THE PENNSYLVANIA STATE UNIVERSITY
5TH YEAR THESIS

Final Report

April 7, 2010

TIMOTHY CONROY
CONSTRUCTION MANAGEMENT
FACULTY ADVISOR: JIM FAUST
2175 K STREET NW
WASHINGTON DC

2175 K Street NW, Washington DC

Project Team

Owner	Minshall Stewart Properties
Construction Manager	Appian Realty Advisors
Architect	FOX Architects
Civil Engineer	Vika
Structural Engineer	Rathgeber/Goss Associates
MEP Engineer	META Engineers
General Contractor	James G. Davis Construction

Project Specifications

Building Function	Class A Office Building
Construction Type	Occupied Renovation
Building Size	173,551 sqft (33,691 sqft new)
Number of Stories Above	11 stories (8 existing, 3 new)
Number of Stories Below	3 stories below grade parking
Construction Dates	February '07 to March '10
Project Delivery Method	CM Agent with GC
Building Cost	$15,500,000

Architecture

2175 K Street NW is located on the North Side of K Street at 22nd Street and Washington Circle. The eight-story structure was built in 1981. Currently, it is 108,000 gross square feet. Through the use of Transfer Development Rights, the building will be increased in height by three floors. This vertical addition will increase the existing gross square footage by 37,500 square feet.

The new 22nd and K Street façades will be a unitized glass and metal curtain wall system. A state-of-the-art solar louver system will screen the existing façade and provides passive solar shading to the new façade; while simultaneously knitting the entire building together. A new glass corner overlooking Washington Circle spans floors 2 through 11, blending the new and the old systems together.

Structure

The foundation consists of existing 48"x48"x24" footers, several of which underwent minor expansions to support the new loads imposed by the additional structure above. The existing building consists of cast in place concrete. Whereas the new structure is structural steel with lightweight slab on deck. Several columns within the existing building were reinforced with steel jackets or carbon fiber to support the additional loads imposed by the new steel structure.

Mechanical

The mechanical system for this project consists of a main cooling tower that services a self contained unit on each floor used for the conditioning of the tenant spaces. To condition the core of the building, a closed loop with VAV's was utilized. The new floors, 9 through 11, and existing Level 8 will be controlled by a new BAS system. The existing floors, B1 through 7, will be controlled by the existing pneumatic system. As tenant floors turnover, the owner will upgrade the entire building to run off of the new BAS system.

Electrical

The electrical service for the new construction enters at 2,000A and is distributed on a 208Y/120V system. The existing building has two 6,000A feeds. The existing switchgear was replaced with new switchgear that has the capacity to feed panels on Levels B3 through 11. A new backup generator was installed to service the whole building.

Lighting

The lighting is operated on a 120V system and uses energy efficient fluorescent lamps with electronic ballasts. The base building did not include common areas on the new floors. Lighting design and installation will be part of the tenant fit out.

Sustainability

This building is trying to obtain LEED EB. To help in this matter, a passive solar shading system was implemented. Another sustainable feature to this project is the use of a green roof. Such a roof is being installed on a portion of the ninth floor.

Timothy Conroy
Construction Management
http://www.engr.psu.edu/ae/thesis/portfolios/2010/tmc5014

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Acknowledgements

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James G. Davis Construction Corporation

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Patrick Cotter	Assistant Project Manager
William Cox	Assistant Project Manager
Dennis Lewis	Sr. Superintendent
Lester Funkhouser	Superintendent

Minshall Stewart Properties

John Stewart	Owner
Thaddeus Minshall	Owner

Fox Architects

J.P. Spickler	Architect
Brad King	Architect
David Buddendeck	Architect

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Weston Solutions Green Grid® System

Chris Dorman	Client Service Manger

Schuco USA

Dennis Hashagen	Architectural Sales Advisor

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Professor Bob Holland	Associate Professor
Dr. David Riley	Associate Professor, Construction
Jim Faust	Faculty Advisor
Dr. Chris Magent	Faculty Advisor

Fellow Fifth Year Students including

Thomas Weaver

… and most of all, my family and friends

Executive Summary

Analysis I – Backup Generator Analysis

This analysis looked into the relative benefit of utilizing a buildings existing backup generator as an energy source in an attempt to reduce peak electrical demand and thereby reduce electricity costs. It was determined that the existing Cummins 300 kW diesel generator was not a viable candidate for such an activity but larger natural gas generators could be. Based upon the proposed Caterpillar 450 kW N.G. generator, this resulted in an annual savings of $6,054 with an initial cost of $176,400 and a payback period of 36.5 years. Along the same lines, a Caterpillar 1040 kW N.G. generator resulted in an annual savings of $135,300 with an initial cost of $507,700 and a payback period of 4.1 years. The cost per square foot when computed based upon new construction area was found to be $16.31.

Analysis II – Green Roof Analysis

This analysis investigated the relative benefit of incorporating a modular green roof onto 2175 K Street. It was determined that a system such as the one chosen would cost the owner an additional $105,900 or $19.26 per square foot to install a GreenGrid® modular green roof. Based upon the existing single-ply EPDM roof as a base, the green roof would result in an annual savings of $5,056 or 32,800 kWhrs based upon an electric rate of $0.1543. This system has a payback period of 20.9 years. When the cost of the existing design is factored in, the payback period drops to 9 years. The cost per square foot when computed based upon new construction area was found to be $3.14.

Analysis III – Curtain Wall Redesign Analysis

This analysis researched the relative benefit of changing the existing curtain wall with a super insulated Schuco FW 50+.SI curtain wall. In addition, based upon the selected system, the benefit of including solar collectors within the glazing was analyzed. The resulting figures are as follows; when simply using the super insulated curtain wall system, the initial cost was $808,000 which works out to an added cost of $38,500 with an annual savings of $132,600. This resulted in a payback period of 5.8 years but the associated added cost was recovered in the first year. When solar collectors were added to the non-vision glass, the initial cost was $846,000, with an annual savings of $138,700, and a payback period of 5.3 years. When solar collectors were included in the vision glass, the initial cost was $962,000, with an annual savings of $152,600, and a payback period of 5.6 years. With both solar collection options, the added cost was recovered the first year. The cost per square foot when computed based upon new construction area was found to be $1.14 based upon a super insulated system.

Analysis IV – Smart Power Strips Analysis

This analysis looked into the relative benefit of implementing a system of Smart Power Strips within an office building setting. Based upon the planned 400 tenants, an annual savings of $105,600 was calculated. The initial cost of this system was found to be just under $12,000, with a payback period of only 0.11 years or 1.36 months. The cost per square foot when computed based upon new construction area was found to be $0.36.

Project Background

2175 K Street NW Washington DC is located in the north side of K Street at 22nd Street and Washington Circle. The eight-story structural concrete building was built in 1981. As originally constructed, it was 108,000 gross square feet. Through the use of Transfer Development Rights, the building height was increased by three floors. This vertical addition increased the existing gross square footage by 37,500 square feet.

Figure 1 Project Rendering by FOX Architects

The new 22nd and K Street facades were designed to be a unitized glass and metal curtain wall system. In addition, a state-of-the-art solar louver system was intended to screen the existing façade and provide passive solar shading to the new façade; while simultaneously knitting the entire building together, old and new. A glass corner feature overlooking Washington Circle spanning floors two through eleven will blend the new and old systems together. These two attempts, along with a new coat of white Tnemec Enviro-Crete paint over the existing brick façade, will provide a unified look to the building.

As previously mentioned, the project consists of a fully occupied eight-story building owned by Minshall Stewart Properties. The architect on this project is FOX Architects with Appian Realty Advisors serving as the construction manager. The Structural engineer was Rathgeber/Goss Associates, MEP engineer was META Engineers, and the general contractor was James G. Davis Construction.

Concerning the project schedule, the design phase began in June of 2006 and preconstruction February 2007. Construction started on 1 August 2008 and was scheduled to be substantially completed on 18 December 2009. Finally, demobilization and project closeout was scheduled to be completed on 11 March 2010.

The scope of this project was to make structural improvements to the foundation of the existing concrete structure, followed by structural upgrades to the existing columns to allow for the safe transfer of newly applied loads down into the bedrock beneath the building foundation. Next, as mentioned previously, three stories of structural steel were to be added to the top of the existing building. To top off the new structure, a new elevator machine room, mechanical penthouse, and cooling tower were to be added. The existing elevator machine room and mechanical equipment was to be decommissioned and removed from the site.

One area of concern on this project was the existing elevator bank of three elevators that needed to be modernized and extended to service the three new levels. According to the contract, the general contractor had with the owner, two of the three elevators were to remain operational throughout construction to allow for the building tenants to move vertically through the building with minor disturbance.

Site Layout Planning

Site Layout Summary

As mentioned in the previous technical report, the project is located on the north side of K Street at 22nd Street and Washington Circle. The neighboring buildings consist of a residential building to the north, a commercial building to the east, K Street to the south, and 22nd Street to the West. For reference, a vicinity map is inserted below.

