thermal imager, they were able to extrapolate that there was actually more heat being lost through the concrete masonry, especially the seal around the windows, than through the neighboring single-pane windows. This discovery probes the question as to what options are available for applying insulation to old, existing concrete walls.

There are two common ways to insulate the concrete walls of the Worcester Printer’s Building, interior and exterior insulation. The process for interior insulation is not extremely labor intensive and eliminates the need for scaffolding and other elevation equipment that would be required for exterior insulation. However, each set of insulation procedures has its own positives and negatives.

The methods used to install exterior insulation depend on the product that is selected by the owner. It should be noted that all exterior insulation contains several vital and similar features. They all must include a multi-inch layer of expanded polystyrene and a watertight sealant. Additionally, the product must be securely fastened to the exterior wall and it is essential that the product be installed correctly to ensure the environmental and operational benefits. The external insulation significantly increases the R-value of the building envelope; however, it is very labor intensive due necessary elevation equipment. In most forms of exterior insulation, the need for some sort of setup is required. The setup includes the installation of metallic studs that the exterior insulation is bolted to. It is also important that any flaws in the masonry be patched before the insulation covers it (Kilpatrick, 1999).

The exterior insulation benefits the building by acting as the first line of defense against the outside climate and as a thermal insulator, keeping the heat or cool air in the interior of the building. It also allows the building to achieve a more contemporary look with the variety of options available. Over time, the options have evolved to mimic almost any appearance desired.
by the owner. Some company’s products can cater to a wider range of detailing, which makes them more appealing to prospective product buyers (Buildings, 2008).

The first technique for interior insulation is semi-permeable foam that is sprayed directly to the back of the concrete wall. It is vital that the foam is in direct contact with the wall leaving no area for moisture collection behind the masonry. If installed correctly, any moisture that seeps through the concrete is controlled and not allowed to collect. Instead, the natural vapor barrier rejects most of the moisture back into the masonry and is then naturally dispersed back out of the masonry into the surrounding air. The remaining moisture that is absorbed by the foam is dispersed through the foam and the interior fixtures. The installation of the foam is very important and must be accompanied by a series of structural and fire-proofing elements such as a metallic stud wall and a thermal barrier respectively. Lastly, drywall is hung as an interior finish (Straube & Schumacher, 2007).

Another technique of internal insulation is called rigid foam board. Rigid foam board consists of a material called expanded polystyrene and is synonymous with the material used for insulated concrete forms (ICFs). Similar to the sprayed foam, it is vital that this foam board make a direct bond with the concrete it will eventually insulate. This can be done using a resin that bonds the concrete to the foam board (Lozowski & Ondrey, 2006). The advantage to these rigid foam boards is the simplicity of installation. The boards are dovetailed in order for the pieces to fit together easily and effectively (Wasieleski, 2007).

At the School of Architecture located at the University of Waterloo, Ontario, rigid foam board was used to insulate parts of the building. Pictured below, this facility is somewhat similar to the Printer’s Building in that it has multiple floors and large windows.
While there are many benefits for interior insulation, there are many potential problems. One of the issues that must be examined is the propensity for increased moisture content in the masonry. Because of the semi-permeability of the insulation, some moisture is recycled back into the masonry. This problem is called freeze-thaw deterioration (Barista, 2006). When the concrete becomes saturated with moisture and exposed to freezing temperatures, the concrete experiences high internal pressures due to the expanding properties of water. These pressures create micro-fractures that lead to the exposition of the aggregate and sometimes complete deterioration (Barista, 2006).

As an addition to the freeze-thaw deterioration, the concrete wall may experience new, colder temperatures. Before installation, the concrete blocks will have had drastic differences in temperature on either side of the wall. With the new insulation on the interior, the concrete wall will have close to constant temperature throughout the wall. This could pose potential problems in that the interior of the wall could experience some freezing and thawing that it has not experienced before. Because the concrete masonry is load-bearing, it is imperative that its structural integrity is not compromised. It may be necessary to have a structural audit performed to ensure that the concrete is capable of this temperature change (Straube & Schumacher, 2007).


2.4.2 Green Roof Technology

Cutting down on energy consumption and limiting the harmful effects of human development is becoming more of a standard in structural design. The highest importance is placed on designing structures that are both energy efficient and eco-friendly. There are numerous green technologies that can be incorporated into new building construction and building renovation. Of these technologies, only one really captures the idea of what being a green building is all about: green roofs.

![East Hall, Worcester Polytechnic Institute, Worcester, MA](http://www.wpi.edu/About/Sustainability/, 2008)

**Figure 6:** East Hall, Worcester Polytechnic Institute, Worcester, MA (Source: http://www.wpi.edu/About/Sustainability/, 2008)

Green roofs are not a new green technology and have been used for many years all around the world. The earliest documented green roofs were located in present day Syria. They were the hanging gardens of Babylon and considered one of the seven ancient wonders (Earth Pledge, 2005). Modern day green roofs originated close to the turn of the 20th century in Germany. The Germans found that the green roofs were very effective in thwarting the damaging effects of solar radiation and that the buildings equipped with green roofs proved to double as fire retardant structures. Reasoning for the implementation of green roofs can be traced back to the growing environmental concerns in the 1970s. This movement was pivotal in giving green roofs their debut in the cities of Germany. In fact, green roofs have become so successful in Germany that the government has gone as far as making laws that require the use of green roofs in some urban settings (Oberndorfer, 2007).
Green roofs are characterized as roofs with a vegetated surface and substrate that provide a service for the ecosystem in an urban setting (Oberndorfer, 2007). Green roofs are very diverse structures and can have many different looks. There are two extremes of green roofs: intensive and extensive. These are simply the two opposite ends of the green roof spectrum. A green roof can incorporate the ideals of both, which in turn helps to make each green roof unique. Intensive roofs typically contain a larger variety of vegetation including the potential for vegetable gardens and can support small trees and shrubs. The soil depth is usually greater than eight inches and because of this, requires a high structural roof capacity. To go along with the added support, the installation price tag for these roofs is usually higher than that of its counterpart (Earth Pledge, 2005). However, the view that an intensive roof provides is quite spectacular for the occupants and surrounding neighbors due to its ability to contain a variety of botanic life. Extensive roofs are much simpler in their design and only support plant life similar to that of a field. The components of the extensive roof are an insulation layer, a waterproofing membrane, a layer of growing medium, and a vegetation layer. In contrast, the soil is only between three to eight inches deep, which deals a smaller structural burden to the host building. Extensive roofs are primarily used in locations where the need for hearty, low maintenance plants is paramount. Also, the installation price can be significantly less than an intensive roof (O’Keefe, 2008).

There are many factors that influence the decision of which green roof is right for our application. The first and most important aspect to consider when building a green roof is the structural integrity of the building. The weight of the fully saturated soil and the relative weight of the vegetation should be considered when calculating a structural analysis (Oberndorfer, 2007). Determining if it is financially feasible to construct a green roof on building is essential. If the building requires ample amounts of materials or work to get it to support the weight of the green roof it is unlikely to be a sound investment. Remodeling a building to support a green roof is much more difficult than building it from scratch. After determining if a green roof is feasible, it is imperative that the building process be overseen. Constantly checking and inspecting the installation of the waterproofing membrane and performing a complete flooding of the roof before any green components are installed are key checks to ensure a functional green roof (O’Keefe, 2008).
The components that go into the green roof should be reviewed with great care. Selecting the proper vegetation and substrate are of extreme importance. The variety of plant life is directly correlated to the depth of the soil; the deeper the soil, the more diverse the vegetation. Many studies have been performed since the 1980s, and low-growing sedum species are the most successful vegetation in extensive green roofs. The substrate involved in green roofs contains high levels of minerals and small amounts of organic matter. Climate also has a huge impact on the types of vegetation used in green roofs. It is very important to pick proper plants for the region. As a general environmental practice, the use of native plants is ideal for green roofs. Due to the harsh roof environment, in some cases it is more difficult to follow this practice (Oberndorfer, 2007).

The benefits of green roofs can be broken down into three main categories: better storm water management, energy conservation, and an increase of urban wildlife habitat. In an urban landscape, rainwater runoff can become a serious problem. There is usually minimal vegetation that can slow the deluge of water coming from cities. Green roofs alleviate the problem by absorbing the precipitation and storing it in the soil and then releasing the water after the storm and the initial runoff has run its course (Oberndorfer, 2007). This reduces the load on the city drainage system as well as prevents too much water overwhelming wastewater treatment plants. The vegetation of a green roof also helps to trap contaminants that could potentially get into drinking sources (Earth Pledge, 2005).

Buildings have a significant impact on the urban ecosystem and green roofs can help lessen the negative impact that the buildings have through a variety of energy saving means. By using a white membrane, along with the coverage of the vegetation, energy usage to cool the building in the summer drastically decreases. An added benefit of a white membrane is that it reflects UV rays, which helps to lengthen the life of the building’s roof (Oberndorfer, 2007). Urban researchers declare that, “during the summer, urban areas are often 2°F to 8°F hotter than surrounding areas, a phenomenon known as urban heat island effect” (Earth Pledge, 2005). The vegetation helps to eliminate the effects of an urban heat island by providing relief from the abundance of dark, impermeable surfaces.

Green roofs support and conserve urban habitats. The most common visitors to green roofs are insects, but some nesting birds also call them home. Green roofs can be the driving
force of biodiversity in urban environments. However, green roofs are not limited to supporting insects and avian species; they are also renowned for their aesthetic appeal and psychological benefits to the urban settlers (Oberndorfer, 2007).

Weighing out the pros and cons of green roofs is the first and last decision made before installation. Though there are a few drawbacks to green roofs such as a relatively high initial price tag due to the cost of special materials, the potential to pay for any maintenance of the installed plants, and the cost to make the building structurally able to support the green roof, the list in favor of implementing one is much more impressive. By installing a green roof there is endless potential to decrease the heating and cooling costs of the building, reduce storm-water runoff, provide better aesthetics for surrounding buildings, possible tax credits, increased roof life, improved air quality, and the potential for social benefits by improving the public relations of the building. The many benefits of installing a green roof make it the answer for eco-friendly urban life (O’Keefe, 2008).

2.5 Summary

The information included in this Literature Review provides a setting for, and insight to long-term implementations of green technology for use by the Printer’s Building in Worcester, Massachusetts. The presented research will be used to identify and suggest feasible alternatives in the attempt to conserve energy and maintain a sustainable building. The procedure for putting the investigation into these aspects to use will be shown in the next chapter: Methodology.
Chapter 3: Methodology

This chapter details the methods for the successful completion of this project. The following subsections describe the procedures used in order to complete each goal. This Interactive Qualifying Project offers a guide for Wyatt Wade, Davis Publication, and the Printer’s Building to follow in their efforts to become a sustainable facility. The objectives of our proposal were to analyze the previous group’s audit, examine the structural integrity of the building, construct a model as a visual for the recommendations to our sponsor and provide our sponsor with a three and five year feasibility/action plan. These plans offer our sponsor larger scale, long-term renovations to implement a green roof and new concrete insulation. Additionally, these plans inform them about the cost and payback analysis of the renovations and the social benefits of converting their facility.

An integral part of the methodology for this project is the many interviews that were conducted in order to make sufficient, long-term recommendations for the green technologies that will be implemented into the Printer’s Building. This process also entailed weekly meetings with our sponsor and building owner, Mr. Wade, as well as the building superintendent, Jim McKeag. We ensured that they were both well-informed with the progress of our work and notified about any changes or new ideas that were presented during the term. We began by focusing on the examination of the information collected by the current IQP group.

3.1 Analyzed Previous Energy Audit

In September of 2008, a research team from WPI began working with the Printer’s Building and Mr. Wade to determine what smaller scale green technologies could be implemented. They spent seven weeks on site, evaluating the energy deficiencies in the building and compiling the energy consumption data. Through meetings with this group, we gained a better understanding of the premise of their project. The examination of their research and final conclusions were our first priority, in order to avoid repeating anything that this group already completed. Although we knew the basics of their findings, we took a deeper look into their work to decide whether or not their findings were sufficient enough to support our project, or if further investigation was warranted. We examined, organized and recalculated their utility usage data and forwarded their CAD drawings on to the building superintendent for his use.
3.2 Analyzed Building Documentation

We researched reports and other studies of retrofitted concrete insulation to examine how other similar facilities dealt with the multitude of problems that can arise in a concrete construction. We spent a considerable amount of time in the first few weeks gathering information about these possible flaws. Our primary research included academic journals and case studies that have either examined or experienced these stresses. Using this research, we identified the focus of the journals and case studies and compared them to the Printer’s Building. Upon arriving at the Printer’s Building, we obtained the building blueprints and a masonry report that was conducted in 2006. These documents were used to explain the basic building layout and masonry status of the building in our interviews.

3.3 Interviews

Through our discussions with Mr. Wade and the previous IQP group, our goal was to arrive at a conclusion that stated whether concrete insulation and the implementation of green roof technologies were the two technologies that would ensure energy efficiency and a positive environmental impact on the Worcester Printer’s Building. In our evaluation, we examined the positives and negatives while seeking professional opinions regarding these two technologies.