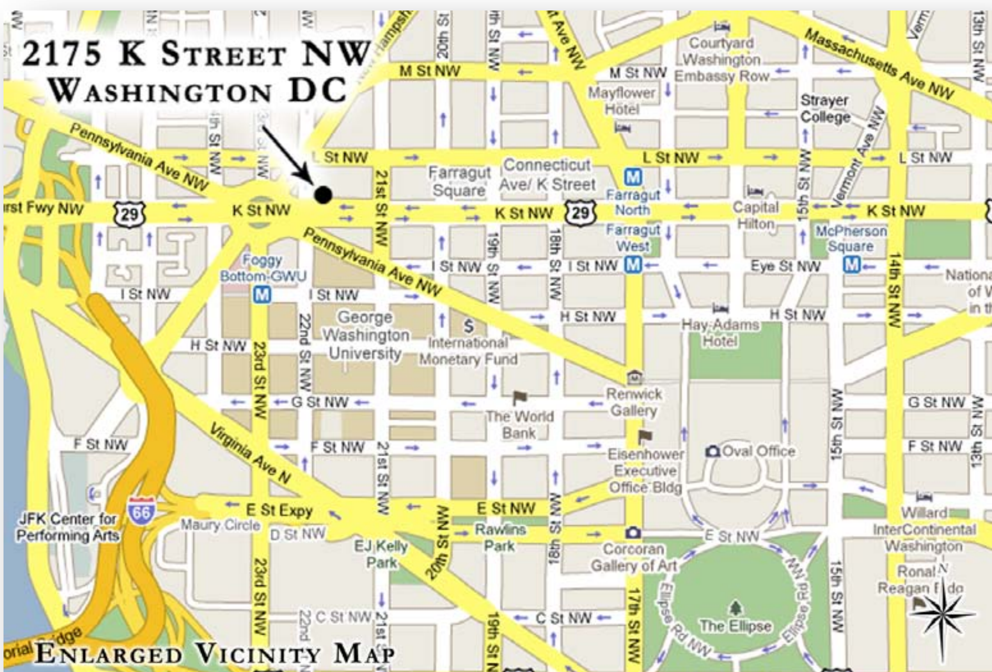

Figure 2 Project Vicinity Map

Site Layout Plan (All Phases of Construction)

A site layout and logistics plan was created for 2175 K Street as a means of maintaining a safe and efficient site for construction and the tenants of the occupied portion of the building. This site plan can be found in Appendix B at the end of this document or a larger version can be found on the 2175 K Street thesis website under Technical Assignments, Technical Assignment Two.

Several key aspects of this site make it more challenging to maintain a safe and efficient working environment, which will be outlined, in the following paragraphs. The most important aspect to all construction sites is safety. Where this project differs from the normal construction project where the key focus is on the construction worker and the pedestrians moving around the site, on this project, the previously mentioned concerns still exist but there was an additional party that had to be protected.

First, this project enforces a safety plan, developed by DAVIS, which is more stringent in comparison to the standard OSHA requirements. A prime example of this is according to DAVIS' safety plan, hardhats and safety glasses are to be worn at all times. Where this differs from OSHA is OSHA only requires hardhat and safety glasses until the area of construction in which a worker is performing his or her work has a finished ceiling.

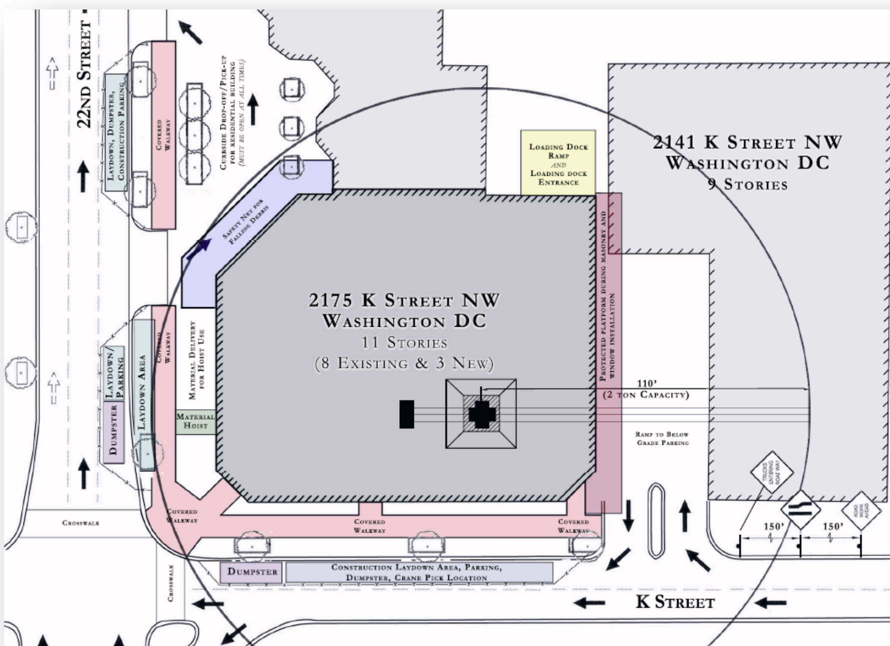

Figure 3 Site Layout Plan

Concerning the tenants of the occupied portion of the building, the project team has to maintain a safe point of entry into the building at all times. This was accomplished by utilizing a covered walkway with access to several points of entry. Additionally, for those workers who do not enter the building from the street, the access to the parking garage and the parking spaces within, have to remain available at all times. To accomplish this, the point of entry into the garage has to be free of construction vehicles at all times. For this reason, DAVIS filed for a permit to allow them to close one of the two lanes of K Street on the south side of the building. Because of this decision, the point of entry remains open and the closed lane allows for a variety of activities to utilize the space. Several examples of how this space could be used might be for dumpsters, laydown area, construction parking, crane pick location etc. Based upon the attached site plan, this area was used for all of the previously mentioned items.

Finally, with respect to the pedestrians traversing the site, covered walkways and safety nets were used to protect them from falling debris. Along K Street and 22nd Street, in accordance with DC regulations, a covered walkway was constructed with plywood and 2" x 4" dimension lumber and safety signs were posted. Regarding the covered walkway running along 22nd street, there is a break in the protection to allow construction materials to enter the site and move to the hoist whereby they would be distributed throughout the project. To maintain the safety of the pedestrians, when materials are being delivered, construction workers block the covered walkway to prevent injury. Once the material is safely on site, the construction workers will free the pedestrians to move about freely. Additionally, to protect the tenant of the neighboring building, a safety net was installed to catch any falling debris off the northwest corner of the building. This net is to remain in place throughout the duration of the project.

Pertaining to the vehicular traffic entering the below grade parking structure, a safety platform will be used during masonry construction on the west façade to prevent any damage or loss of life due to falling debris.

The loading dock on the north side of the building is to remain operational until construction on it is to begin. The construction in this area had to be completed prior to the start date of the tenant contractor's contract as to allow the tenant in the existing floors to vacate the building. The scope of work for this location primarily entailed renovating the ramp to allow larger trucks to access the space. To achieve this, a number of structural beams had to be moved and the loading dock to be extended outward.

The crane used on this project was a 2-ton tower crane with a modified base to allow it to sit atop four existing columns. As previously mentioned the maximum lifting capacity was two tons and the crane had a reach of 110 feet. The location of the crane is based upon the location of a future elevator shaft serving levels nine through eleven. The location of this tenant elevator shaft resulted in less patchwork needing to be completed at the point when the crane was to be removed. The only place where this patchwork was needed was on the roof level. Based upon the location of the tenant elevator shaft, the crane could still reach all areas of the site. Special attention had to be given to the patios of the northern residential tower when lifting over the rooftop patios.

The material hoist was strategically located on the west side of the building where it was possible to deliver material and distribute it throughout the project. No other location on the site is conducive for such a task.

To gain more space for tasks such as waste removal, laydown and/or storage, the right lane of 22nd street was partially closed as indicated on the attached site plan. Additional storage area was located on the roof of the covered walkway. As a result, the covered walkway had to be constructed in a way that would allow it to carry the load imposed by the stored material.

The site layout plan shown in Appendix C is very similar to the one used by the general contractor on the project. Due to the space constraints, there are very few possible altercation that could be made.

Site Workflow Plan

In addition to the Site Layout Plan, two workflow plans have been created to show how material, work in progress, and subsequently trash flows throughout the various floor plans. Located in Appendix D, are such diagrams. The first of two plans attached is level 8 followed by level 9. Level 9 is representative of levels 10 & 11 with the exception of the partial roof covering level 8 located on north side of level 9 closest to the neighboring residential building.

In general, the material enters the designated level and is distributed throughout. The material entering the floors is indicated by the gray arrows and moves from the material hoist located at the southwest corner and flows in both directions surrounding the core of the building and meets at the northeast corner. This was done to maximize the efficiency of the workers. The flow of work is typically counterclockwise as indicated by the black arrows.

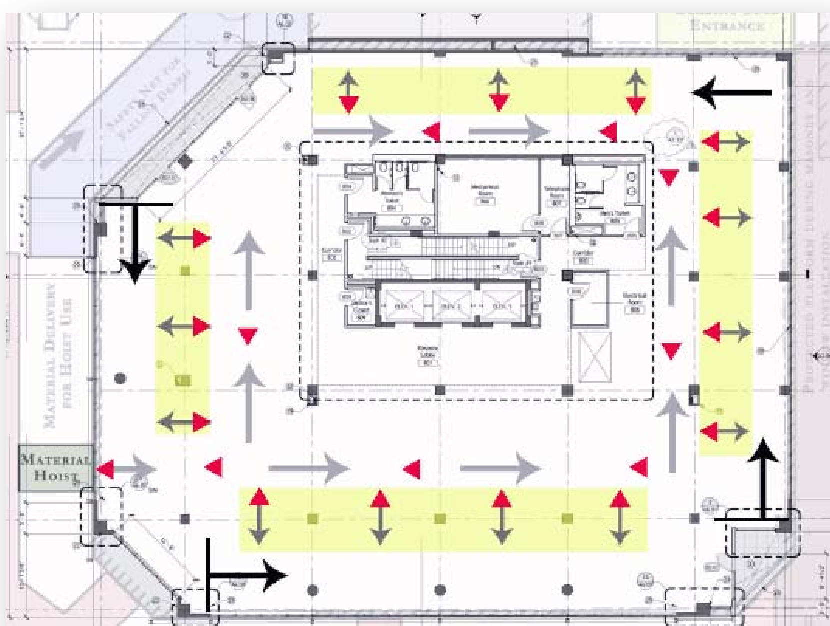

Figure 4 Workflow Plan (8th Floor)

To maintain a clean site to help mitigate safety risks, the trash flowed in the opposite direction as the material. Therefore, the trash flowed from the northeast corner and moved toward the southwest corner where the hoist is located. This is indicated on the plan by the red triangles.

The work in the core of the building generally followed behind the work on the facade. This can also be seen when referencing the attached detailed project schedule located in Appendix B.

Moving onto levels nine through roof, the workflow is very similar to the workflow as indicated in the previous few paragraphs. The key difference is on the north wall; as mentioned above, there is a portion of the roof that begins on the ninth floor thereby changing the flow of material on the floor. On this façade, scaffolding was erected on the ninth floor roof to create a working platform from which work was done.

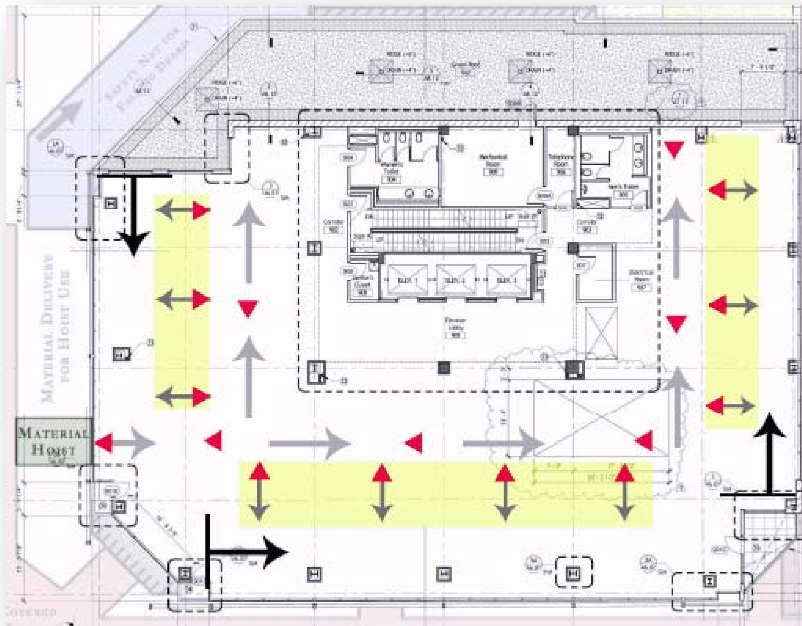

Figure 5 Workflow Plan (9th Floor – Roof)

Please reference Appendices C and D respectively for a visual representation of what was described in this section.

Project Schedule

The drawing preparation for 2175 K Street began in early February and proceeded to bid in the following year. This process took much longer than anticipated by the owner due to several impeding factors. Davis quickly began the submittal process in April '08 with the award of the subcontracts, which was followed by submittal preparation, approval, and fabrication. After a few changes to the construction documents, Davis then mobilized in August of the same year.

The work began with the improvements to the existing cellar levels, followed by preparation work to the existing façade and roof. After which, work on the new steel structure was started. This phase is primarily composed of framing and pouring the concrete piers from which the load imposed by the new steel structure and live load associated with the floor area will be transferred into the existing structure. To ensure the existing structure will be able to carry the newly imposed loads, steel jackets or carbon fiber reinforcing was incorporated. Column reinforcing used varied by location.

Subsequently, after the steel structure was complete and the associated lightweight concrete on metal deck, work began preparing the existing elevator machine room for construction. To begin work on the existing elevator machine room, the new penthouse and new elevator machine room needed to be watertight. While this was ongoing, the work on the new façade began, starting on level nine and working to level eleven. Once the penthouse was dry, work could begin on installing the equipment needed to take the building off the outdated HVAC system and turn it over to the new system.

Simultaneously, once the new elevator machine room was dry, work began on extending the existing elevator shaft up to the new EMR. This work started with elevator number one then two and finally three, always maintaining two operational elevators for tenant use. The proper phasing and timely completion of these activities was of the utmost importance to the owner. To accomplish this task safely, much work had go into place. The shaft under construction was required to be isolated from the other two to prevent debris and other hazards from entering the occupied shafts. Additionally, any work that affected all three elevators needed to be done after hours while a trained operator was in control of the elevator's movement. Because of this, a great deal of effort was expended to consolidate the number of events where all three elevators were being worked on. These activities primarily occurred in the existing elevator pits.

Concurrently, with the previously mentioned areas, work on the building core and perimeter was started. This category involves the installation of ductwork, electrical conduit, plumbing, fire suppression, etc. Additionally, the elevator shaft construction is included within this category. For reasons pertaining to workflow, the elevator shaft was discussed above. Furthermore, wall framing, drywall, ceiling construction, restroom construction, doors & hardware, and a number of other actives are included in this category.

Work on the cores of the building began on the tenth floor, then moved up to the eleventh, then down to the eight, and finished on the ninth. This was done to allow enough time for the new EMR to be completed prior to demolishing the existing one. Additionally, the project field offices were initially located on the eighth floor and were to be relocated when work on the eighth floor was scheduled to begin. Once this happened, the offices and other support items were relocated to the B1 level.

Next, work began on the first floor, beginning with the storefront system and composite metal panels, followed by the construction of the new main lobby. The work on the northwest corner of the building needed to be completed prior to work starting in the main lobby. This was due to the main entrance of the building being relocated to the entrance located at said corner while the lobby entrance was closed due to construction activities.

This project was completed in March 2010, with demobilization being completed in November 2009 and closeout was started in December. This project has two substantial completion dates. The first is to be at the completion of the second elevator and the second is to be at the completion of the third elevator.

For reference, the detailed project schedule can be found in Appendix B at the end of this document.

The intent of the following table is to be a quick synopsis of the project schedule for 2175 K Street. It contains the key features from the Primavera P6 schedule but in a condensed format. Included in the table are the categories of construction activities, the start and finish dates, the duration, and most importantly, the percent of total duration. This percent compares the duration of the category to the sum total of all the category durations. To draw attention to the top five categories based upon duration, they have been highlighted in yellow and are in bold font.

2175 K STREET, NW
Project Schedule Duration Comparison

Category	Start	Finish	Duration	Percent of Total Duration
Preconstruction	**02-Feb-07**	**01-Oct-08**	**434**	**16%**
Submittals	**27-May-08**	**28-Sep-09**	**350**	**13%**
Contract Changes	03-Nov-08	31-Mar-09	107	4%
Mobilization	**01-Aug-08**	**19-Dec-09**	**361**	**13%**
Cellar and Existing Levels	03-Nov-08	12-Oct-09	246	9%
New Structure	08-Dec-08	31-Aug-09	191	7%
Façade and Roof	**24-Nov-08**	**09-Dec-09**	**273**	**10%**
Penthouse	13-Apr-09	21-Jul-09	72	3%
Elevators	**19-Mar-09**	**04-Mar-10**	**251**	**9%**
First Floor	17-Jun-09	15-Dec-09	130	5%
Core and Perimeter	08-Apr-09	12-Nov-09	157	6%
Project Completion	20-Jun-09	11-Mar-10	189	7%
			2761	**Total Days**
Project Total	**02-Feb-07**	**11-Mar-10**	**810**	**Callendar Days**
			162	**Weeks**
General Conditions	**01-Aug-08**	**11-Mar-10**	**420**	**Callendar Days**
			84	**Weeks**

Figure 6 Project Schedule Duration Comparison

The purpose of this table is to quickly emphasize the key contributors to the overall length of the schedule by comparing the duration of each construction category to the total duration of the project. This way, the reader can quickly see areas of greatest emphasis. This becomes critical when attempting to accelerate the project schedule. To make the key contributing factors more apparent, the top five categories, based upon duration, have been highlighted in yellow and are in bold font.

Building Systems Summary

Demolition

The nature of this project is an occupied renovation. The demolition portion of this project consists of selective demolition on the two parking levels, the cellar level, the ground level, the cores of levels two through seven, level eight, and Roof and Penthouse level. Most of the materials involved with these areas consisted of drywall, light gauge metal framing, electrical conduit, lighting fixtures, and ceiling tile and track.

Going into a little more detail, the demolition work on parking level three consisted of removing the old generator and fuel oil tank, the concrete pad beneath the previously mentioned equipment, and the chain-link fence used to surround the generator and tank.

On the ground floor, the project scope contains the renovation of the space occupied by Starbucks Coffee. In addition, the building lobby is to receive a makeover. In general, the majority of the demolition is the removal of interior walls.

Moving onto another place of interest, on levels two thru seven, the demolition consists of the removal of the toilets and toilet partitions, the partition support steel, the vanities along with the supporting steel, the ceiling tiles and track, lighting fixtures, and the floor tile. The support steel for the vanities and the partitions will be reused in the new construction but the rest is to be scrapped.

On levels eight, the demolition is quite extensive leaving only the structural concrete, elevator shaft, and façade intact.

With regards to the roof and penthouse demolition, the work consisted of maintaining operation of the existing cooling tower and mechanical equipment until the new penthouse was completed.

The existing building was built in 1981 and because of this, there was no lead paint or asbestos abatement necessary.

Structural Steel Frame

This project involves the addition of three levels of structural steel with lightweight slab on deck construction. Levels ten and eleven structural slab is to be 3 ¼" lightweight concrete over 2" deep by 18 gauge galvanized composite metal deck measuring a total of 5 ¼" reinforced with 6x6 –W2.0 x W2.0 welded wire fabric. The typical bay size is 23'-3" by 36'-8". To achieve these spans, composite beams were utilized. The crane used to erect the steel and pour the concrete slabs was placed where a future elevator and grand staircase was to be installed. This elevator was to only service levels eight thru eleven. Due to the constraints imposed by the limited space on site, the crane was placed atop four columns on the existing roof. Concrete piers were poured to create the foundation on which the crane was placed. Carbon fiber and/or steel jackets were used to allow the column to carry the new load imposed by the crane and the material lifted by it. The crane used was a 2-ton tower crane.