Our schedule consisted of conducting interviews within the first three weeks that we were working in the Printer’s Building. This series of interviews with professionals familiar with the Worcester area were important to discuss each aspect of our project. Our interviews consisted of meeting with an insulation specialist, a construction manager, two green roof specialists, two LEED Accredited Professionals, and two sales associates.

<table>
<thead>
<tr>
<th>Contact</th>
<th>Expertise</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bob Morus</td>
<td>Insulation Specialist</td>
<td>January 15, 2009</td>
</tr>
<tr>
<td>Ron Thomas</td>
<td>Construction Manager</td>
<td>January 30, 2009</td>
</tr>
<tr>
<td>Neil Benner</td>
<td>Green Roof Specialist</td>
<td>January 30, 2009</td>
</tr>
<tr>
<td>Jared Markham</td>
<td>Green Roof Specialist</td>
<td>February 2, 2009</td>
</tr>
<tr>
<td>Mike MacEachern &amp; Alan Green</td>
<td>LEED Professionals</td>
<td>February 3, 2009</td>
</tr>
<tr>
<td>Betty Davis</td>
<td>Sales Associate-Dryvit®</td>
<td>February 4, 2009</td>
</tr>
<tr>
<td>John Rogers</td>
<td>Sales Associate-Centria®</td>
<td>February 4, 2009</td>
</tr>
</tbody>
</table>

**Table 1: Interview Schedule**
An insulation specialist and a construction manager with experience in retrofitted concrete insulation were our primary contacts for this technology. Our goal in meeting with these professionals was to obtain as much expertise as possible as well as to receive a professional opinion regarding the feasibility of installation. Our discussion also included alternative solutions that could limit or negate these issues. The meeting consisted of a sit-down interview that included brainstorming alternatives to portions of the installation in addition to a discussion regarding the criticality of the freeze-thaw stresses that may occur within the concrete blocks.

We first got in touch with an insulation specialist who has experience insulating concrete. This interview required an in-depth consultation in which we asked the specialist to give us feedback on a range of topics. These included the availability of concrete insulation subcontractors and labor, different methods that other facilities have implemented, alternatives to expanded polystyrene foam-board, a rough cost estimate, an estimated length of work and how much the Printer’s Building will benefit from the insulation.

In our interview with the construction manager or project engineer, we discussed the feasibility of concrete insulation as well as alternatives to this process. Also, we needed to obtain a rough estimate of how much the installation would cost. The construction manager’s insight would give our group well-rounded, objective insight to the completion of this project. We conducted a personal interview that comprised of a discussion regarding feasibility, a cost estimate and alternatives. The conjunction of these interviews was vital for determining any potential problems for the Printer’s Building as it upgrades its insulation.

Part of our project description was to look in depth into green roof technology. To further gain insight on this topic we contacted green roof specialists that would be able to help us understand this renovation further. We identified that we needed to talk to two professionals, one who was experienced with the construction of green roofs and another that was well-informed on the components of a green roof system.

In our interview with the construction manager with green roof experience, we focused our questions specifically around the cost of installation of a green roof. Obtaining this information was vital to our cost/payback analysis of green roof implementation. In addition,
we inquired about any construction issues that had risen in the construction manager’s experience. We also asked the exact same questions to the construction manager with retrofit experience in order to cross reference the two responses and formulate a more educated recommendation.

Our next task was to learn more about the components of a green roof system. Before going into this interview, we researched several different green roof systems, familiarizing ourselves with several installation techniques. We then contacted a sales associate of a local green roof vendor familiar with the Worcester community. Our inquiries focused mostly on what a green roof can bring to the building environmentally and socially as well as the constituents of the vendor’s system.

Following these interviews, we focused our attention on LEED Accredited Professionals. These professionals are trained and educated to design structures by using eco-friendly equipment and materials. In this interview we anticipated to gain knowledge on several green insulation techniques and discuss possibilities that the Worcester Printer’s Building could implement in their goal to be a sustainable landmark. We prepared for this interview by carefully reading through LEED Rating Systems supplied by the United States Green Building Council and bringing a LEED checklist in which to discuss what credits were feasible for the Printer’s Building. Additionally, we prepared questions for the professionals that were designed to learn about the details of green roof technology, specifically cost, storm water management and the mitigation of urban heat island effect.

Throughout our discussions with the construction managers there were two exterior insulation vendors that were consistently mentioned. Eventually, our group recommended one of these products as a practical solution to the building’s insulation deficiency. To learn more about each product, we contacted representatives from each company to request information packets. With the given product information, we were able to comb through the specifications and make well-informed decisions regarding product selection.

3.4 Viable Green Technologies

As the Printer’s Building aspires to become a green building, it is important not to overlook the products that will eventually become part of this sustainable facility. It is important
for us to make sure that the recommendations we make are both beneficial for the health of the occupants, the wellbeing of the community and the green progression of the building. We conducted independent research to find insulation alternatives with green properties. This research includes examinations of case-studies and specific inquiries about green insulation in our interviews with our selected experts. We compared our findings and selected the best alternatives based on effectiveness, cost, and overall “green” qualities.

3.5 Social Footprint

Since the Printer’s Building is to someday be a model for green technology in the downtown area of Worcester, our group explored adaptive reuse in the Worcester community through field research. The two facilities that we toured were the Sprinkler Factory and the Lamoureux-Pagano. The purpose of these tours was to determine how buildings similar to that of the Printer’s Building were refurbished and observe how their respective tenants utilized their allotted space. We also documented the tenants’ recommendations for improvements of their work areas. We presented these recommendations to Jim McKeag and collectively considered their application to the Printer’s Building.

3.6 Educational Tools

Visual aids are powerful tools that promote awareness and education. One of the criteria of a LEED certified building is to educate the occupants and guests of the building. An example of this can be found on the grounds of WPI in the new dormitory East Hall. The building uses pylons that explain and identify the various green technologies that are implemented on each floor. To bring this concept to the Printer’s Building, we constructed a model of the green roof technology that we recommended. Next to the model is a description of each component that is illustrated in the model (see Appendix A).

In addition to the model, we compiled two product binders that contained all of the information about the products that were researched. We provided a means to guide the building superintendent in determining which products he felt were most appropriate for application to the building. Furthermore, we created a data CD containing all of the CAD files, pictures, documents, PDFs and other materials that outlined the energy usage and condition of the
building. The binders and data CD were presented to our sponsor at the culmination of the project.

3.7 Cost/Payback

The Printer’s Building, similar to any company, has a cost of operation. We investigated the energy consumption of the building over the past few years by analyzing the previous team’s findings and looked for any trends that would be helpful to our research. We also focused on the expenses that the energy usage placed on the Printer’s Building and calculated an average operating cost for the Printer’s Building on a monthly and yearly basis. Our objective was to recommend the implementation of technologies that would save them the most money in the long run. Using the figures from our findings, we were able to prepare a cost and payback analysis to present to our sponsor.

In order to determine the feasibility of implementing the selected technologies into the Printer’s Building we had to conduct a cost and payback analysis of the multiple scenarios and then compare. The total renovation of the building envelope was the ultimate goal of the owner, but due to budget constraints it was necessary to find the technology that was the most pertinent and cost effective at the current time. After researching and acquiring all the necessary literature on all the product lines recommended by the professionals, we searched for all the information that would be needed in order to conduct the analysis. This information was compiled and organized in a Microsoft Excel spreadsheet (see Appendix B) which was used to complete all the necessary calculations. One formula we used for the calculation of the cost/payback analysis was found on the Department of Energy website. The other formula was generated by our group as a practicality check.

3.8 Formulated Timeline for Implementation

The final contribution to the completion of the project is to devise a three and five year plan for our sponsor. This is a guide for them to follow in order to be financially able to implement these technologies over the ensuing years. Although there are budget constraints placed on the project, we formulated our analysis on the building’s expenses using an assumed budget. This is a plan that is well suited for their financial situation. We gathered all of the research, data and results during the seven-week process and have provided our sponsor with an
accurate and useful timeline that illustrates a cost, time and sequence plan that can facilitate their goal of becoming a sustainable facility.

3.9 Project Time Schedule

The following table details our group’s achievements throughout the seven week term. Our procedures included setting up interviews and tours, analyzing the previous audits, conducting the interviews and tours, constructing a visual model and providing our sponsor with a long-term plan.

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<td>Formulate 3 and 5 Year Plans</td>
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Table 2: Project Time Schedule
Chapter 4: Results

In this chapter we will discuss the relevant information collected through the methods presented in the preceding chapter. This data explains and supports the proposed long-term renovations. The following sections present all information that will support our recommendations.

4.1 Building from Previous IQP

After careful examination and analysis of the previous IQP, one of the most important concepts was to avoid overlap in the information that had been presented before us. We found that much of the previous IQP had relevant details that coincided with our project and we were careful not to recreate these areas. Instead, we were able to obtain the necessary information from the previous material and use it to improve our understanding and draw conclusions that could later be introduced in our recommendations for the Printer’s Building. Specifically, the previous IQP was most helpful in supplying the approximate utility usage of the building and Computer Aided Design (CAD) files.

The utility usage data of the Printer’s Building was compiled in order to visualize the recorded expenditures. According to the information, we recognized that there was not a particular trend due to the loss and gain of tenants over periods of time. Our own calculation was done that affirmed our initial results. We decided that the utility usage over two calendar years, from 2006 to 2008, would be sufficient since it would provide current information and eliminate most of the fluctuations caused by different numbers of tenants.

The separate averages between gas and electric usage over the two years yielded a better trend to be utilized for the energy analysis. According to the averages, the gas usage, as expected, peaked in the colder months at a maximum of approximately 10,000 Therms but dropped drastically to a minimum of about 50 Therms in the hotter months. At an average cost of seventy-five cents per Therm, this resulted in an average cost of heating of approximately $28,000 per year. The electricity usage was relatively constant over the course of the year around $6,000. This, in turn, produced an approximate cost of electric use at $73,000 per year.
The CAD files that were received from the previous IQP group, as mentioned in the Methodology chapter, were passed along to Jim McKeag. These renderings were inserted into a program in order to create a dimensional analysis regarding the amount of energy being used. The projected results of this modeling process provided our group with a more precise depiction of the amount of energy that was being lost throughout the building. From this, more accurate recommendations could be made.

4.2 Building Documentation

Before starting major research on green implementations that would be specific to the Printer’s Building, our group needed an extensive visual regarding its current condition and its layout. As a primary investigation of the Printer’s Building, we took a walkthrough of the facility and documented any visible flaws with photographs and considered certain areas that may or may not require the benefits of a long-term renovation. Along the evaluation we discovered that the walls, both inside and out, were in a rough state and one side or the other would need a very effective insulation.

Figure 7: Interior Masonry of Printer’s Building, Window Sill

The photographs further supported our initial assumptions by providing a way to look back and observe smaller details that may have otherwise been missed. The next few walkthroughs were concentrated on the roof and top floor where we found unused ventilation stacks that had been
closed off. If removed the unused stacks would create more area to be used up by our recommended green implementations such as the green roof. These assessments were very helpful but were not the only source of building information that produced results for our utilization.

4.2.1 Blueprints

Documentation of the Printer’s Building was acquired and put to use in ways that yielded the most valuable results. Blueprints were used to find and calculate square footages of the building, its surface area, and the area of the windows for a comparison ratio.

![Figure 8: Typical Floor Plan of Printer's Building](Courtesy of Jim McKeag)

The total surface area of the building was calculated to be 46,290 square feet and the surface area covered by windows was 15,440 square feet. This gave a ratio of windows to total surface area equaling 33%. We were able to forward this information to Jim McKeag as numerical evidence
that the building was covered in a significant amount of windows and he was able to use this ratio for an individual project that he was working on. The blueprints also aided our evaluation of the existing roof for determining possible placements for the palletized green roof system. Our group found the location of the concrete support structures, leading us to create potential designs for the green roof layout.

![Figure 9: Green Roof Layouts](image)

In each plan the pallets are arranged so as to be directing their weight over the supports of the building. This would substantially alleviate the threat of failure due to overcapacity.

### 4.2.2 Masonry Report

Another source of supportive information was a masonry report that was obtained in the early stages of our time spent at the Printer’s Building. This document was used as another means to assess the concrete. The entire report was brought to interviews with professionals as a way to depict the condition of the masonry on the building with its contents.
In addition to a summary of observations, photographic evidence of the diminishing condition of the masonry was incorporated in this piece of literature.

![Photograph of exterior masonry of Printer's Building]

**Figure 10: Exterior Masonry of Printer's Building**

This concurred with the pictures taken by our group in the numerous walkthroughs. There are labels located on the photographs that show frequent occurrences of cracks, spalls, and efflorescence on all sides of the building. We found that the cracking is mostly due to freeze-thaw cycles, a process in which water freezes and exerts pressure on the concrete. The spalls are most likely from the expansion due to corrosion of reinforcing steel causing chunks of concrete to break off. The efflorescence, a fine, powdery white substance, is caused by water entering the concrete. This is all verification for the implementation of an exterior insulation that will not only seal the building off and keep tenants comfortable on the inside, but also improve the look and condition of the outer surface of the building.