Cast in Place Concrete

There was limited cast in place concrete on this job. It was limited to the lightweight slab on deck, equipment pads, and the minor expansion of several of the existing footers. The foundation of the existing building consists of 48" x 48" x 24" footers, where several underwent minor expansions as previously mentioned to support the new loads imposed by the additional structure above. The existing building consists of cast in place concrete where several columns received carbon fiber or steel jackets to help them carry the newly imposed load from the new construction. Where there was new cast in place concrete, edge angle was used to create the edge of slab and wood formwork for the equipment pads. The concrete used for the lightweight slab on composite metal deck was 3,000psi (110 PCF) and the concrete used in the above mentioned concrete piers was 4,000psi (145 PCF). Where the footings needed expanding, 3,000psi (145 PCF) concrete was used.

Mechanical System

The primary mechanical room for this project is located on the penthouse level. Located there is one 1,200 GPM 350 ton induced draft cooling tower which serves eleven self-contained packaged water cooled units throughout the building. Each of the self-contained units on levels nine, ten, and eleven contain a 14,000 CFM fan with an incoming air temperature ranging between 65° and 80°F and a returning air temperature of 53°F with respect to cooling. Each SCU is rated for 35 tons of cooling. On the other hand, with respect to heating, electrical resistant heating coils operated on 3-phase 208V power were used. The previously mentioned self-contained units service the tenant spaces whereas a closed loop system with VAV's was used in the building core.

The fire-suppression system combined sprinkler/standpipe system. In areas affected by freezing conditions, a dry system was used. Such a location included a portion of the loading dock. In all other areas, a wet system with heat sensitive sprinkler heads was used.

Electrical System

The main service feeders for the building enter from the Pepco transformer vaults on K Street at the cellar level. Due to the nature of the project, the Pepco vaults were not touched and therefore the size and type of transformers held within is unknown. The electrical service for the new construction enters at 2,000A and is distributed on a 208Y/120V system. To handle the new electrical load, a new switchgear along with two 2,000A distribution panels were added. The emergency power is supplied by a 250 KW 208Y/120V diesel generator.

Masonry

The masonry used on this project was only a veneer. Red clay brick was used on the North façade facing the neighboring apartment buildings from level nine thru the roof. Incorporated into the brick façade is one punch window on each floor with three punch windows in total. To assist in the placement of the brick, scaffolding was erected on the eight floor roof and extended up to the eleventh floor roof. Where the roof on the ninth floor was not present, swing stages were utilized in the placement of the brick. The brick dead loads at each level and is then carried by a piece of angle iron attached to the structure. To prevent lateral movement in and out of the plane of the wall, brick ties were used every couple of brick courses.

Curtain Wall System

There are several types of systems that make up the building façade. As mentioned above, masonry was used on the north façade while a curtain wall system was used on the south and west façade and ribbon windows were used on the east façade. The curtain wall system used on the south and west facades is a unitized system comprised of aluminum framing and exterior glazed glass panels. Each unit is one story in height and four feet in width. On the southwest corner of the building, due to its prominent location, a separate type of curtain wall system was used. This stick built system is three units wide and spans the total height of the building starting on level two and extending up to the roof. Accent Metal Services was responsible for the design and Harmon was responsible for the installation.

Support of Excavation

There was very limited excavation on this project because it was an existing building before the project started and the building was to remain in use throughout construction. The only excavation needed was to expand a number of the footings below parking level two. This excavation did not require any support because the footers are on bedrock and the expansion only adjusted the width in the x-y plane. The height of the footer was not adjusted therefore underpinning was not required either.

LEED Requirements

When the owner first approached the design team with the desire to put this project into the works, they had no intention of pursuing any LEED certification. Approximately one year into the construction phase of the project, the owner came to one of the owners meetings and started tossing around the idea of going for a LEED certification. Due to the public desire to rent "green" space, the owner decided to move ahead with LEED in mind. Due to the nature of the project and the point at which they expressed an interest, LEED in the traditional terms was not an option. The architect mentioned the possibility of achieving LEED EB (LEED for Existing Buildings). The owner, based upon a suggestion from the architect, decided to contract a third party consultant to conduct a LEED feasibility study and they would go from there.

Even though LEED was never an end goal, the design team did incorporate a few LEED strategies into their design. First, the solar shades on the façade of the building could provide passive solar shading and thereby reduce the thermal gain and consequently reduce the mechanical load on the building during the summer months. The other distinct green feature was the green roof that covers the roof on the ninth floor. Because the green roof is not the primary roof system, the area it covers is rather small, only approximately 12% of the total roof surface.

General Conditions Estimate

An estimate was compiled to represent the general conditions on the 2175 K Street site. A summary of this general conditions estimate is located in the tables below. More detail is available in Appendix E at the end of this document.

The estimate is comprised of the following areas:

- permitting
- supervision and management teams salaries
- general conditions
- miscellaneous labor
- courier fees
- a dump truck driver
- DAVIS equipment/vehicle rental
- temporary facilities
- punch list / warrantee

Sales tax is included for the DC area on all applicable material. Additionally, insurance and employee benefits are included in the grand total. The grand total, as shown below, comes out to $1,467,112. A detailed cost comparison is outlined on the next few pages.

The table below is designed to show a price comparison between the various items included in the estimate as well as shows the percentage of each item with respect to both the subtotal and the total for each category. These categories are material and labor. To highlight the largest contributing factors, they have been highlighted in yellow and the font is bold.

Going into more detail, the percentage located in the "Percent of Subtotal" beside each item compares that items material or labor cost respectively with the subtotal for that category. Similarly, the percentage located in the "Percent of Total" compares the total for that item with respect to the total for that category. The only difference between the subtotal and total is the addition of the insurance and employee benefits on the labor cost.

The category "DAVIS rentals" is the primary contributing factor in relation to the total material cost. This cost is $177,442, which computes to 74.6% of the total cost of material. Included in this line item is vehicle rental, field office equipment, etc. The largest contributing factor for the cost of this line item is the project manager's vehicle and the cost associated with it.

On the other hand, the supervision and project management line item is the largest percentage with respect to the total labor costs for the project. This line item costs $712,626, which computes to almost 90% of the subtotal and almost 58% of the total cost associated with labor. The reason for the decrease in the percentage when going from subtotal to total is due to the addition of insurance and employee benefits. This number is within reason because typically the staffing cost on a project is the primary factor in the cost of general conditions.

2175 K STREET, NW
Contractor General Conditions
(Price Comparison - Percentage)

Category/Activity	Total Material Cost	Percent of Subtotal	Percent of Total	Total Labor Cost	Percent of Subtotal	Percent of Total
Permit	$ -	-	-	$ -	-	-
Supervision & Project Management	$ -	-	-	$ 712,625.72	**89.86%**	**57.97%**
General Conditions	$ 8,581.61	3.61%	3.61%	$ -	-	-
Miscellaneous Labor	$ -	-	-	$ 43,206.00	5.45%	3.51%
Courier	$ -	-	-	$ 6,992.92	0.88%	0.57%
Dump Truck - Driver	$ -	-	-	$ 3,496.46	0.44%	0.28%
Rentals (DAVIS)	$ 177,441.96	**74.59%**	**74.59%**	$ -	-	-
Temporary Facilities	$ 25,723.69	10.81%	10.81%	$ -	-	-
Safety	$ 25,128.34	10.56%	10.56%	$ 24,277.50	3.06%	1.98%
Punch List / Warrantee	$ 1,000.00	0.42%	0.42%	$ 2,457.00	0.31%	0.20%
SUBTOTAL	$ 237,875.60		16.21%	$ 793,055.60		54.06%
TOTALS	$ 237,875.60		16.21%	$ 1,229,236.18		83.79%
GENERAL CONDITIONS GRAND TOTAL	$1,467,112					

Figure 7 General Conditions Price Comparison - Percentage

The next table shows the relation between each line item and the associated cost per week over the duration of the specific activity. As shown in the below table, the total weekly material cost comes out to $2,673 and the total weekly labor cost is $13,812. Similarly, in comparison to the last table, with respect to materials, "DAVIS rentals" has the highest weekly cost equaling $1,994. Additionally, with respect to material, supervision and project management equates to $8,007 per week. This amount is over four times the highest weekly cost concerning material. This fact reinforces the statement above regarding staffing being the largest cost associated with general conditions. The total general conditions, when compared to the duration of the project, come out to $16,484 per week.

2175 K STREET, NW

Contractor General Conditions

(Price Comparison - Cost per Week)

CATEGORY/ACTIVITY	QUANTITY	TOTAL MATERIAL COST	COST PER WEEK	TOTAL LABOR COST	COST PER WEEK
Permit	0	$ -	-	$ -	-
Supervision & Project Management	89	$ -	-	$ 712,625.72	$ 8,007
General Conditions	89	$ 8,581.61	$ 96	$ -	-
Miscellaneous Labor	69	$ -	-	$ 43,206.00	$ 626
Courier	56	$ -	-	$ 6,992.92	$ 125
Dump Truck - Driver	3	$ -	-	$ 3,496.46	$ 1,249
Rentals (DAVIS)	89	$ 177,441.96	$ 1,994	$ -	-
Temporary Facilities	69	$ 25,723.69	$ 371	$ -	-
Safety	69	$ 25,128.34	$ 362	$ 24,277.50	$ 350
Punch List / Warrantee	3	$ 1,000.00	$ 400	$ 2,457.00	$ 983
SUBTOTAL	89	$ 237,875.60	$ 2,673	$ 793,055.60	$ 8,911
TOTALS	89	$ 237,875.60	$ 2,673	$ 1,229,236.18	$ 13,812
GENERAL CONDITIONS GRAND TOTAL		$1,467,112			*$16,484*

Figure 8 General Conditions Price Comparison - Cost per Week

The total general conditions, when compared to the duration of the project, come out to $16,484 per week. To calculate this amount, the maximum duration was used, in the case of 2175 K Street, this duration is eighty-nine weeks. This duration differs slightly from the one calculated in the project schedule because the project team is involved before the site is mobilized. The duration found in the detailed project schedule section was calculated from mobilization to the completion of the closeout phase.