Also in the report is a remedial cost opinion worksheet (see Appendix C) for the repair of the masonry and replacement of the windows. This was done in 2006 and projects a total cost, including trade and related costs, of $2,073,812. The replacement of only the windows was calculated to be $586,715 and only the masonry to be about $388,750. Three years have passed since the time of this cost opinion so we regenerated the numbers with a multiplicative factor of 1.034. This factor is a compounded yearly percentage increase in construction costs. The window replacement now stands at a projected cost of $606,663 and the masonry repair, with
added contingency of $50,000, at a projected $473,188. These numbers were then used in cost/payback calculations for the green renovations.

4.3 Interviews

This section is the compilation of the multiple interviews we conducted over the course of our project. Each segment includes the professional views and recommendations of the specialists we conversed with. Their opinions were the main basis for our final recommendation.

4.3.1 Insulation Specialist

Contacting and setting up a phone interview with the insulation specialist was essential for getting the information we needed about various types and installation processes of insulations. The insulation specialist was very knowledgeable in his trade and was recognized by the Printer’s Building superintendent, Jim McKeag, as the foremost insulation specialist in the Worcester area. Talking with the insulation specialist was the foundation for our recommendations.

4.3.1.1 Bob Morus

Bob works for Heatsavers, located in Worcester. Being from and working in the Worcester community, he was already familiar with the location and condition of the Printer’s Building. It was very convenient and beneficial that Bob already knew how the building was heated with a steam system and that the exterior masonry was in poor condition. The significance of the steam heating system was pivotal for our recommendations. We discussed the hardships and impracticality of insulating the building from the inside due to the waste of materials trying to accommodate the steam piping and bulky radiators. Also, interior insulation was suggested as a secondary approach due to the concern of attracting tenants and the condition of the exterior masonry: potential tenants would be able to see the changes on the building without entering the building. With this in mind Bob referred EIFS (Exterior Insulation Finishing System) or more commonly known as outsulation. The product he told us to investigate was the Dryvit® Outsulation® system. Bob gave us a brief description of the system and how it was probably the most logical insulation technique for the building. He mentioned that the Dryvit® Outsulation® systems were as expensive as brick at approximately $5 to $8 per
square foot, but also came with an additional set-up cost for installation. Also, he presented that there were cheaper forms of insulation, which are cellulose sprays. Bob made certain that we knew cellulose spray technology is not typically applicable to a project of this scale. Another reason for his hesitation in applying the cellulose spray is the fact that it doesn’t have as high of an R-value as outsulation products. As an alternative, he said that the Outsulation® systems typically can be installed with a sealant coat that mimics the look of stucco to vary the appearance and come pre-mixed with a range of 1\text{mm} to 3\text{mm} aggregate for aesthetics. Our interview concluded with Bob reiterating his support of an EIFS system for the Printer’s Building.

4.3.2 Construction Manager

Contacting the construction manager was essential for getting the information we needed about various methods and installation processes of insulation. We expected to receive analysis and recommendations regarding the construction feasibility of making renovations to an existing concrete structure.

4.3.2.1 Ron Thomas

In our interview with Ron Thomas, construction project manager for O’Connor Constructors, we focused on the feasibility of installing internal insulation that would directly attach to the concrete walls. Our interview began by familiarizing Ron with the facility by showing him the masonry report and giving him information about the building such as tenants, parking and the availability of the freight elevator. Also, we inquired about any experience that Ron had with respect to renovation or LEED certified construction projects. He mentioned that he worked on a four story elementary school in South Attleboro, Massachusetts named the Thatcher School that involved installing partitions and demolishing concrete. He also said he had no experience working with LEED certification.

Ron seemed to believe that internal insulation would be most fitting for this project because of the high construction. He estimated that the scaffolding needed to install external insulation could reach up to $400,000 and would require a crew of laborers that are solely responsible for the erection and maintenance of the scaffolding. With internal insulation and a
freight elevator, materials and labor would be able to be transported up to the specified floor and installed using a rolling stage (a piece of equipment that the Printer’s Building owns).

Next, we moved on to possible insulation materials that would be applicable to this facility. The first material that Ron mentioned was fiberglass because of its price. It is the cheapest of the available materials yet its downfall lies in its susceptibility to water damage. Another material Ron mentioned was expanded polystyrene foam board. This material is easy to install and is a healthier and greener alternative to fiberglass, however, it is a more costly investment. Ron also suggested that consulting the Building Code for Worcester would allow our sponsor to identify what thickness of insulation would work best for the facility.

Regardless of the insulation material selected, Ron estimated that the total cost for the internal insulation to be about \$8 per square foot, not including labor costs. Typically, labor costs would vary depending on the size of the labor force, assigned to the installation, the time of year and the availability of work.

Lastly, we asked Ron about the environmental or health issues that could be raised by the installation of the insulation. He referenced his experience with the Thatcher School in that all cutting adjustments to the insulation had to be made in a controlled setting as to limit the amount of airborne particles of insulation.

Overall, Ron’s interview gave us solid information regarding internal insulation. His insight on labor trends and scaffolding costs gave us a good background on which to compare to external insulation techniques.

4.3.3 Green Roof Specialists

To ensure that we covered every aspect of the green roof we found it appropriate to interview with two green roof specialists. Both of these specialists were very helpful in our data collection on green roofs and offered solutions to any problems that could arise in green roof installation.
4.3.3.1 Neil Benner

Neil is already known around the WPI community for his work on the green roof of the new East Hall dormitory, the soon-to-be LEED certified dormitory on WPI’s main campus. He is employed with Gilbane Construction and was very excited about another green roof project in the Worcester area. Having worked in the Worcester area he was also familiar with the Printer’s Building. When he was informed about our proposal for the building, Neil also said that the cellulose spray was not applicable to this project. We used this information as another opinion, but the focus of the interview was Neil’s knowledge of green roofs and their construction. Neil asserted that the very first information needed for construction of green roof is an engineer evaluation of the capacity of the roof. Without this information he said that it is impractical to suggest implementing a green roof, but didn’t foresee any inabilities in implementation when he was informed that the roof was a six inch concrete slab. He stated that a green roof is a two product system for maximal environmental benefits to be obtained: a regular roof and a PVC white membrane. For the white membrane he suggested a Sarnafil white membrane and commended their products rating them extremely effective.

When he was told that the building was a seven story structure he immediately mentioned that there would be problems with high construction. The need for lifts and ample room for the large hoisting machinery lead Neil to the suggestion of a palletized green roof. He said that the palletized system was the most logical decision because of the availability of the freight elevator in the building. When we asked Neil for a cost estimate he said that the price range was $5 to $15 per square foot depending on the depth of soil of the palletized system. For additional price information and palletized green roof options he gave us Jared Markham’s contact information. We continued the interview with our questions about the installation of the green roof and asked if there were any particular areas of concern. Neil identified that most important construction aspect for a palletized green roof is field dimensioning or pre measuring the space in which the pallets are intended to be placed. When we asked what typical problems arose in installations of the green roofs he said that the lack of field dimensioning and the need to have more sponsor involvement in the placement of the pallets were the main issues.

The next set of questions was about the functionality of the system when it was in place. Focusing on the water retention function of the green roof, we asked if any modifications were
need to the building’s drainage system. He said that the existing drainage system should be sufficient and that no additional precautions were necessary. The conclusion of our interview with Neil was about his suggestions for appropriate vegetation. He said that picking botanic life that could withstand low water conditions was imperative. With this in mind he said that sedums were always used and chives were also utilized and thrived in the Worcester climate.

4.3.3.2 Jared Markham

Jared was referred by Neil Benner as a palletized green roof specialist. He is an employee of GreenGrid® Roofs, located in Connecticut. We were in contact with Jared through a series of emails during the first three weeks of the project. He is a graduate of Clark University and was also very familiar with the Worcester area. In our correspondences we sent him pictures of the roof. From looking at the photos Jared said that the palletized system was the best candidate for the job, but the gravel that is scattered on the roof had to be removed before installation. He said the project has the potential to help conserve energy, particularly during the summer months when the green roof can reduce roof temperatures dramatically versus a standard rubber roof. Jared also said that in the winter the green roof provides additional thermal mass and would reduce peaks and valleys in daily temperatures. Additionally, he stated that the green roof could produce a significant reduction (40-60% annually for a standard 4" system) in runoff from the greened areas. Jared stressed that the roof definitely needed to be prepared before considering applying any green roof system. When we mentioned the Sarnafil system, he was able to vouch for the reputation given by Neil Benner. Through further contact with Jared, he sent us ample literature on the GreenGrid® palletized green roof system. The literature included the options for the palletized system, payback information, and a rough estimate of the cost per square foot.

4.3.4 LEED Professionals

Our interviews with the LEED Accredited Professionals were helpful in benchmarking the ability for the Printer’s Building to be altered from an energy inefficient facility to a sustainable landmark in the heart of Worcester. These discussions gave us perspective as to how much work is needed to complete this changeover.
Mike MacEachern and Alan Green

One of the fundamental requirements of our project involves making recommendations to our sponsor that are sustainable renovations. Because of this specification by our sponsor, we conducted an interview with two LEED Accredited Professionals that gave us educated recommendations and professional opinions on the feasibility of renovating the building while achieving LEED points in hopes of becoming a sustainable facility.

Mike MacEachern, a senior architectural designer and Alan Green, a mechanical engineer, are LEED APs who work at the Wakefield branch of AECOM Water, an international engineering, construction and architectural firm. These individuals were selected based upon years of experience and exemplary business practice. We began our interview by familiarizing our interviewees with our project background and overall goals. We stated that Wyatt Wade would like to make his facility a sustainable landmark for the downtown Worcester area. We also stressed that funding was at a premium for the Printer’s Building and that we were focused on larger scale projects, as opposed to smaller scale projects that were the focus of the previous IQP team.

First and foremost, Mike and Alan directed our attention to a different, more appropriate LEED accreditation guideline. Previously, we had been comparing the Printer’s Building to LEED-Existing Buildings, a guideline designed for facilities that have been fully renovated and are now trying to achieve a level of LEED accreditation. The two professionals mutually agreed that we should shift our focus to LEED Core and Shell, an accreditation guideline designed for renovations of older, dilapidated facilities that are looking to be renewed into sustainable, eco-friendly buildings. By inquiring about their professional backgrounds we found that of the two, Alan was the most experienced with renovation projects having worked primarily with HVAC units on a three story office building.

After printing out a copy of the LEED Core and Shell checklist (see Appendix D), we showed Alan and Mike the existing masonry report and our own photo documentation of the facility. This allowed them to become familiar with the building, particularly the exterior, interior walls, windows and roof. From there, we worked our way through the LEED Core and Shell checklist, discussing what renovations could fulfill certain requirements and earn points.
Mike, a senior architectural designer, said that this technique was the typical protocol to identify what buildings could support what technologies.

We projected that the facility would get considerable points in the “Sustainable Sites” category. One area that building could succeed in is Alternative Transportation as it is very close to a form of public transportation, the Worcester Regional Transit Authority buses. Additionally, there are plenty of rooms in the basement that could be transformed into men’s and women’s changing rooms and bicycle storage closets. Also, assuming the green roof is implemented, it will earn points fulfilling the Stormwater Design: Quantity Control and the Heat Island Effect: Roof credit. As we went through, we noticed a few credits that will be very hard for the Printer’s Building to attain such as Heat Island Effect: Non-roof and Alternative Transportation: Parking Capacity.

![LEED Accredited Professionals Logo](http://www.buildinggreen.com, 2009)

Next, we moved on to Water Efficiency, an area that our project does not necessarily cover. However, the previous IQP’s recommendations may be able to earn points in this subsection. In the Energy and Atmosphere section, Alan and Mike warned us that this section is usually the hardest to attain points as it is based upon a constantly evolving benchmarking system set by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). One of the required credits such as “Fundamental Commissioning of the Building Energy Systems” is notoriously expensive. Also, the Printer’s Building would have to increase its energy performance by 3.5%, a statistic that could be easily attained by the implementation of our recommendations.
Similar to the “Sustainable Sites” category, Alan and Mike projected that the Printer’s Building has great opportunity to capitalize on points in the category of “Materials and Resources”. By reusing most of the facility’s existing walls and floors in addition to reusing existing materials, the building could earn up to three points. Moreover, by recycling waste, managing construction waste and using regional materials for construction, the building could earn substantial credits.

In the section of “Indoor Environmental Quality”, Mike stressed that good ventilation and insulation could help in achieving credits. Mike and Alan agreed that this section would be tough to attain points, particularly Thermal Comfort, without the installation of some sort of insulation. However, the advantage of having close to a third of the building covered in windows could lead to points in Daylight and Views. Also, careful selection of finishing materials could lead to points in the categories of Low-Emitting Materials.

Lastly, Alan and Mike suggested that our sponsor encourage Whipple Contractors, a construction management firm located in the Printer’s Building, to employ a LEED Accredited Professional as an on-site LEED AP generates a point for the structure. Not only would this be good for the building, but also helpful for the next IQP that may need advice from a LEED AP.

After going through the LEED Core and Shell checklist, we moved on to our questions. We asked Mike about his experiences of Dryvit® and Centria® insulation products from the perspective of an architect. He told us that Centria® is generally regarded as a superior product, however it is more costly. Also, Centria® has a more contemporary look due to its metallic finish. According to Mike, the Dryvit® system experienced issues with water penetration about a decade ago but believed that the system had solved this problem. Dryvit® also has the ability to be sculpted to better contour the original features of the building, giving the owner more control of the aesthetics of the building.
One of the technologies that our sponsor recommended that we look into was pervious pavement technology for the repaving of the building’s parking lot. We asked Mike about any projects that he had worked on that specified for permeable pavement. He was encouraged by the fact that a downtown facility would be interested in using this water management technology. However, he did stress that the pavement does not directly affect the building itself and may be a renovation that is implemented later. His justification for this opinion was based on a few important characteristics of pervious pavement. He mentioned that the pervious pavement on average cost $8 to $10 dollars per square foot, about three times more than regular pavement. Also, he mentioned that the combination of the freeze-thaw climate of Worcester and the commercial traffic at the loading dock may cause failure of the pavement. He added that a possible benefit of waiting to install this pavement is that there may be improvements in the technology that will specialize in heavy loads in freeze-thaw climates.
Before the interview ended, Alan gave us some information regarding a new heating and cooling system that would be ideal for the Printer’s Building. This device, called a Modulating Condensing Boiler (ModCons), reduces the water temperature needed to heat specified areas, therefore reducing energy costs. Although this technology does not directly pertain to our project, it may be of use to Jim McKeag. This information has been compiled onto our Data CD and has been forwarded to Jim.

4.3.5 Sales Associates

The sales associates were crucial in getting the information for the two main outsulation systems that we are recommending for the Printer’s Building. Without their product packages, we would not have the documentation we needed to complete our project.

4.3.5.1 Betty Davis-Dryvit®

The first company we contacted for the outsulation system was Dryvit®. Although we were only in contact with the sales associate, Betty, for a few days, the information we received from her was extremely significant in our project. We received a package in the mail filled with product information regarding the Dryvit® system that detailed the components and function of the insulation system. From that we were able to calculate all the necessary information we needed for the cost/payback section of our project.

4.3.5.2 John Rogers-Centria®

Through contacting the sales department at Centria®, we were able to get the contact information for John Rogers. Communications with John were elusive at first, but after a week we were able to get through to him at his office. After explaining to him the premise of the project, we gave him our mailing information and he sent us a binder with an extensive compilation of the Centria® outsulation products. The product that he suggested would be the most effective for a project like the Printer’s Building was the Versawall® product line. With this product binder, finding the required information to complete the cost/payback segment presented no difficulty.
4.4 Recommended Technologies

This section describes the information that we received and deemed appropriate for application to the Printer’s Building. These products are outlined, detailed and broken down into their effectiveness, cost and overall green qualities.

4.4.1 Dryvit®

We were first exposed to the Dryvit® external insulation product in by Bob Morus. In our phone interview, we asked him to recommend any insulation technique that had a low environmental impact while still offering a product that would significantly improve the building’s envelope. While meeting with the construction managers, LEED APs and Mike Pagano, we asked about their experiences with the product. They all seemed to agree that the product is cheaper than most alternatives but may sacrifice some thermal insulation, may require more maintenance and had moisture penetration issues in the past. However, this product does allow the owner to have more control over the final appearance of his or her building, something that may be important to our sponsor when our sponsor is selecting a product to install.

![Dryvit® Logo](http://www.dryvit.com, 2009)

The Dryvit® Outsulation® product line is the simplest, least costly and most experienced insulation technique offered by the Dryvit® Outsulation® systems. Our contacts estimated the product to be about $20 per square foot as opposed to its counterpart Centria®, estimated at approximately $23.

The product is made of a series of layers each serving a certain purpose in the whole wall system. First, the product is attached to the existing masonry by C-shaped metallic studs located 16-inches on-center. Next, a layer of climate approved substrate is attached to the studs. These two layers act as the backbone for the insulation as all layers depend on the structural integrity of
these two materials. A fiberglass reinforced “Dryvit® Adhesive” is then applied that acts as a waterproof barrier, wall reinforcement apparatus and a bonding agent for the 3 to 4-inch expanded polystyrene foam that is the heart of the insulation system. This thickness of EPS provides an R-value between 12 and 16, an enormous upgrade from the Printer’s Building insulation rating. The next layer begins the finishing system that provides the exterior appearance to the building. A wire mesh network is embedded in a base coat that acts as a primer for the Dryvit® finish that is selected by the owner. Lastly, at joints and edges, the insulation system is protected by a watertight sealant.

Our project focuses on making recommendations that have green, eco-friendly qualities. Dryvit®’s self-proclaimed motto is “As Green as it Gets”. Dryvit® claims that on average their systems can save a building almost 20% of energy costs, thereby decreasing the consumption of fossil fuels and reducing the amount of carbon dioxide in the atmosphere. Additionally, Dryvit®’s five-step manufacturing process is monitored by ISO 14001-2004, an environmental management guideline that ensures minimum energy consumption while still offering a quality product. One negative characteristic of Dryvit® is its lack of recycled material. Though a green system, the product seems to fall behind in this aspect, a feature that should not be overlooked when examining green renovations.

Dryvit®’s ability to conform to the aesthetic appearance of the existing building is second to none. Located in downtown Worcester, the Printer’s Building still contains its original
exterior and has been a fixture on Portland Street for almost 90 years. Preserving this rustic look may be of the utmost importance to the owner of the building. Dryvit®’s exterior finishing systems come in a great number of options, allowing the facility to preserve its original façade and texture.

Overall, Dryvit® offers a product that achieves similar to Centria® in energy savings and environmental benefits. Additionally, Dryvit® offers the ability to easily conform to the specifications of the owner regarding exterior appearance. However, Centria® is widely considered by professionals to be a superior product.

4.4.2 Centria®

The Centria® products were first recommended to us by Neil Benner as an alternative to the Dryvit® Outsulation® systems. What drew us to this system is its solid reputation for high efficiency and unsurpassed green qualities. It was also a product line that offered the Printer’s Building a drastic appearance change as well as immense energy improvement.

![Centria® Logo](http://www.centria.com, 2009)

The outsulation products of Centria® can be described as insulated metal composite wall systems. There are two products that Centria® offers for jobs similar to that of the Printer’s Building: Versawall® and Versapanel®. This project focuses on the use of Versawall®, which was recommended by John Rogers as the most effective for this project. All subsequent calculations are based off the retrofit of this product. The metal composite panels of Versawall® are formed with a galvanized steel face and lining with preformed joinery and thick, rigid CFC-free (chlorofluorocarbons) foam insulation.
The panels are installed quickly and in any weather conditions, in contrast to other forms of outsulation like Dryvit® that requires particular weather conditions to be installed. The weather tight, double tongue-and-groove vertical joinery with factory-applied non-curing vapor-resistant sealant provides a complete air and vapor barrier. This characteristic of Versawall® is a very attractive feature because it ensures that no mold can grow behind the retrofitted external insulation system. The Dryvit® insulation system had these issues in the past. Not having to worry about this issue brings financial ease of mind of owners because of the security of the product’s integrity.

Aesthetically, a concealed clip fastening system offers a clean uninterrupted look to the panels. Also, the thermal break prevents conduction between face and liner panels, which gives this system such a high R-value. These R-values for the systems range from R-15 at 2 inch to R-27 at 4 inch thick panels. The values are incomparable to the existing R-value of two. The panels are lightweight and strong, and are capable of spanning vast lengths. Typically, the panels come in 36 foot spans, but are able to reach up to 40 feet. For variety the panels have three looks striated, planked, and flat. To further diversify and make any building truly unique, the panels come in over 70 different colors including micas and metallics. The only concern that the Printer’s Building will have with this system is the fact that it will change the appearance of the building. Owner, Wyatt Wade, will have the final say if the Printer’s Building will be modernized by implementing the Versawall® system.
The system is far superior to the other outsulation products, but also has the highest price tag with a cost of $23 per square foot. The substantial cost is attributable to its high effectiveness and the company’s extra effort for utilizing recyclable material.

The green qualities of the Versawall® system are quite impressive. The product boasts the ability to supply a long-lasting, energy efficient wall that is comprised of significant levels of recycled materials. The Versawall® line is made of 100% recyclable steel and with the system in place it drastically decreases energy consumption of the facility. Also, the CFC-free foam insulation does not harm the ozone layer, and the use of any other harmful products is completely eliminated.

4.4.3 Weston Solutions: GreenGrid® Roofs

As we looked at possibilities for the green roof, we recognized the need for a versatile product that was able to accommodate to the eccentricities of an existing roof. This green roof would need to be able to work its way around vents and other equipment that are stationed on the roof. After exploring a few green roof systems, our team settled on the Weston Solutions GreenGrid® Roof System. This is a palletized module system that has a variety of module sizes
and depths. Its versatility was unmatched compared to other systems. Additionally, this system has also been successfully installed on the roof of the new residence hall at WPI, East Hall.

![GreenGrid® Roof Logo](http://www.greengridroofs.com, 2009)

Figure 19: GreenGrid® Roof Logo

The existing roof system is the structural base for the modules. In the Printer’s Building, the base layer is a 6-inch thick layer of reinforced concrete. On top of the reinforced concrete is the existing rooftop. This roof is a five-ply system consisting of coal, tar, pitch, felt and slag. This type of roofing is typical to other building roofs in the surrounding area and will most likely need to be touched up to avoid leaks. The modules are comprised of layers that sit upon the top of the existing roof and serve a purpose in the overall makeup of the system.

The thermoplastic membrane is one of the most important aspects of the green roof. It serves multiple purposes that are all vital to the total package of the GreenGrid® system. First and foremost, the white membrane reflects sunlight away from the roof in the warmer months and insulates the building in the colder months. This aspect of the system can potentially earn valuable LEED points as it reduces urban heat island effect. The membrane is made up of a material called thermoplastic polyolefin which also acts as a root barrier that protects the bottom layers from deep root systems produced by the vegetation.

The next layer is an insulating material that will prevent heat from escaping in the winter and keep cool air in during the summer. GreenGrid® employs an insulating layer in every pallet to help in seal the building’s envelope. Unlike the exterior insulation materials we researched, expanded polystyrene is strongly discouraged due to its propensity to absorb water.

On top of the insulation is the drainage system, this intricate layer is divided into two parts, a corrugated plastic drain that is under a mesh cover. The plastic drain allows for equal dispersion of rainwater that hydrates the soil which supports the vegetation. The drain also
directs excess water to the roof drain, reducing roof flooding and run-off. The upper mesh layer serves as a barrier for the growing medium above. Because the drainage system depends on the constant, unrestrained flow of water, it is important that no medium clogs the drain and forces water to collect.

The growing medium is synthetic high mineral content dirt made of both organic and inorganic material that also contains expanded clay. This gives the rooftop vegetation a strong foothold in preparation for the harsh environment of a rooftop.

Grown within the medium is the vegetation. These plants are the namesake of the green roof; however, careful selection of the vegetation is vital to the life of the green roof. In an extensive green roof system, plants must require minimal to no maintenance. Therefore, robust, native plants must be used to ensure that the rooftop horticulture survives under particularly intense weather conditions typical to a rooftop environment. Our data led us to find that chives and sedum are particularly successful in our climate. They have been successfully been in use since the opening of East Hall.

The GreenGrid® system has many advantages that are not as easily offered as other green roof systems. First of all, and most applicable to the Printer’s Building, is the lightweight features of the pallets. The 2½-inch growing medium model only adds 11 to 13 psf (wet) to the
existing roof. This feature is very attractive to the building in that the roof is roughly 70 years old. It is imperative that the roof have sufficient structural capacity to hold the added weight of the pallets, therefore, a green roof system that does not burden the structure with excess weight is ideal for our recommendations. Additionally, the GreenGrid® system offers easy installation with pre-planted, ready-to-place pallets. Because each model is 2 ft x 2 ft, the labor involved in placing each model is minimal. The transportation of the pallets will be aided by the availability of the building’s freight elevator.

The mobility of the modules also offers great opportunity for maintenance and repairs in case of incidental damage. Furthermore, the transportable pallets allow for the owner to shift the modules into desired locations, a great feature for a facility that may need to temporarily move them. Also, the materials that the roof systems are made of all contain recycled materials that contribute to LEED certification points.