Basis for Chosen Analyses

Concerning 2175 K Street, very little effort was invested into reducing the building's energy consumption. This was considered to be an opportunity for improvement given the current state of the economy and rising fuel costs. According to the United States Green Building Council, in the United States alone, buildings account for 72% of electricity consumption[1].

In the following pages, several analyses will be discussed, all of which involve the theme of reducing energy consumption in buildings. These analyses will be custom tailored to the project constraints of 2175 K Street but the principles discussed within each could be applied to any number of projects.

All four analyses were chosen based upon the aforementioned theme of reducing electricity consumption in buildings. Another important component is upfront cost and thereby will be discussed because it is typically the primary deciding factor when a building owner is choosing to implement a given strategy or not to. Additionally, payback period is extremely important because they want to know if they invest a given amount of money, how quickly do they recover that initial investment and begin to receive a positive cash flow from the given change. One last metric that will be discussed within each section is the relative cost per square foot floor area.

Consequently, at the end of each section is a brief conclusion that summarizes the finding of the analysis as well as any associated final recommendations regarding the feasibility of the suggested changes. In addition, at the end of this report is a "Final Words" section which serves to summarize all of the analyses in one location and provide the final recommendations based upon the relative payback periods of each component of each analysis.

Masters of Architectural Engineering Requirement

To satisfy the Master of Architectural Engineering Requirement, the knowledge gained through several masters level classes was implemented throughout this report. For example, the knowledge gained through AE 597D Sustainable Building Methods helped to shape the theme of the four analyses within. In addition, with respect to the analysis entitled Backup Generator Analysis, the premise that forms the foundation of said analysis was envisioned during said class. Additionally, the mechanical calculations were done based upon the knowledge gained through AE 542 Building Enclosure Science and Design. More information regarding the specifics of the knowledge gained through said courses can be found within each analysis. Lastly, the knowledge gained in AE 572 Project Development and Delivery Planning helped to create more thorough financial models that were discussed within this report.

[1] USGBC. http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1718

Backup Generator Analysis

Area of Potential Improvement

As discussed previously, it is estimated that buildings in the United States use upwards of 72% of the electricity produced. This is a rather large number and needs to be addressed. Over the past several years, much emphasis has been placed on reducing this number in an attempt to prevent the worsening effects of global warming. This analysis was conducted to help do just that. Many people would never consider using the backup generator as a source of sustained power in a building, but this "out-of-the-box" thinking is needed to help drive the effort to reduce electrical consumption by buildings and promote on-site electricity generation.

Proposed Solution

The first analysis conducted is one that investigated the area of peak energy shaving. Currently, most if not all electricity utilities charge a premium on energy consumed at peak times during the day. To reduce the amount of electricity the building is consuming during these hours several strategies could be implemented. Some examples of such strategies are, utilizing a combined heat and power system, using the backup generator to supplement the electricity load, and many others. Two additional strategies that could prove beneficial in some situations could be the use of ice storage in conjunction with the building mechanical system and photovoltaics in conjunction with the building electrical system. An ice storage system could be used to offset the energy consumed by the mechanical system when cooling the building to the design temperatures. Likewise, a photovoltaic system could offset some of the building electrical load.

Based upon the concern of increasing first time costs, this analysis will look into the benefits of utilizing the existing backup generator to decrease electrical loads. Due to the current state of the economy, owners are increasingly wary of adding cost to their projects. Because of this concern, it was decided to investigate using the backup generator that was already specified to be installed to reduce the electrical demand the building is imposing on the local grid. Another benefit to using on-site power is the loss of energy due to transmission losses is reduced. Transmission losses occur when power is transported long distances from the generation plant to the end user due to resistance in the copper lines. By shortening this distance, the system can become more efficient.

Benefits

There are a number of benefits to implementing any of the aforementioned strategies. The immediate benefits would be the reduction in the electricity bill for the owner. Additionally, one benefit not realized at first would be the savings associated with leveling out the electricity demand which would be a cost savings to the electric utility thereby reducing wasted efficiency associated with running a power plant at less than full load. A great deal of efficiency is lost when a utility has to ramp down a power plant. If more effort was invested in balancing out the electricity demand from buildings, the power plants would be able to run at optimal efficiency, thereby electricity would cost less and fewer greenhouse gasses would be emitted. Additionally, the nation is starting to realize the power of the sun and other sources of renewable energy. This is why photovoltaics will become more influential in the near future as the technology is fine tuned and initial cost is reduced.

Regarding the conducted analysis, using the backup generator to help offset building electricity loads was the primary focus and will be discussed in the following pages.

Drawbacks

One major area of resistance is in terms of first time cost. Concerning the opportunity of using the backup generator to offset the electricity usage of the building has no additional cost to implement and therefore will be the focus of this analysis. Another facet that will need to be explored is the impact of running the backup generator in a sustained manner would have on the building and its tenants. This analysis will look into the sound and exhaust characteristics to ensure safe and practical use of this system.

Research

The research component of this analysis was to investigate the potential health implications that result from the proposed solution. Additionally, research into other types of generators was investigated to determine if one type has benefits that outweigh another. In other words, the base generator studied was a 300kW diesel generator and in addition, several sizes of natural gas generators were explored. Lastly, research was done to determine if additional design criteria are necessary when proposing to use the backup generator in such a manner.

Methodology

- Research drawbacks to proposed solution (occupant health)
- Calculate energy savings vs. added fuel cost
- Evaluate adequacy existing wall construction
- Investigate ways to further increase sound attenuation
- Evaluate schedule impact
- Perform a constructability review
- Summarize findings

Preliminary Tools to be Used

- Original Equipment Manufacturers and Dealers
- Project Owner, Professors, and colleagues
- Microsoft Excel

Expected Outcome

The expected outcome from this analysis included having a positive effect on the energy consumption of the building while creating a guide for other projects to use to evaluate their potential energy savings. To do this successfully, occupant health was a key facet of this analysis.

Occupant Health

When proposing to use a fuel-burning generator to supplement the building's electrical demand, occupant health must be considered. When introducing a combustion engine into an enclosed environment, numerous toxic agents will need to be addressed. The following chart includes the permissible exposure limits for various toxins associated with the combustion of a diesel engine.

Carbon Monoxide	50 ppm
Carbon Dioxide	5000 ppm
Nitric Oxide	25 ppm
Nitrogen Dioxide	5 ppm
Sulfur Dioxide	5 ppm

Carbon Monoxide[2]

The symptoms associated with carbon monoxide exposure are headaches, tachypnea (shortness of breath), nausea, weakness, dizziness, confusion, hallucinations, depression, cyanosis (blue coloration of the skin), and eventually death.

Exposure to this toxin will have a negative effect on a person's cardio vascular system, lungs, blood, and central nervous system.

[2] OSHA Chemical Sampling Information: http://www.osha.gov/dts/chemicalsampling/data/CH_225600.html

Carbon Dioxide[3]

The symptoms associated with carbon monoxide exposure are headaches, dizziness, restlessness, heart rate, elevated blood pressure, coma, asphyxiation, and convulsions.

Exposure to this toxin will have a negative effect on a person's lungs, skin, and cardio vascular system.

Nitric Oxide[4]

The symptoms associated with nitric oxide exposure are eye, nose, throat, wet skin irritation; cough, shortness of breath, pulmonary edema (may be delayed); methemoglobinemia, cyanosis; headache; abdominal pain, nausea; confusion, drowsiness, convulsions, unconsciousness.

Exposure to this toxin will have a negative effect on a person's eyes, skin, respiratory system, blood, and central nervous system.

Nitrogen Dioxide[5]

The symptoms associated with nitrogen dioxide exposure are irritation of eyes, nose, throat; cough, mucoid frothy sputum, decreased pulmonary function, chronic bronchitis, dyspnea (breathing difficulty); chest pain; pulmonary edema, cyanosis, tachypnea, tachycardia; eye, skin burns; dermatitis, frostbite (upon contact with liquid); Acute: Burns in mouth, throat and stomach. Chronic: Headache, weakness, loss of appetite, nausea, sores in nose and mouth, erosion of teeth and emphysema.

Exposure to this toxin will have a negative effect on a person's eyes, respiratory system, and cardiovascular system.

Sulfur Dioxide[6]

The symptoms associated with sulfur dioxide exposure are eye, nose, throat irritation; rhinorrhea, nosebleeds; choking, coughing, shortness of breath, chest pain, pulmonary edema, cyanosis; reflex bronchoconstriction; eye, skin burns; frostbite (on contact with liquid); asthma; chronic bronchitis.

Exposure to this toxin will have a negative effect on a person's eyes, skin, and respiratory system.

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[3] OSHA Chemical Sampling Information: http://www.osha.gov/dts/chemicalsampling/data/CH_225400.html
[4] OSHA Chemical Sampling Information: http://www.osha.gov/dts/chemicalsampling/data/CH_256700.html
[5] OSHA Chemical Sampling Information: http://www.osha.gov/dts/chemicalsampling/data/CH_257400.html
[6] OSHA Chemical Sampling Information: http://www.osha.gov/dts/chemicalsampling/data/CH_268500.html

Based upon the specifications supplied by the manufacturers of the chosen generators, all of them comply with emissions standards of the governing bodies and are therefore acceptable to use in the proposed scenario. Additionally, with regards to the adequacy of the existing exhaust duct, it was determined through discussions with the mechanical subcontractor on the project that the added cost associated with the proposed change with regards to the size of the generator would be negligible.

Resulting Energy Savings

The energy saving results are based upon the existing generator and three different proposed generators. The first generator analyzed was the existing Cummins 300kW diesel generator. In addition, three different sizes of Caterpillar generators were investigated. These generators were 350kW, 450 kW, and 1040 kW; all using natural gas as the fuel source. The following table is a summary of the results of this analysis.