Environmentally, GreenGrid® roofing systems offer equal benefits to their traditional, built-in-place counterparts. GreenGrid® systems claim to detain and hold up to 90% of a 1-inch rainstorm. Moreover, green roof systems can detain approximately 50% of all annual precipitation. By retaining this water and covering a portion of the roof with the pallets, the Printer’s Building could potentially reduce its stormwater runoff impact by 25% to 30%.

The GreenGrid® pallets, in conjunction with the installation of a white thermoplastic membrane, can also significantly reduce the building’s urban heat island effect. This is a result of the black tar roofing systems radiating solar heat back into the surrounding atmosphere. The green roof and white membrane reflect the sun’s energy, resulting in a cooler surrounding area. A study completed by the University of Central Florida noticed a 35 degrees Fahrenheit difference at midday between a green roof and a typical black tar roofing system.

Seen below, our group produced a replica of a typical green roof pallet. Made completely of plywood, our model shows a cross section of the module with a description of each layer. Our group hopes that this model will prove to be an educational tool for the tenants and visitors of the Printer’s Building.
4.5 Social Footprint: Examining Adaptive Reuse

One of the important aspects of our project was to look into spaces that include the similar qualities to those of the Printer’s Building. We looked to find buildings that were alike in age and floor layout. This allowed for accurate comparisons to be made and offered us ideas of how others have used similar spaces. From this study we also gained insight of how certain spaces were meant to be used by a select group of tenants. The primary qualities that were focused were mainly found in the factory or mill style construction which was found in abundance throughout Worcester. The only problem was to find a building like the Printer’s Building that has been renovated and is currently being reused in a way that is successful and would make sense to implement into the Printer’s Building.

The Printer’s Building has close to 60 percent of its building dedicated to product storage or unused space. Most of these spaces have not been updated and the products or items stored in these areas have potential to be consolidated to a smaller space. They have an opportunity to open up some new space throughout the building, allowing them to bring in a variety of new tenants. We collected, as previously mentioned, CAD drawings of the individual floors of the Printer’s Building that detail how each space is used. In addition, we increased our knowledge by walking through the building to familiarize ourselves with the way certain spaces were used. Since the original use of the building was for the operation of large printing presses, the layout of
the building offers large open floor space. Although over time some of this floor space has been divided into sections by partitions, as shown in the various CAD drawings, each subdivision has ample space and plenty of natural lighting provided by the large bay windows on every side of the building. After becoming more knowledgeable of the building and its qualities, we found helpful sites that we used to draw direct comparisons from.

We established two useful interviews and tours of buildings that were adaptively reused into successful spaces; these two buildings are the Sprinkler Factory and Lamoureux-Pagano Associates, both located in the Worcester area.

4.5.1 The Sprinkler Factory

The Sprinkler Factory was built just over a century ago and is located on 38 Harlow Street in Worcester, MA. The Sprinkler Factory was just that, a 225,000 square foot factory that manufactured sprinkler systems right around the time of World War II. The current sprinkler head design also known as the “waterfog nozzle” was invented by Howard Freeman, a Worcester Polytechnic Institute Alumni and then an employee of the Rockwood Sprinkler Company during the World War II era. His design was specifically used for the purpose of fighting fires on the U.S. ships during the war (http://www.worcesterhistory.org/enterprise-4b-freeman.html).

Figure 22: Exterior: The Sprinkler Factory, Worcester, MA
Since the building had such a rich historic background, the current owner, Paul Conga, had trouble deciding what to use the building for and it was left untouched for many years. He knew that the charm of the building should not be altered but also wanted the space to be used and maintained. Over the past decade, the owner rented out space for local artists to use as a studio and small creative businesses to run their company. He soon realized that this was what the building needed and these types of tenants were meant to be in a space like this. It also allowed the creativity that the building once had to stay alive and give it room to grow. The building is now home to upwards of 18 studio spaces and 15 small companies.

![Figure 23: Main Atrium: The Sprinkler Factory, Worcester, MA](image)

The photo above is the main atrium, which is used as the gallery space for the many exhibits put on periodically by the tenants. By touring through the building, we found that the original shell of the structure was not altered in any way other than for basic maintenance. The windows and perimeter walls are all original as well as the roof and sprinkler systems. The owner felt that these aspects of the building should not be changed in order to maintain the historic appeal. As shown in the picture above, there are two large blowers that heat the main area. These blowers were one of the more recent installments put in by the owner. Although the owner does what he can to keep the tenants happy, he has handed the reins over to many of the current tenants. It has allowed them to become more independent when it comes to the operation the building. He has entrusted them with the job to maintain and attract new occupants. They
have created brochures, flyers, and even a website to advertise their space as well as relying on word of mouth.

The first impression of the building and the renovations after moving past the main hall was that this was not our vision for the Printer’s Building. Although we found that some of the newer spaces were sectioned off by stud and brace sheetrock partitions, most of the original studio spaces were sectioned off by plywood dividers. A few spaces had dead bolted doors but some were sealed off with plywood sheets on hinges that were padlocked shut. The walls of the spaces were either bare or used as a canvas for the artists to paint on. Most of the floors are the original wood boards. The more commonly traveled areas have been sanded down and resurfaced to provide viable floor space.

![Image: Example of Older Studio Space: The Sprinkler Factory, Worcester, MA](image)

**Figure 24:** Example of Older Studio Space: The Sprinkler Factory, Worcester, MA

After talking with two of the current tenants, we were able to gain some insight as to why the building functions the way it does. We were able to discuss some of our first impressions and questions we had about the renovations among our group. From this we formulated pros and cons regarding the building. Although our first impression of the empty studio spaces for rent was negative, we quickly learned that this was how all the spaces look when a new artist comes into the space. The spaces ranged from 200 to 600 square feet in size and started at $200 a month. The rent included wireless internet and parking. The building parking lot allowed for many people to park whether it may be tenants or customers. The artists come into a room
which they can consider their own “blank canvas” or a space they are free to do what they want with. It promotes creativity and individuality while creating a sense of ownership which leads to a better appreciation for the building in general. The reason that the space is so successful is due to the fact that all the tenants are supportive and connected with one another. Although their arts and professions are different, they are all accepting and appreciative of each other’s passions.

We learned about certain spaces being meant for a particular style of person. In addition, we found out how a place can promote community within the walls of a single building. Even though there were many positives, we were able identify other aspects of the building that we would not like to see at the Printer’s Building. The Sprinkler Factory is an example of an adaptively reused building. However, the Printer’s Building is striving to be a more energy efficient or “greener” facility, which the Sprinkler Factory is not currently focusing on. Since the structure has not been touched, other than for small maintenance purposes, the insulating properties of the original roof, walls, and windows are very poor. The industrial space heaters that were installed are blowing heat into the building at a rapid rate. Due to the meager insulation that the building has, the heat is escaping at about the same rate as it goes in. We went around and felt the temperatures of the walls and noticed that they were about as cold as the temperature outside. Overall, the building is energy inefficient, but the tenants are able to afford and use their spaces effectively.

4.5.2 Lamoureux-Pagano Associates, Architects

The next building that we looked at was the facility in which the architectural firm Lamoureux-Pagano Associates is running their business. The building, located on East Worcester Street in Worcester, is about 40,000 square feet and was built in the past century. It was originally used as a warehouse space for pharmaceutical products and its location in relation to the railroad was helpful for its success at the time. The location now is ideal because it is just off of Shrewsbury Street which is one of the more traveled areas in Worcester; it also is very close to downtown.
The building is currently shared amongst multiple companies, but Lamoureux-Pagano has acquired and occupied the entire third floor as they have expanded over the last 30 years. The building’s exterior has not been altered other than for minor changes in the masonry or for basic maintenance to preserve the structural integrity of the building. The owner of this building had a different outlook on how to renovate their space in comparison to that of the Sprinkler Factory. We found that even though the firm wanted to maintain the exterior brick work, they still made efforts in order to compensate for the lack of insulation in the walls by installing a new roof and windows.
This photo shows the main office areas that offer spaces to about 15 employees as well as a space for a library. As mentioned before, Lamoureux-Pagano wanted the original brick masonry to remain, so all the interior perimeter walls are simply painted brick. Since the floor layout is similar to that of the Printer’s Building, they faced problems that the Printer’s Building will have to overcome. The windows in Lamoureux-Pagano although smaller than the Printer’s Building, supply a majority of the light for the office space during the daytime hours. The design of the cubicle walls that enclose each space stand about 4 feet in height which allow for a private but communal feel. They were also designed in a manner that optimized the use of the natural light rather than artificial lighting. The suspended light fixtures use more energy efficient bulbs and are used only when necessary. There were more offices that offered a more private feel to them but the half walls were maintained. The walls of these private offices stood just over head height. This allowed them to gain the privacy aspect they desired while letting the light from the windows inside these spaces to pour into the common spaces that were neighboring them.

Our first impression of the Lamoureux-Pagano space and their renovations were that this was what the Printer’s Building should strive to create in their available spaces. The renovations were constructed well, creative, aesthetically pleasing, and they optimized the buildings key aspects. We were able to sit down with Mr. Pagano and ask him a few questions in relation to the building itself and any advice he had for how to reuse spaces similar to that of the Printer’s Building. We learned that people usually know just by looking at an empty space that it is the place for them. In addition, spaces that are reused are typically more successful when the least amount of renovation is needed to be done to the facility of focus. For example, transforming a space in the Printer’s Building to a restaurant would involve a significant amount of time, money and labor with no guarantee that it would pay for itself in the end. The overall understanding we gathered from the interview was that the owner of the Printer’s Building needs to decide who will be in the allotted spaces and what the spaces should be used for.

4.5.3 Compare and Contrast

After reviewing the interview notes and the data collected from the tour of each facility we were able to compile the things we liked and disliked about each building. We learned a lot
about how the proper tenants create a sense of community within a building, resulting in a positive inhabitance. We thought that the idea of the “blank canvas” used in the Sprinkler Factory would work well in the Printer’s Building. It creates a sense of ownership which will ultimately result in a greater respect for their personal space. Reasons being that the cost of renovations would be lower and the tenants would be attracted to said spaces

4.6 Cost/Payback

Through conducting the necessary research and collecting the required values needed for the calculations, we were able to make accurate estimates on the amount of time it would take to payback these technologies solely on the savings from utilities. We assumed the value for cost per Therm at $0.7, the lowest recorded value on the building’s natural gas bill from the past two years. The average Therms per year was about 37,000 Therms and the average cost of electricity per year was about $73,000. After briefly researching the significance and the meaning of an R-value, we approximated the insulation properties of the structure in its current state. The building has 8 inch concrete panel exterior walls which have an insulating R-value of about 1. This is a result of the thickness and the fact that they are solid concrete. The existing 6 inch concrete, coal, tar, pitch, felt and slag roof is estimated to have an R-value of 3. The single paneled windows have an R-value of about 1 due to their age and the poor quality of sealant. The new high efficiency double paneled window that has replaced one of the old windows was tested to have a U-factor of .35 winter night-time and .33 winter day-time. This correlates to an R-value of 2.86 and 3.03 respectively because U-values and R-values are reciprocals. All values were approximated using the insulating U-factor values gathered for a specified material or materials. For a section with multiple layers we added the respective numbers to get a total value for the section.

After looking into the values regarding the existing conditions of the building, we focused our attention on the cost and insulation properties of each product. By reading through the product literature, we learned that the Centria®-Versawall® product was best suited for the Printer’s Building and had a cost of about $23 per square foot with an insulating R-value of 15. We had to take note of the fact that the cost per square foot did not take into account for the necessary masonry repairs, preparatory work that needed to be done, or the cost to put up the
required scaffolding for the job. We were able to estimate a total cost per square foot to be about $38 including all the miscellaneous costs to install. In comparison we found that the best product from the Dryvit® line, Dryvit® Outsulation®, had a cost of $20 per square foot and an insulating R-value of 12. Similar to Centria®, the cost estimate only reflected the materials and construction, not the scaffolding or prep work that needed to be done. We estimated this product to cost about $35 per square foot when all these costs are factored in. All the previously mentioned values are shown in the table below for comparison.

<table>
<thead>
<tr>
<th>R-Value</th>
<th>Cost per sq. ft. (Materials)</th>
<th>Cost per sq. ft. (Miscellaneous)</th>
<th>Total Cost per sq. ft.</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centria® Versawall®</td>
<td>15</td>
<td>$23</td>
<td>~ $15</td>
<td>~ $38</td>
</tr>
<tr>
<td>Dryvit® Outsulation®</td>
<td>12</td>
<td>$20</td>
<td>~ $15</td>
<td>~ $35</td>
</tr>
</tbody>
</table>

Table 3: Comparing Cost and R-Value of the two Selected Insulation Products

The following graphs describe how the change in natural gas cost per Therm will affect the years it will take to payback the specified products. The first shows the payback period or years to payback (YTP) of the selected insulation product with the current singled paned windows, while the second graph shows the payback period if both the insulation and new windows were installed.