Summary

Generator Type	Size (kW)	Annual Energy Savings	Cost	Additional Cost	Payback Period
Diesel*	300	($47,498.67)	$58,800		N/A
Natural Gas	350	($34.86)	$137,200	$40,076	N/A
Natural Gas	450	$6,053.72	$176,400	$40,076	35.76
Natural Gas	1040	$135,308.33	$407,680	$40,076	3.31

**Existing Generator*

Figure 9 Summary of Energy Savings

This analysis was based upon running the generator for a full eight hour day and five days a week. Additionally, each generator was analyzed at 25%, 50%, 75%, and 100% load. With regards to electrical utility rates, a price of $0.1543 was assumed. This rate was determined by contacting the local electric provider' PEPCO. Additionally, the fuel prices were found at the Department of Energy website for the District of Columbia. More information on the details of this analysis can be found in Appendices G through J. Included within each appendix is a table showing the breakeven points associated with each generator option. Additionally, each table shows the energy savings associated with running each generator at partial load.

Option One (Existing Generator)

Going into more detail, with regards to the base case, the projects existing generator, this option turned out to have a negative energy savings associated with it. When operating the diesel generator at full load, the yearly savings was calculated to be approximately negative $48,000. This was attributed to the fact that the owner was not purchasing a generator for which was intended to run on a daily basis. This generator was chosen based on a standby output that was sufficient to run the life safety systems within the building and its price point.

After determining the net savings for this option was negative, breakeven points were calculated. This was done to determine the operational limits of several key factors that would cause the net savings to be turn positive. When discussing fuel efficiency, the generator's fuel consumption rate would need to be reduced by 33%, or from 23.15 gallons per hour to 15.50 gallons per hour. Similarly, fuel costs would need to drop by 33%, or go from $2.986 to $2.000. This factor would be the most important to the owner because if the cost of diesel fuel were to drop below $2.00, however unlikely, this option would become a viable solution for reducing the overall cost associated with the building's electrical load. Additionally, it was determined if the existing generator had an output 50% larger than it does now, this would also cause the net savings to breakeven. This factor is beneficial to the owner because it indicates what minimum performance is needed if this strategy of peak energy shaving were to became a future goal. The last contributing factor that was assessed was the cost of electricity. It was determined, for the net savings to end up positive, the cost of electricity would have to rise above $0.2304 per kWhr. As discussed previously, the current rate is $0.1543 in Washington DC, which mean the cost of electricity would need to increase by 50%.

When discussing these breakeven points, it is important to point out that the assumption was made that all other factors were held constant and only the one factor in question was altered. This could prove to be unrealistic based upon simple economics. In other words, if the fuel cost were to increase, the cost of electricity would increase accordingly.

Option Two (350kW Natural Gas Generator)

A similar set of calculations were performed using a natural gas generator manufactured by Caterpillar with an output of 350kW. Analogous to the resulting net savings of Option One, this generator's savings ended up being negative. These values were calculated based upon the current cost of natural gas being $12.08 per thousand cubic feet and the cost of electricity the same as discussed option one.

In terms of net savings, this scenario results in net annual savings of negative $34.86. Consequently, the breakeven points are as follows, a maximum fuel consumption rate of 4471 cubic feet per hour (0.03% reduction), a maximum fuel cost of $12.076 per thousand cubic feet (0.03% reduction), a minimum generator capacity of 350.11 kW (0.03% increase), and a minimum electricity cost of $0.15435 per kWhr (0.03% increase). These values prove to be encouragement for further investigation.

Option Three (450kW Natural Gas Generator)

As expected based upon the results discussed with respect to option two, this generator configuration results in a positive net annual savings of approximately $6,100. After this was determined, a dealer was contacted regarding the cost associated with this generator. This cost was figured to be approximately $180,000. When the additional cost associated with the labor and material needed to get the natural gas from the main line running north-south along 22nd Street into the building and over to the generator enclosure, the payback period was calculated to be around 36 years. This is reasonable due to the high initial cost and relatively low annual payback.

The cost breakdown is as follows, $176,400 equipment, $20,000 excavation, $10,000 roadway patching, and $10,000 piping. These prices include labor and material. The equipment cost was provided by a Caterpillar dealer in the metro-DC area and the other three costs were estimated after contacting the general contractor on the project.

Option Four (1040kW Natural Gas Generator)

The same calculation was performed based on a 1040kW natural gas generator. This calculation was done on a purely speculative basis. This is because the current size of the generator enclosure would need to be substantially increased, which is beyond the purpose of this analysis. In addition, the results to be discussed in the following section, "Sound Attenuation," are based upon the base generator not one of this size. With that said, the net annual savings associated with this generator were calculated to be positive $135,000. When the additional costs are assessed, the payback period would be approximately three years. This assumes the current electrical feeders are of sufficient size and capacity to handle the startup of this generator.

If the owner wanted to install such a large generator, substantial costs could arise depending on the currently installed infrastructure. New piping and other electrical wiring and equipment might be needed to support the larger generator.

The calculations discussed within this section along with more details can be found in Appendix G, H, I, and J respectively.

Sound Attenuation

Another factor controlling the success of this analysis is the resulting sound level associated with running a generator for a sustained length of time during normal business hours. Consequently, an acoustical analysis was performed. First, the adequacy of the existing construction was assessed and determined to be insufficient in containing the sound waves emitted by the generator.

The sound pressure levels for the base case, generator enclosure walls made of concrete and CMU, ranged from 58.3 dB at 4000 Hz up to 70.8 dB at 125 Hz. These values are unacceptable based upon the control cases, discussed in the following section, and therefore more attention must be given to this situation in an attempt to reduce the amount of sound that is allowed to exit the generator enclosure and make the construction code compliant.

Subsequently, alternative construction methods were considered. The local code in Washington, DC stipulates that a point source can have a maximum sound pressure level equal to that of traffic on the roads directly outside of the building. To assess the existing generator, it was compared to several acceptable situations. These being typical office activities sound levels, classroom sound levels, and normal conversation sound levels. These sound levels are shown in the table below.

Goal Transmission Loss						
	Frequency (Hz.)					
Location Type	**125**	**250**	**500**	**1000**	**2000**	**4000**
Office Activities	50	50	50	50	50	50
Classroom	66	72	77	74	68	60
Normal Conversation	57	62	63	57	48	40

Figure 10 Goal Transmission Loss

The values within the table are measured in decibels. These values can be found in Architectural Acoustics by M. David Egan as well as the rest of the values within the following tables.

In an attempt to reduce the transmitted sound levels emanating out of the generator enclosure, several wall assemblies were considered. The following table outlines the chosen assemblies.

Construction Description	
Construction No. 7	2 by 4 wood studs 16 in oc with 1/2-in gypsum board both sides
Construction No. 8	Construction No. 7 with 2-in glass-fiber insulation in cavity
Construction No. 9	2 by 4 staggered wood studs 16 in oc with 5/8-in gypsum board both sides

Figure 11 Construction Type Descriptions

As outlined in the table on the previous page, the selected construction type was Construction No. 9. The figure to the right is a representation of what was determined to be the best method of wall construction that reduced the sound transmission to the predetermined levels that will be discussed in the following few pages. As discussed above, this construction entails using 2" x 4" staggered wood studs with 5/8" drywall on both sides. It is important to point out, this wall construction is not in lieu of the existing construction but in addition to. To summarize, the existing construction is cast-in-place concrete up to four feet above the slab elevation with concrete masonry units making up the rest of the wall height.

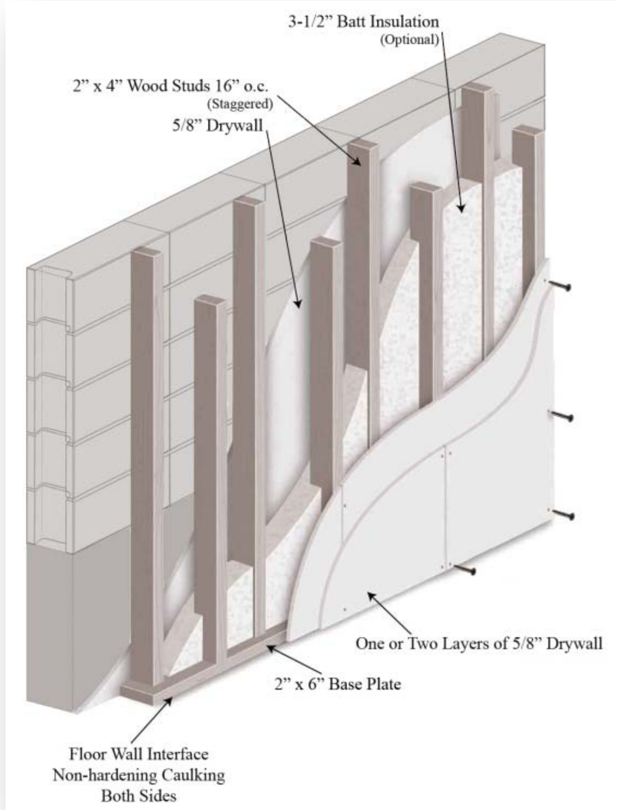

Figure 12 Construction No. 9

These assemblies were chosen based upon their inherent transmission loss values and ease of construction. This was done to maximize the reduction of sound at key frequencies while maintaining a reasonable added cost. The table on the next page shows the transmission losses associated with various building materials or assemblies as outlined above.

Transmission Loss						
	Frequency (Hz.)					
Material	**125**	**250**	**500**	**1000**	**2000**	**4000**
Concrete	38	43	52	59	67	72
CMU	34	40	44	49	59	64
Door	23	28	36	41	39	44
Construction No. 7	17	31	33	40	38	36
Construction No. 8	15	30	34	44	46	41
Construction No. 9	23	28	29	46	54	44

Figure 13 Associated Material Transmission Loss

Each material has a different effect on the sound transmission based upon the frequency of the sound wave.