Figure 27: Years to Payback: Insulation While Keeping Current Windows
The approximate amount of years it would take to payback either of the products with the current windows would be 17-19 years. It would take about 31-33 years for the products with new windows to pay for themselves. As seen in the graphs the amount of years decreases exponentially as the cost per Therm increases. This shows the drastic change in the timeframe it would take to payback either of the two products. Although $4 per Therm is an extreme, the inconsistencies in gas and oil prices over the past few years have shown that there is no real prediction as to where it will be in a year from now. These figures also give the owner an idea as to how similar the products are in cost.

Using two separate equations to calculate the payback periods for the various products, we found the years to payback each product and an approximate percent of savings on utilities that the implementations will provide. By comparing the values of each equation, we determined that both of the selected insulation products will save the building about 56 percent on its total utility bill.

We then focused our attention on the information regarding the existing roof, a replacement roof, and the green roof. As stated above, the five ply roof currently on the building has an estimated R-value of about 3 due to the multiple layers. This does not take into account the identified flaws of the roof. Following this, we acquired information about the possibility of a replacement roof for the building from George Barnard, a roofing specialist that was referred to
us by Jim McKeag. He spoke with us briefly and was able to estimate that the cost for a replacement roof would be approximately $150,000 or $13 per square foot, including all costs for the job. This roof would comprise of a 2.5 inch layer of insulation under the top sealant coat, which would give the roof an R-value of about 18. Finally, we retrieved the information needed from the GreenGrid® palletized green roof system product literature. The selected system for the Printer’s Building was the 2 foot by 2 foot by 4 inch (1 inch of insulation) pallets. This specific pallet has a cost of about $10 per square foot and offers the building an insulating R-value of about 10. As mentioned previously, we used the blueprints of the building to create three different layouts that focused the weight of the systems over the columns of the building using the GreenGrid® products. The table below shows the values for comparison purposes.

<table>
<thead>
<tr>
<th></th>
<th>R-Value</th>
<th>Area Covered</th>
<th>Total Cost per sq. ft.</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Existing Roof</strong></td>
<td>3</td>
<td>11653 sq. ft.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Replacement Roof</strong></td>
<td>18</td>
<td>11653 sq. ft.</td>
<td>$\sim 13$</td>
<td>$150,000$</td>
</tr>
<tr>
<td><strong>GreenGrid® Layout # 1</strong></td>
<td>10</td>
<td>2520 sq. ft.</td>
<td>$10$</td>
<td>$25,200$</td>
</tr>
<tr>
<td><strong>GreenGrid® Layout # 2</strong></td>
<td>10</td>
<td>3072 sq. ft.</td>
<td>$10$</td>
<td>$30,720$</td>
</tr>
<tr>
<td><strong>GreenGrid® Layout # 3</strong></td>
<td>10</td>
<td>4800 sq. ft.</td>
<td>$10$</td>
<td>$48,000$</td>
</tr>
</tbody>
</table>

Table 4: Comparing Cost and R-Value of the Roof Options

The payback period of installing a replacement roof is about 6 to 7 years. This allows for small fluctuation in energy costs and in the rough estimate cost that was given to us by the roof specialist. The payback period for the three GreenGrid® layouts range from 1.5 to 2.5 years to payback due to the small amount of coverage.

The findings gathered from the cost and payback analysis done on the selected products allowed us to make educated recommendations to our sponsor.
Chapter 5: Recommendations and Conclusions

The purpose of this project was to determine the feasibility of implementing long-term green technologies into the Worcester Printer’s Building. Ultimately, the Printer’s Building would like to become a sustainable and energy efficient facility as well as a landmark in the Worcester community. In order to complete this goal we formulated a series of objectives. The first of which was to analyze and build upon the previously conducted IQP. This was done to prevent any overlap in the projects and to provide ourselves with a solid base on which we could conduct our research. The second objective was to find green technologies applicable to the building and to become more knowledgeable about these technologies through professional assistance and independent research. Once we identified the applicable technologies we provided the means to educate our sponsor and the other occupants of the building about these products. The last objective was to provide a three and five year feasibility/action plan that will guide our sponsor in his aspiration to become a sustainable landmark. After completing these objectives, we were able to formulate recommendations for the Printer’s Building even though we encountered set-backs that forced us to reevaluate our data collection techniques.

Recommendations

We have formulated many recommendations for the Printer’s Building in regards to the two large technologies which we have proposed to them at the commencement of the project. We recommend that they utilize the educational tools that we have created and compiled for their benefit. The product binders offer all current information about each product including documents that explain the inner working of each technology, insulation properties, sizing, and other specifications. It also provides information that discusses the installation process and the multiple options available. However, with the rapid advancement of technology, especially innovation within the field of sustainability, it is of the utmost importance that the Printer’s Building keeps these educational tools up to date. These tools will be extremely helpful to our sponsor but over time will eventually lose their educational value.
Educational Tools

We hope that our green roof model will not only serve as an educational tool, but also as a visual motivator for Wyatt in order to inspire him to fulfill our plan. As mentioned previously, we strongly encourage our sponsor to keep up to date with the Product Binder, recording any technological advances that occur within the fields of external insulation and green roof technology.

3 & 5 Year Plan

Furthermore, in the next three years, we would like to see our sponsor create a separate account solely for the purpose of large renovations. Our team believes that over time, this account will grow to the point where large green renovations are a possibility for the building. Also, included within the Data CD that we provided are templates that are designed to organize future utility records. We encourage the Printer’s Building to begin documenting all utility bills. These templates, made in Microsoft Excel, will allow our sponsor to input the information on each bill and visualize trends that occur month to month and year to year. We would also like our sponsor to identify one renovation, whether it is windows, insulation or green roof and start working towards getting that one project done. The Printer’s Building has many opportunities for renovation; however, it is vital that they recognize one project to address at a time.

Over the next five years, we would like our sponsor to become more aggressive to get new tenants to inhabit the building. The benefits of getting more tenants into the Printer’s Building include the ability to gain more capital that can be invested into the large renovation account. We would like our sponsor to sell the space that he has, this means that the Printer’s Building needs to know who they want in a tenant, what they want in a tenant and be sure to advertise their available space.

Feasibility

Presently, regarding the insulation and green roof technologies, we do not believe that either renovation is a feasible implementation. As mentioned in our cost and payback analysis findings section, a renovation that has a payback period of over ten years is not a wise investment. Right now, at about seventy cents per Therm, the external insulation renovations
have payback periods are about seventeen to nineteen years, not including the new windows which drastically increase the payback periods to over thirty years. As the cost per Therm increases, the payback period decreases exponentially, making the renovations more reasonable. Regarding the green roof, the payback period came out between one and three years depending on the layout selected. Although the green roof renovation is feasible, our group believes that updating the roof is more of a priority. We recommend that a green roof for this facility not be solely used for insulation purposes. The green roof should be implemented for its environmental impact and aesthetic properties. A specific roof insulation system should be used to address the current defects in the building’s existing roof.

**Future IQP**

Finally, we would like to recommend that the Printer’s Building invest in at least one more Interactive Qualifying Project. From the very beginning of our project, we noticed the overwhelming amount of usable floor space that was taken over by storage. In order for this building to gain more tenants, a study should be done to find the best way to consolidate the inventory and develop a building-wide recycling plan. One topic to address may include referencing building codes regarding where these boxes can be placed and finding the appropriate use for each space in the building. Also, the team should research the recyclability of any waste generated by the building’s occupants. Methods should include extensive tours and case studies of similar facilities that have consolidated storage and developed recycling plans.

**Conclusions**

Although we faced several setbacks, we were able to work around these obstacles and get the necessary information to complete our objectives and ultimately prepare our recommendations for our sponsor. In order to obtain information from professionals for the technologies that we had researched, it was necessary to conduct interviews in order increase our understanding of products. It was also essential to learn more about products that we had no experience with. The interviews were not always an easy task to schedule and prepare for. Since we are only college students, we found it difficult to contact professionals that were willing to sit down and meet with us without receiving any compensation. When we were able to set up meetings, we quickly found that our projected timetable would have to be altered to
accommodate rescheduling. This was due to the changing schedules of the professionals and wintery weather. Some interviews were also rescheduled as a phone interview rather than personal ones because of time constraints. This posed a few problems when it came to talking to them. Only one person was able to ask the questions as well as transcribe the interview notes simultaneously and there was no practical way of recording the conversation to review at a later time. Although these caused initial concern, we were still able to gather the appropriate information that was needed for our project. Overall, the preparation for our meetings using relevant questions never posed a problem and helped us tremendously in extracting the facts that were most important to us.

Exploring adaptive reuse in the Worcester area was found to be more pertinent than we had initially planned. We originally planned to gather the information regarding the social benefits by surveying surrounding buildings on the idea of sustainability. We wanted to find the impact a “green” changeover of the Printer’s Building would have on the surrounding buildings. We found that this idea would have been too time consuming to complete effectively in the seven weeks on site. We also felt that the results we would have gathered may have been skewed because the owners of these buildings might not be in the area or may have perceived the survey as a way for the city to solicit money. The tours and interviews gave us more information about how spaces were used and how tenant relations were important to the overall success of a shared space. We went to the Sprinkler Factory with an open mind and did not realize the wealth of information we received until we sat down and discussed it as a group following the tour. In contrast, we approached the Pagano interview with clear objectives, expecting to see a renovated space that the Printer’s Building could eventually emulate. In general, the changes made to our methods in regards to gathering information about the social aspects of renovation turned out to be time effective and very useful.

An initial requisite of our project was to create a three and five year implementation plan that would be submitted to our sponsor. As we collected the interview recommendations, cost/payback analysis reports and product information, we were able to gain a general idea as to what actions were critical for the Printer’s Building to complete. One of the largest problems we faced was the inability to find an exact formula for our cost/payback analysis. None of the formulas we found through independent study encompassed all of the information that we
deemed necessary to project an accurate estimate. However, we were able to work around these issues by critically thinking of the numbers generated and reflect on its precision. Another point that we considered was to determine the goals and realistically think of how this will help our sponsor reach his personal goals. Additionally, we were unsure about the timescale of each goal. Differentiating which goals were feasible in a three year period, which ones were feasible in a five year period and which should be completed in five to ten years proved to be a difficult decision. Our group talked extensively about this issue and produced a series of goals that we believe the Printer’s Building can accomplish within their allotted timeframe.
References


McKeag, Jim. (November 12, 2008). Personal Interview.


Wasieleski, Rebecca. (2007) Insulated Concrete. Concrete Contractor. 7(6). 34


Appendix A: Description of Green Roof Components

**Printers IQP Group B08-C09**
Matthias Downey
Paul Galligan
Peter Holmes
Derek Snow

**Description of Components**

**Vegetation:** Selecting the vegetation for a roof is considerably different than determining what vegetation goes in your garden. The harsh rooftop conditions limit the variety of floral life that can thrive. Depending on the amount the owner is willing to pay for maintenance the variety of plant life can increase. Typically, native vegetation is chosen for use on green roofs. The most successful types of vegetation are sedums, which are capable of flourishing in the severe rooftop climates.

**Layer 6 – Growing Medium:** The growing medium depth directly dictates the variety of plant life that exists on the roof. A common misconception is to label the growing medium as “soil”. The distinction between the two is the high mineral content, which is synthetically produced, and the expanded clays of the growing medium. The expanded clays in green roof systems are also used in hydroponic gardens.

**Layer 5 – Drainage System:** The drainage system is unique because it benefits both the building and the vegetation. The top portion of the system, located directly below the growing medium, is a mesh skirt. The mesh is used to keep the growing medium from infiltrating the actual drainage system and prevent the growing medium from inhibiting water flow. It is imperative that no soil clogs the drainage layer as this will lead to a deficiency of water for surrounding plants due to the water pooling in one spot. Water is a necessity for plants trying to survive in a rooftop environment. The lower section of the drainage system is a corrugated plastic drain mat that keeps the water under the roots to provide water for the plants, but can also allow the water to flow to the roof drain to prevent overwatering and flooding. The drainage system is essential for reducing harmful run-off and maintaining plant hydration.

**Layer 4 – Insulation:** Insulation improves the building envelope performance. The insulation prevents heat from escaping during the winter. The system that is being employed for this building is a palletized system and the insulation is incorporated within the pallet. The use of expanded polystyrene (EPS) insulation is discouraged because of its ability to absorb water.

**Layer 3 – Thermoplastic Membrane:** The thermoplastic membrane is the aspect of a green roof that mitigates Urban Heat Island Effect. To obtain maximum LEED points the membrane needs to be white because it reflects the heat away from the roof in the summer and the membrane acts as an insulator in the winter. This white membrane is made from thermoplastic polyolefin (TPO), which also doubles as a root barrier for the vegetation.

**Layer 2 – Current Roof:** The existing roof is a standard five ply coal, tar, pitch, felt and slag roofing construction. In its current state, the roof is prone to leaks and will be fixed with the proper installation of the thermoplastic membrane.