The sound levels of the generator was found collected from the product data submitted by the subcontractor to the general contractor and are as follows.

Sound Level						
	Frequency (Hz.)					
	125	250	500	1000	2000	4000
Generator	100.3	104.8	109.9	113.1	111.7	109.7

Figure 14 Base Generator Sound Level

After calculating the composite TL based upon the added wall construction, the resulting sound pressure levels could be calculated. These values are shown in the following table and are based upon the three construction types discussed earlier in this section.

Resulting Sound Level						
Construction No. 7	53.8	39.2	35.0	26.1	27.3	22.3
Construction No. 8	55.8	40.2	34.0	22.1	19.3	17.3
Construction No. 9	47.8	42.2	39.0	20.1	11.3	14.3

Figure 15 Resulting Sound Level

To assist in the comparison between these resulting values and the predetermined accepted values, the following table was created.

Summary							
	Frequency (Hz.)						Per Activity
	125	250	500	1000	2000	4000	
Construction No. 7							
Office Activities	✗	✓	✓	✓	✓	✓	✗
Classroom	✓	✓	✓	✓	✓	✓	✓
Normal Conversation	✓	✓	✓	✓	✓	✓	✓
Construction No. 8							
Office Activities	✗	✓	✓	✓	✓	✓	✗
Classroom	✓	✓	✓	✓	✓	✓	✓
Normal Conversation	✓	✓	✓	✓	✓	✓	✓
Construction No. 9							
Office Activities	✓	✓	✓	✓	✓	✓	✓
Classroom	✓	✓	✓	✓	✓	✓	✓
Normal Conversation	✓	✓	✓	✓	✓	✓	✓

Figure 16 Summary of Acceptable Sound Levels

This table quickly shows if and at what frequency each construction type fails based upon the accepted sound level with each category offering a different type of environment.

As shown in the table on the previous page, the only construction type that passed all three situations was Construction no. 9 which consists of 2" x 4" staggered wood studs 16 in on center with 5/8-in gypsum board on both sides.

It is important to note that this wall construction is not in lieu of the concrete and CMU wall but in addition to. When the new cost associated with construction no. 9 was calculated, the total was determined to amount to $1,656 or $4.87 per square foot. Based upon this added cost, if the owner wanted to reduce it, construction no. 7 could be used to reduce the sound levels to that where normal conversation could take place but might be slightly annoying in an office setting. Below is a table containing the relative costs for each construction type.

Construction Type	Unit Cost	Unit	Extension	Total
Construction No. 7	$ 3.09	SF	340	$ 1,050.60
Construction No. 8	$ 3.94	SF	340	$ 1,339.60
Construction No. 9	$ 4.87	SF	340	$ 1,655.80

*Totals include a 15% waste factor

Figure 17 Construction Type Cost Breakdown

Another important aspect of this analysis that has not been mentioned, is the above sound levels are those directly outside of the generator enclosure not those four stories up in the tenant office spaces. The generator enclosure is separated from the office spaces by two parking levels and a lobby level. When considering this separation, all three construction types would prove suitable for this application. On the other hand, any shafts that travel directly from the generator enclosure to any other parts of the building will need to addressed accordingly to prevent sound from propagating through the shaft and being allowed to enter occupied space.

Schedule Impact

When discussing the impact these proposed changes have on the project schedule, several scenarios must be addressed. First, the owner were to attempt to use the existing generator to reduce the building's electrical demand without addressing sound attenuation, there would be no change to the schedule because everything is being used as is. As outlined above, this would not be recommended due to the negative affect this had on net savings.

Similarly, if the 350kW generator or the 450kW generator were to be used, the additional area needed to install either generator was determined to be acceptable based upon the current size of the generator enclosure. Thereby not affecting the schedule to build a larger room. To make this scenario code compliant, the sound pressure levels would need to be addressed. Based upon the time needed to install the material needed to reduce sound transmission to an acceptable level would amount to a day or two. Additionally, because the general contractors self performs this type of work and because of the location of this work, no time would be added to the schedule and thereby this change would result in zero dollars of added cost in general conditions.

Constructability Review

As discussed in the previous sections, three new generators were analyzed. The original diesel generator was 144 inches in length, 72 inches in width, and 80 inches in height. This became the basis for determining if the new generators would be able to fit on the existing concrete pad or if a new one would be needed. In addition, the existing diesel generator required a “day tank” or a fuel tank capable of supplying four hours of fuel to the generator in the event of an electrical outage. After talking with the dealer of the three new generators, it was determined that a natural gas generator does not need such a tank because it would be feed directly from the gas line that runs parallel to the building.

After determining the new dimensions of the three new generators, it was concluded that all three could fit into the existing generator enclosure but the layout of the housed equipment would need to be altered. The figure on the next page demonstrates what needed to be done.

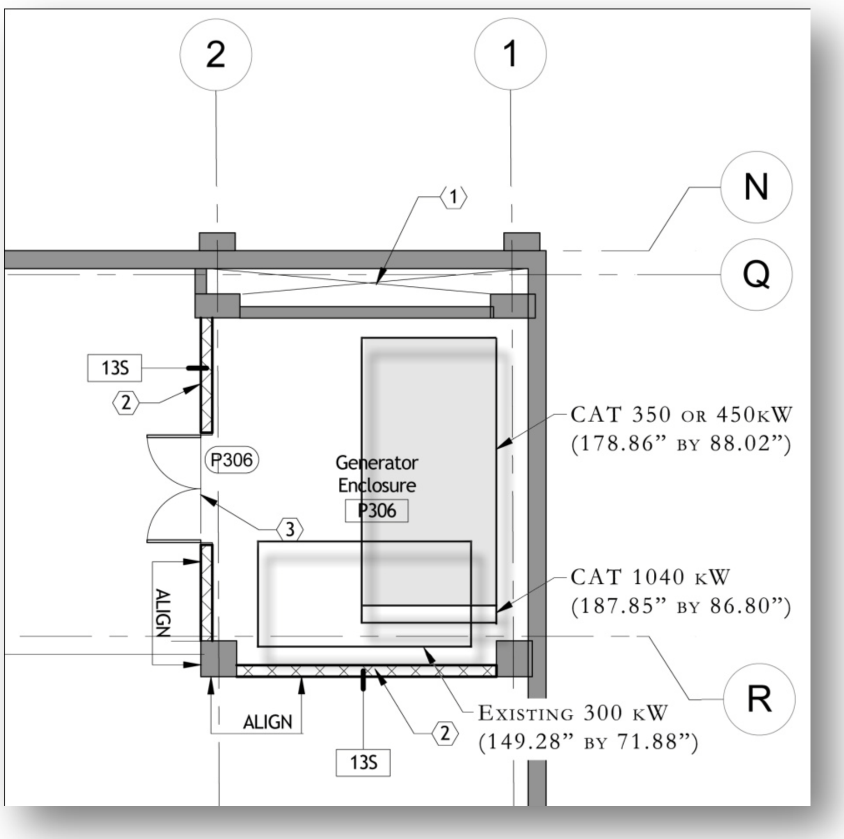

Figure 18 Generator Enclosure Layout

As previously mentioned the new natural gas generators no longer require a fuel tank but instead would require the installation of a gas line that ran from the gas main running under 22nd street to the generator enclosure, located on parking level three. The gas line would need to be run from the main along 22nd street under the roadway into the building, then drop to parking level three and over to the generator enclosure. This distance is approximately 290 linear feet of piping.

The cost associated with tearing up 22nd street as well as patching it after the new gas line was included in the cost analysis and payback period previously mentioned. In addition, the cost associated with the installation of the new gas line was also included. These prices were determined by contacting the contractor responsible for the project and other similar contractors within the DC area.

The conclusion of the constructability review is this solution is possible but would require advanced planning by the owner, designer, and construction manager. In addition, substantial upfront costs could be encountered that would need to be addressed. In the "Final Words" section of this document, there is a summary of this analysis as well as the others yet to be discussed with the final payback period that could be expected if all proposed changes were implemented.

Conclusions

After all the variables are considered, the proposed attempt to reduce the building energy load could prove beneficial if planned for from the beginning of the project and the owner was committed to the end result of saving money through reducing electricity usage in the building. As indicated by the 450kW generator and more drastically by the 1040kW generator, this could be very cost effective if an owner is willing to invest the upfront cost. Based upon the calculations associated with this section, it appears that for this specific use of a building's backup generator to be worth the upfront cost, larger capacity generators are needed. When considering a payback period of just over four years, this could prove plausible and more investigation into the aspects of this analysis could prove to be extremely useful and could change the way the industry looks at backup generators and their role in the building's grand scheme.

In an effort to allow other building owners to compute the cost of the proposed change based upon the size of a different building, the cost per square foot based upon new construction area and total building area was computed and found to be $16.31 per square foot and $3.17 per square foot respectively.

Note: Based upon discussions with a representative from J.E. Richards, it was determined that utilizing such a large generator such as the one discussed would require a new switchboard and would result in an additional cost of $60 - $70K. Because this information was received late in the development of this document, it was not figured into the above results.

MAE Requirement

For this analysis, the knowledge gained though AE 572 Project Development and Delivery Planning was applied in terms of financial calculations. More specifically, the knowledge gained regarding lifecycle cost analysis was used to determine the lifecycle cost and respective payback period for the proposed change. Any time a change is proposed that increases the initial cost of a project or activity, a lifecycle cost analysis should be performed and payback period determined in order to show the owner the amount of time from then the initial cost is encountered until when that money is recovered based upon the proposed design change.

Additionally, as mentioned earlier within this report, the premise behind this analysis topic was based upon a theme of reducing energy consumption within buildings. This theme was selected based upon the knowledge gained by completing AE 597D Sustainable Building Methods. The 2009 PACE Roundtable also factored into the decisions regarding the theme and selected topics. It was determined through AE 597D and the 2009 PACE Roundtable that the topic of energy consumption within buildings is a critical issue faced by the industry.