**Layer 1 – Concrete:** The roof is a 6” reinforced concrete slab and is capable of housing the palletized green roof system that was proposed.
Appendix B: Cost/Payback

Printer's Building Information Spreadsheet

Basic Building Information

<table>
<thead>
<tr>
<th></th>
<th>Height</th>
<th>Column Diameter</th>
<th>Floor Thick.</th>
<th>Live Load</th>
<th>Net (sq. ft)</th>
<th>Gross (sq. ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basement</td>
<td>10'</td>
<td>36''</td>
<td>-</td>
<td>-</td>
<td>8661</td>
<td>12148</td>
</tr>
<tr>
<td>1st Floor</td>
<td>13'</td>
<td>32''</td>
<td>8''</td>
<td>200 lbs./ft²</td>
<td>6963</td>
<td>12820</td>
</tr>
<tr>
<td>2nd Floor</td>
<td>12'6''</td>
<td>30''</td>
<td>8''</td>
<td>200 lbs./ft²</td>
<td>10237</td>
<td>11853</td>
</tr>
<tr>
<td>3rd Floor</td>
<td>12'6''</td>
<td>28''</td>
<td>9 ¼''</td>
<td>300 lbs./ft²</td>
<td>10268</td>
<td>11653</td>
</tr>
<tr>
<td>4th Floor</td>
<td>12'6''</td>
<td>26''</td>
<td>9 ¼''</td>
<td>300 lbs./ft²</td>
<td>10282</td>
<td>11653</td>
</tr>
<tr>
<td>5th Floor</td>
<td>12'6''</td>
<td>22''</td>
<td>9 ¼''</td>
<td>300 lbs./ft²</td>
<td>10303</td>
<td>11653</td>
</tr>
<tr>
<td>6th Floor</td>
<td>12'</td>
<td>20''</td>
<td>7 ½''</td>
<td>150 lbs./ft²</td>
<td>10313</td>
<td>11653</td>
</tr>
<tr>
<td>7th Floor</td>
<td>12'3''</td>
<td>20''</td>
<td>7 ½''</td>
<td>150 lbs./ft²</td>
<td>10313</td>
<td>11653</td>
</tr>
<tr>
<td>Roof</td>
<td>-</td>
<td>-</td>
<td>6''</td>
<td>~100 lbs./ft²</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>97'3''</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>79370</td>
<td>94886</td>
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</table>

Building's Surface Area

Exterior Walls

<table>
<thead>
<tr>
<th>Wall</th>
<th>Length (ft)</th>
<th>Height (ft)</th>
<th># of Units</th>
<th>Area (sq. ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West</td>
<td>104</td>
<td>97.25</td>
<td>1</td>
<td>10114</td>
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<tr>
<td>East</td>
<td>93.33</td>
<td>97.25</td>
<td>1</td>
<td>8103.9425</td>
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<tr>
<td>North/South</td>
<td>90</td>
<td>97.25</td>
<td>2</td>
<td>15580</td>
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<tr>
<td>East</td>
<td>10.33</td>
<td>97.25</td>
<td>2</td>
<td>2009.185</td>
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<td>North/South</td>
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<td>97.25</td>
<td>2</td>
<td>10503</td>
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<td>Total Surface Area of Entire Building</td>
<td>46290.0275</td>
<td></td>
<td></td>
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Windows

<table>
<thead>
<tr>
<th>Length (ft)</th>
<th>Height (ft)</th>
<th># of Units</th>
<th>Area (sq. ft)</th>
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</thead>
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<tr>
<td>17.25</td>
<td>8.5</td>
<td>36</td>
<td>6278.5</td>
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<tr>
<td>16</td>
<td>8.5</td>
<td>21</td>
<td>2856</td>
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<tr>
<td>14.75</td>
<td>8.5</td>
<td>25</td>
<td>3134.375</td>
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<td>13.6</td>
<td>8.5</td>
<td>18</td>
<td>2080.8</td>
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<tr>
<td>4.8</td>
<td>8.5</td>
<td>38</td>
<td>1550.4</td>
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<td>3.75</td>
<td>8.5</td>
<td>13</td>
<td>414.375</td>
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<tr>
<td>6.15</td>
<td>8.5</td>
<td>1</td>
<td>52.275</td>
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<tr>
<td>8.67</td>
<td>8.5</td>
<td>1</td>
<td>73.906</td>
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<td>Total Surface Area Covered by Windows</td>
<td>15440.42</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Surface Area Covered by Masonry | 30849.6075 |

Total Surface Area Covered by Roof | 0.20111134 |

Window to Masonry Ratio | 0.33355824 |
Replacement/Upgrade Cost

Replacement Windows
Note: based on 2006 report

<table>
<thead>
<tr>
<th>Cost ($) per Unit</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>5500</td>
<td>198000</td>
</tr>
<tr>
<td>5100</td>
<td>107100</td>
</tr>
<tr>
<td>4827</td>
<td>120675</td>
</tr>
<tr>
<td>4447</td>
<td>80046</td>
</tr>
<tr>
<td>1581</td>
<td>60078</td>
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<td>1228</td>
<td>15964</td>
</tr>
<tr>
<td>2016</td>
<td>2016</td>
</tr>
<tr>
<td>2836</td>
<td>2836</td>
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</table>

Total Cost for Window Replacement (2006) 586715

Projected Cost for Window Replacement (2009) 606633.31

Cost for Windows per square foot 39.29059837

Fixing Masonry

<table>
<thead>
<tr>
<th>Cost ($)</th>
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<tbody>
<tr>
<td>Mending Existing Concrete 288750</td>
</tr>
<tr>
<td>Scaffold 303187.5</td>
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<tr>
<td>Projected for 2009 120000</td>
</tr>
<tr>
<td>Contingency 50000</td>
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Total Projected Cost ($) for Masonry Section 473187.5

Insulation Products
Note: Cost Estimate is for Materials and Construction (excludes Scaffolding)

<table>
<thead>
<tr>
<th>R-value</th>
<th>Product $ per sq. ft</th>
<th>Equipment $ per sq. ft</th>
<th>Total $ per sq. ft</th>
<th>Total Cost</th>
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<tr>
<td>None (Current Wall)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Centria</td>
<td>15</td>
<td>23</td>
<td>15.33852578</td>
<td>38.33852578</td>
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<tr>
<td>Dryvit</td>
<td>12</td>
<td>20</td>
<td>15.33852578</td>
<td>35.33852578</td>
</tr>
<tr>
<td>Single Paned Windows</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Doubled Paned Windows</td>
<td>3</td>
<td>see above</td>
<td>see above</td>
<td>see above</td>
</tr>
<tr>
<td>Existing Roof</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Roofing

Replacing Existing Roof With Similar Roof (w/ Insulation)
Information Provided By George Barnard
Estimated Cost of Replacing Existing Roof with Normal roof 150000
Estimated Cost per sq. ft to Replace Existing Roof 12.87222175

<table>
<thead>
<tr>
<th>R-Value</th>
<th>Thickness (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Green Roof
Note: Green Grid Palletized System

<table>
<thead>
<tr>
<th>R-Value</th>
<th>Thickness (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weight (wet)</th>
<th>Proposed sq. ft</th>
<th>Tot. Weight</th>
<th>$ per sq. ft</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layout #1</td>
<td>13</td>
<td>2520</td>
<td>32760</td>
<td>10</td>
</tr>
<tr>
<td>Layout #2</td>
<td>13</td>
<td>3072</td>
<td>39936</td>
<td>10</td>
</tr>
<tr>
<td>Layout #3</td>
<td>13</td>
<td>4800</td>
<td>62400</td>
<td>10</td>
</tr>
</tbody>
</table>

Percentage of Surface Area Covered by selected Green Roof Layout
Layout #1     0.043490996
Layout #2     0.053017596
Layout #3     0.082839993

Utility Usage

Existing Heating Unit

<table>
<thead>
<tr>
<th>Type</th>
<th>Age (years)</th>
<th>Efficiency (E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td>24</td>
<td>0.81</td>
</tr>
</tbody>
</table>

Avg. Cost ($) of Natural Gas (Worcester) per therm 0.7
Avg. Worcester, MA Heating Degree Days (HDD) 6976
Avg. Cost ($) of Electricity (Worcester) per them *see previous IGP groups spreadsheet
### Utility Usage (cont.)

#### Printer's Building Gas Usage

<table>
<thead>
<tr>
<th>Month</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Average</th>
<th>Cost per Therm</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>5521</td>
<td>7174</td>
<td>6367.5</td>
<td>HDD</td>
<td></td>
</tr>
<tr>
<td>February</td>
<td>12014</td>
<td>8587</td>
<td>10300.5</td>
<td>HDD</td>
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<tr>
<td>March</td>
<td>7379</td>
<td>5710</td>
<td>6544.5</td>
<td>HDD</td>
<td></td>
</tr>
<tr>
<td>April</td>
<td>5328</td>
<td>3375</td>
<td>4351.5</td>
<td>HDD</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>703</td>
<td>728</td>
<td>715.5</td>
<td>HDD</td>
<td></td>
</tr>
<tr>
<td>June</td>
<td>202</td>
<td>51</td>
<td>126.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>58</td>
<td>60</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>46</td>
<td>54</td>
<td>50</td>
<td>1.6356</td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>67</td>
<td>66</td>
<td>44</td>
<td>59</td>
<td>0.78985</td>
</tr>
<tr>
<td>October</td>
<td>202</td>
<td>148</td>
<td>175</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>1930</td>
<td>2122</td>
<td>2026</td>
<td>HDD</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>4210</td>
<td>8245</td>
<td>6227.5</td>
<td>HDD</td>
<td></td>
</tr>
</tbody>
</table>

**Total Therms per Year**: 36981.5

**Average Cost of Heating (Gas) per Year**: 25887.05

#### Printer's Building Electricity Usage

<table>
<thead>
<tr>
<th>Month</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>7,222.49</td>
<td>6,202.82</td>
<td>4,837.69</td>
<td>6,087.67</td>
</tr>
<tr>
<td>February</td>
<td>7,548.19</td>
<td>5,690.38</td>
<td>5,237.22</td>
<td>6,158.60</td>
</tr>
<tr>
<td>March</td>
<td>10,953.00</td>
<td>4,973.67</td>
<td>4,519.36</td>
<td>6,815.34</td>
</tr>
<tr>
<td>April</td>
<td>3,041.89</td>
<td>5,083.79</td>
<td>5,069.71</td>
<td>4,408.43</td>
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<tr>
<td>May</td>
<td>5,487.58</td>
<td>5,508.41</td>
<td>4,371.48</td>
<td>5,122.49</td>
</tr>
<tr>
<td>June</td>
<td>5,909.07</td>
<td>6,873.42</td>
<td>4,638.99</td>
<td>5,807.16</td>
</tr>
<tr>
<td>July</td>
<td>10,217.20</td>
<td>7,683.47</td>
<td>6,600.36</td>
<td>8,167.01</td>
</tr>
<tr>
<td>August</td>
<td>6,157.28</td>
<td>7,741.86</td>
<td>7,005.23</td>
<td>6,986.12</td>
</tr>
<tr>
<td>September</td>
<td>7,297.11</td>
<td>6,189.78</td>
<td>6,181.94</td>
<td>6,556.28</td>
</tr>
<tr>
<td>October</td>
<td>6,134.08</td>
<td>5,806.58</td>
<td>5,970.33</td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>5,474.79</td>
<td>5,023.78</td>
<td>5,249.29</td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>5,730.37</td>
<td>5,326.71</td>
<td>5,528.54</td>
<td></td>
</tr>
</tbody>
</table>

**Average Cost ($) of Electricity per Year**: 72,839.26
### Years to Payback (Insulation)

#### Equation #1: Simple Payback Analysis

\[
YTP = \frac{x}{(y^2)}
\]

- **Centria**
  - Total Expenses for Renovations (x) 1182728.473
  - Total Expenses for Renovations w/ Windows (x) 1789391.783
  - Total Expenses for Utilities per Year (y) 98,726.31
  - Projected Savings (Percentage) (z) 0.56

  - Years to Payback w/o New Windows 21.39262813 years
  - Years to Payback w/ New Windows 32.36566454 years

- **Dryvit**
  - Total Expenses for Renovations (x) 1090179.65
  - Total Expenses for Renovations w/ Windows (x) 1696842.96
  - Total Expenses for Utilities (y) 98,726.31
  - Projected Savings (Percentage) (z) 0.56

  - Years to Payback w/o New Windows 19.7186492 years
  - Years to Payback w/ New Windows 30.69189561 years

#### Equation #2: Applying Just Insulation w/o New Windows

\[
YTP = \left(\frac{(C(i)^* R(1)^* R(2)^* E) - (C(e)[R(2) - R(1)]^HDD^*24)}{.66}\right)
\]

<table>
<thead>
<tr>
<th>Centria</th>
<th>Total Renovation Cost</th>
<th>1182728.473</th>
<th>18.92039077 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryvit</td>
<td>Total Renovation Cost</td>
<td>1090179.65</td>
<td>17.75693534 years</td>
</tr>
</tbody>
</table>

#### Equation #3: Applying Insulation w/ New Windows

\[
YTP = \left(\frac{(C(i)^* R(1)^* R(2)^* E) - (C(e)[R(2) - R(1)]^HDD^*24)}{.66}\right)
\]

- **Centria**
  - Total Renovation Cost 32.50730443 years

- **Dryvit**
  - Total Renovation Cost 31.3438672 years

#### Equation #4: Applying Green Grid Green Roof System on Existing Roof

\[
YTP = \left(\frac{(C(i)^* R(1)^* R(2)^* E) - (C(e)[R(2) - R(1)]^HDD^*24)}{% of SA}\right)
\]

| Layout #1 | Total Renovation Cost | 25200 | 1.28822534 years |
| Layout #2 | Total Renovation Cost | 30720 | 1.570408033 years |
| Layout #3 | Total Renovation Cost | 48000 | 2.453762552 years |

#### Equation #5: Replacing Existing Roof with New Roof w/o Green Roof

\[
YTP = \left(\frac{(C(i)^* R(1)^* R(2)^* E) - (C(e)[R(2) - R(1)]^HDD^*24)}{% of SA of Roof}\right)
\]

Total Renovation Cost 150000 6.441126698 years
Plot: Cost per Therm vs. Years to Payback

Equation #2: New Insulation

<table>
<thead>
<tr>
<th>Cost Per Therm</th>
<th>Centria YTP</th>
<th>Dryvit YTP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.7</td>
<td>18.92030077</td>
<td>17.75665364</td>
</tr>
<tr>
<td>0.8</td>
<td>16.85634192</td>
<td>15.83733434</td>
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<tr>
<td>0.9</td>
<td>14.71658649</td>
<td>13.81065386</td>
</tr>
<tr>
<td>1.1</td>
<td>12.42427354</td>
<td>12.42966747</td>
</tr>
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Plot: Cost per Therm vs. Years to Payback (cont.)

Equation #3: New Insulation and Windows

<table>
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<tr>
<th>Cost Per Therm</th>
<th>Centria YTP</th>
<th>Dryvit YTP</th>
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New Windows
## Appendix C: Remedial Cost Opinion Worksheet

The Printers Building  
Worcester, MA

**Note:** See notes that follow the table.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Unit Cost</th>
<th>Quantity</th>
<th>Extension</th>
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</thead>
<tbody>
<tr>
<td>Remove the existing cementitious coating</td>
<td>Square Foot</td>
<td>$3.25</td>
<td>15,000</td>
<td>$48,750</td>
</tr>
<tr>
<td>Epoxy-inject concrete and masonry cracks</td>
<td>Allowance</td>
<td>----</td>
<td>----</td>
<td>$240,000</td>
</tr>
<tr>
<td>Remove and replace windows: 17” - 3” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$5,500</td>
<td>36</td>
<td>$198,000</td>
</tr>
<tr>
<td>Remove and replace windows: 16” - 0” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$5,100</td>
<td>21</td>
<td>$107,100</td>
</tr>
<tr>
<td>Remove and replace windows: 14” - 9” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$4,827</td>
<td>25</td>
<td>$120,675</td>
</tr>
<tr>
<td>Remove and replace windows: 13” - 7” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$4,447</td>
<td>18</td>
<td>$80,046</td>
</tr>
<tr>
<td>Remove and replace windows: 4” - 10” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$1,581</td>
<td>38</td>
<td>$60,076</td>
</tr>
<tr>
<td>Remove and replace windows: 3” - 9” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$1,228</td>
<td>13</td>
<td>$15,964</td>
</tr>
<tr>
<td>Remove and replace windows: 6” - 2” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$2,016</td>
<td>1</td>
<td>$2,016</td>
</tr>
<tr>
<td>Remove and replace windows: 8” - 8” x 8” - 6”; includes window perimeter sealant.</td>
<td>Each</td>
<td>$2,836</td>
<td>1</td>
<td>$2,836</td>
</tr>
<tr>
<td>Remove and dispose of damaged window sills.</td>
<td>Hours</td>
<td>$150 (2 persons)</td>
<td>400</td>
<td>$60,000</td>
</tr>
<tr>
<td>Provide new precast concrete window sills.</td>
<td>Each, average</td>
<td>$1,200</td>
<td>153</td>
<td>$183,800</td>
</tr>
<tr>
<td>Apply new coating to entire surface area</td>
<td>Square Foot</td>
<td>$4.25</td>
<td>15,000</td>
<td>$63,750</td>
</tr>
<tr>
<td>Staging cost; access to the façade</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>$100,000</td>
</tr>
<tr>
<td>Obstruction permit and police detail</td>
<td>Month</td>
<td>$7,740</td>
<td>6</td>
<td>$46,440</td>
</tr>
<tr>
<td>Dumpster and hauling</td>
<td>Month</td>
<td>$2,000</td>
<td>6</td>
<td>$12,000</td>
</tr>
<tr>
<td>Port-A-Toilet</td>
<td>Month</td>
<td>$600</td>
<td>6</td>
<td>$3,600</td>
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</table>

**Sub-total: Trade Costs**  
$1,344,898

**Contingency at 15%**  
$201,728

**General Conditions at 10%**  
$154,658

**Overhead and Profit at 15%**  
$255,186

**Other permits and fees at 5%**  
$117,385

**TOTAL TRADE AND RELATED COSTS**  
$2,073,812
# Appendix D: LEED Core & Shell Checklist

## LEED for Core and Shell v2.0

Registered Project Checklist

<table>
<thead>
<tr>
<th>Project Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Address:</td>
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</tr>
</tbody>
</table>

### Project Totals (Pre-Certification Estimates)

<table>
<thead>
<tr>
<th>Yes</th>
<th>?</th>
<th>No</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**69 Points**

Certified: 23-27 points  
Silver: 28-33 points  
Gold: 34-44 points  
Platinum: 45-61 points

### Sustainable Sites

<table>
<thead>
<tr>
<th>Yes</th>
<th>?</th>
<th>No</th>
</tr>
</thead>
</table>

*Prereq 1: Construction Activity Pollution Prevention*  
*Required: Required*

*Credit 1: Site Selection*  
1 point

*Credit 2: Development Density & Community Connectivity*  
1 point

*Credit 3: Brownfield Redevelopment*  
1 point

*Credit 4.1: Alternative Transportation, Public Transportation*  
1 point

*Credit 4.2: Alternative Transportation, Bicycle Storage & Changing Rooms*  
1 point

*Credit 4.3: Alternative Transportation, Low-Emitting & Fuel Efficient Vehicles*  
1 point

*Credit 4.4: Alternative Transportation, Parking Capacity*  
1 point

*Credit 5.1: Site Development, Protect or Restore Habitat*  
1 point

*Credit 5.2: Site Development, Maximize Open Space*  
1 point

*Credit 6.1: Stormwater Design, Quantity Control*  
1 point

*Credit 6.2: Stormwater Design, Quality Control*  
1 point

*Credit 7.1: Heat Island Effect, Non-Roof*  
1 point

*Credit 7.2: Heat Island Effect, Roof*  
1 point

*Credit 8: Light Pollution Reduction*  
1 point

*Credit 9: Tenant Design & Construction Guidelines*  
1 point

### Water Efficiency

<table>
<thead>
<tr>
<th>Yes</th>
<th>?</th>
<th>No</th>
</tr>
</thead>
</table>

*Credit 1.1: Water Efficient Landscaping, Reduce by 50%*  
1 point

*Credit 1.2: Water Efficient Landscaping, No Potable Use or No Irrigation*  
1 point

*Credit 2: Innovative Wastewater Technologies*  
1 point

*Credit 3.1: Water Use Reduction, 20% Reduction*  
1 point

*Credit 3.2: Water Use Reduction, 30% Reduction*  
1 point

---

*Last Modified: May 2008*  
1 of 4
### LEED for Core and Shell v2.0
#### Registered Project Checklist

**Yes** | **?** | **No** | **Energy & Atmosphere** | **14 Points**
--- | --- | --- | --- | ---

| Prereq 1 | Fundamental Commissioning of the Building Energy Systems | Required |
| Prereq 2 | Minimum Energy Performance | Required |
| Prereq 3 | Fundamental Refrigerant Management | Required |

*Note for EA 1: All LEED for Core and Shell projects registered after June 26, 2007 are required to achieve at least two (2) points.*

<table>
<thead>
<tr>
<th>Credit 1</th>
<th>Optimize Energy Performance</th>
<th>1 to 8</th>
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<tbody>
<tr>
<td>Credit 1.1</td>
<td>10.5% New Buildings / 3.5% Existing Building Renovations</td>
<td>1</td>
</tr>
<tr>
<td>Credit 1.2</td>
<td>14% New Buildings / 7% Existing Building Renovations</td>
<td>2</td>
</tr>
<tr>
<td>Credit 1.3</td>
<td>17.5% New Buildings / 10.5% Existing Building Renovations</td>
<td>3</td>
</tr>
<tr>
<td>Credit 1.4</td>
<td>21% New Buildings / 14% Existing Building Renovations</td>
<td>4</td>
</tr>
<tr>
<td>Credit 1.5</td>
<td>24.5% New Buildings / 17.5% Existing Building Renovations</td>
<td>5</td>
</tr>
<tr>
<td>Credit 1.6</td>
<td>28% New Buildings / 21% Existing Building Renovations</td>
<td>6</td>
</tr>
<tr>
<td>Credit 1.7</td>
<td>31.5% New Buildings / 24.5% Existing Building Renovations</td>
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</tr>
<tr>
<td>Credit 1.8</td>
<td>35% New Buildings / 28% Existing Building Renovations</td>
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| Credit 2 | On-Site Renewable Energy | 1 |
| Credit 3 | Enhanced Commissioning | 1 |
| Credit 4 | Enhanced Refrigerant Management | 1 |
| Credit 5.1 | Measurement & Verification - Base Building | 1 |
| Credit 5.2 | Measurement & Verification - Tenant Sub-metering | 1 |
| Credit 6 | Green Power | 1 |
### LEED for Core and Shell v2.0

**Registered Project Checklist**

<table>
<thead>
<tr>
<th>Yes</th>
<th>?</th>
<th>No</th>
<th>Materials &amp; Resources</th>
<th>11 Points</th>
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</thead>
<tbody>
<tr>
<td>Yes</td>
<td></td>
<td></td>
<td>Prereq 1</td>
<td>Storage &amp; Collection of Recyclables</td>
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<tr>
<td></td>
<td></td>
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<td>Credit 1.1</td>
<td>Building Reuse, Maintain 25% of Existing Walls, Floors &amp; Roof</td>
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<tr>
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<td>Building Reuse, Maintain 50% of Existing Walls, Floors &amp; Roof</td>
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<td>Credit 1.3</td>
<td>Building Reuse, Maintain 75% of Interior Non-Structural Elements</td>
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<td></td>
<td></td>
<td>Credit 2.1</td>
<td>Construction Waste Management, Divert 50% from Disposal</td>
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<tr>
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<td>Credit 2.2</td>
<td>Construction Waste Management, Divert 75% from Disposal</td>
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<td></td>
<td>Credit 3</td>
<td>Materials Reuse, 1%</td>
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<td>Recycled Content, 10% (post-consumer + 1/2 pre-consumer)</td>
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<tr>
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<td>Credit 4.2</td>
<td>Recycled Content, 20% (post-consumer + 1/2 pre-consumer)</td>
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<td>Credit 5.1</td>
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<td>Credit 5.2</td>
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<td></td>
<td>Prereq 1</td>
<td>Minimum IAQ Performance</td>
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<td>Prereq 2</td>
<td>Environmental Tobacco Smoke (ETS) Control</td>
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<td>Credit 1</td>
<td>Outdoor Air Delivery Monitoring</td>
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<td>Yes</td>
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<td>Credit 2</td>
<td>Increased Ventilation</td>
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<td>Credit 3</td>
<td>Construction IAQ Management Plan, During Construction</td>
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<td>Controllability of Systems, Thermal Comfort</td>
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<td>Thermal Comfort, Design</td>
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<td>Credit 8.1</td>
<td>Daylight &amp; Views, Daylight 75% of Spaces</td>
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<td>Daylight &amp; Views, Views for 90% of Spaces</td>
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*Note for EQc4.1-4.4: Project teams will receive 1 point for achievement of 2 credits, 2 points for achievement of 3 credits, or 3 points for achievement of 4 credits among EQc4.1, EQc4.2, EQc4.3 and EQc4.4.*
LEED for Core and Shell v2.0
Registered Project Checklist

<table>
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**Innovation & Design Process**

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<th>Description</th>
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<tr>
<td>1.2</td>
<td>Innovation in Design: Provide Specific Title</td>
<td>1</td>
</tr>
<tr>
<td>1.3</td>
<td>Innovation in Design: Provide Specific Title</td>
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</tr>
<tr>
<td>1.4</td>
<td>Innovation in Design: Provide Specific Title</td>
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</tr>
<tr>
<td>2</td>
<td>LEED® Accredited Professional</td>
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