Green Roof Analysis

Area of Potential Improvement

Continuing with the theme of building electricity reduction, this analysis investigated the electricity usage associated with heat gain and loss through the building envelope. The mechanical system within a building is one of the primary consumers of electricity, but as shown by buildings that use innovated strategies, this does not need to be the case.

Proposed Solution

One way to increase energy saving through electricity usage is with respect to the roofing system of the building. The standard roofing material for many years has been asphalt. The problem with asphalt is it absorbs and transmits into the building a large amount of energy. Additionally, it stores heat and at a later time dissipates it into its surroundings, the atmosphere, when the ambient temperature is less than its internal temperature. This simple result can have a profound effect on the local microclimate of the region, also known as the heat island effect. Additionally, the standard roofing systems tend to breakdown in sunlight, which leads to the need to periodically replace the weather barrier on the roof.

Several different roofing types have been introduced to help combat the negative characteristics associated with hot applied asphalt roofs or other similar roofing materials. The three most common types are solar roofs that use solar panels to generate electricity as well as prevent direct sunlight from hitting the roof membrane, vegetated or green roof that use plants to control the heat gain and longevity of the roofing materials, and cool roofs that use light colored membranes with high reflective properties to control heat gain. With respect to vegetated or green roofs, two subtypes were explored, which are extensive and intensive. Because the project being investigated consists of adding three stories to an existing eight story building, it was determined that an extensive roof was better suited.

The new green roof was evaluated based upon energy consumption, thermal characteristics, and imposed load on the building structure. Concerning energy, the amount of work needed to install the roofing system as well as the associated energy savings will both be factored into the results. In terms of thermal characteristics, thermal resistance, "R-Value", and thermal gain was considered. Subsequently, absorption will be addressed in an effort to reduce or eliminate the heat island effect. Finally, because this project consists of adding three floors to an existing building, additional load on this structure must be a primary focus.

Benefits

Each system inherently comes with its own associated benefits. Green or vegetated roofs can significantly reduce the amount of storm water runoff a building needs to handle. Additionally, the system can have significant mass and therefore has thermal characteristics that make it appealing. In other words, because the system incorporates earth and vegetation onto the roof, the building is more insulated from the elements. This can have a positive effect on the mechanical system of the building which was investigated and will be discussed in the following pages.

Subsequently, solar roofs also have their benefits. One type of solar roofs is solar thermal, which uses the suns energy to heat a medium which can then be use to heat water for use within the building. This system would have very limited application on 2175 K Street, therefore it was not by analyzed. On the other hand, solar photovoltaic or solar PV collects the suns energy and converts it into electricity. The direct current (DC) generated can be converted to alternating current (AC) and used within the building to supplement the electricity demand. Because the solar panels cover the roof, the amount of direct sunlight that reaches the roofing membrane is reduced, which in turn reduces the thermal load. Due to the time constraints, this system was not analyzed.

The third type of roof is the cool or white roof. This system is significantly cheaper in comparison to the other two but its benefits are fewer too. The primary benefit to using this type of roof is the light color serves to reflect more of the suns energy back into the atmosphere and absorb less, thereby reducing the thermal load imposed on the building. Similarly, this roofing type serves to reduce the heat island effect in comparison to the typical asphalt roof. Because it was determined that the green roof could be used on this project, this roofing type was not analyzed.

Drawbacks

As with anything, there are drawbacks associated with each roofing type. With regards to the green roof, the primary disadvantage is sheer weight. Consequently, the structure needs to be able to support the additional weight, which isn't typically an issue if it is decided upon early in the project lifecycle when the roof can be designed to withstand the added load. In the case of 2175 K Street, this presents a problem seeing as how the new construction sits atop an existing building. Consequently, it was determined that the existing structure can support the weight of a green roof.

Additionally, with respect to a any of the three roofing types, substantial first time cost can be associated with them. This aspect would need to be addressed along with the possibility of financial incentives to offset this cost. Due to time constraints, this was not included.

Lastly, cool roofs have fewer drawbacks but the associated performance of the system is substantially less than the previous two. On the other hand, in some cases, this roof type is the only feasible solution and on 2175 K Street, could have been the case but luckily wasn't.

Research

This analysis required research into each type of roofing system with respect to design characteristics, performance data, cost per square foot, and constructability. Because this project is located in Washington DC, weather data was needed to be collected to create a baseline from which each system were evaluated against.

Methodology

- Research system's design characteristic
- Determine net allowable load on existing structure
- Evaluate newly imposed load on structure
- Calculate potential energy savings
- Relate cost to above savings
- Calculate cost per square foot
- Evaluate schedule impact
- Conduct constructability review
- Summarize findings

Preliminary Tools to be Used

- Energy10
- Microsoft Excel
- Weather.com
- STADD or similar structural program
- Professors and colleagues
- Equipment Manufacturers

Expected Outcome

This analysis was designed to determine the potential benefits associated with green roofs if implemented on 2175 K Street and what the impacts would be on budget, schedule, and overall value. Based upon the results of this analysis, the data collected could be applied to other similar projects to determine the feasibility of this roof type and establish an estimated cost and performance.

Description of Existing System

The existing roofing system implemented on 2175 K Street is a typical built up single-ply EPDM roof. The penthouse roof is comprised of several materials, first of which is the metal roof decking. The roof deck used on this project is 3" deep rib, 20 gauge galvanized metal deck. Above the metal deck is a layer of rigid insulation which is to taper toward the roof drains to promote proper drainage. Next, there is a layer of single-ply EPDM roof membrane with a gravel ballast system. At all perimeter conditions, the EPDM is continuous up and over the parapet and extends down as to overlap the facade material by two inches. Where there are walkways, there is two layers of a protective mat above the roof membrane and roof pavers above. This will create the needed walking surface but will protect the roof membrane from damage. Because the roof membrane is EPMD, a dark colored material, the surface temperature could reach temperatures in excess of 190 degrees Fahrenheit. This was the basis for the proposed green roof.

Proposed Changes

In an attempt to reduce the heat gain associated with the building roof, a green or vegetated roof was investigated. To do this, several aspects had to be addressed. First, the associated weight of a green roof had to be determined. Next, the existing structural design had to be assessed to determine if it could withstand the newly imposed dead load of the green roof. In addition, the existing roof deck was not designed to withstand such loads therefore a new roof structure was needed. To carry the weight of the green roof, composite deck was used with a concrete topping slab was implemented to form the appropriate substrate. On top of this would sit a system of insulation and roof membrane similar to that of the original system. Finally, the modular green roof would be installed as shown in Figure 8 to the right.

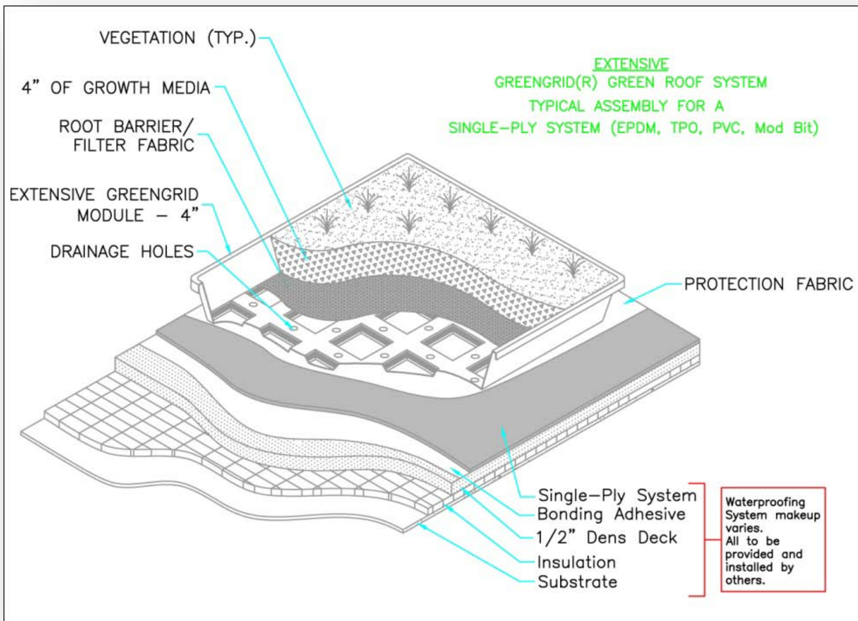

Figure 19 GreenGrid Green Roof (Weston Solutions GreenGrid® System)

As alluded to in the previous section, it was determined that the benefits of using a modular green roof for this project outweighed those of a typical built-up green roof. An example of this is the residential building that shares a common wall with this building up to the ninth floor roof carry a great deal of influence over decisions affecting what they see out of their windows. As in the case of the built-up green roof already included in the scope of the project, in its current state is in essence a mud pit without any vegetation. The vegetation was never planted because construction of the green roof finished late in the year 2009. This would have resulted in the roots having very little time to become established and thereby would die when the snowfall began in the region. In the case of a modular green roof, the modules could be procured and stored in a nursery where the plant medium would have optimal conditions for growth and ensuring that upon installation, plant growth would be in full swing. This would mitigate the complaints the tenants of the neighboring residential building would have and thereby make the process more streamline.

In addition, the storage of these modules is at no additional cost to the owner and they could be stored for a time period up to two years until the building is prepared and ready for installation. The only drawback to this system, in terms of storage, is based upon the discussions with GreenGridRoofs, there are no deliveries between the months of October and April.

Evaluate Newly Imposed Loads

As previously mentioned, the addition of a green roof on top of an existing structure adds challenges in terms of added load. At the beginning of this analysis, the existing roof structure was analyzed and the net allowable load that could be added onto it was established. Based upon these findings, the green roof was selected from the three options previously discussed.

To calculate the net allowable load the roof structure could carry, first the beams were analyzed then the girders. Based upon conversations with the structural engineering and several structural students at Penn State, it was determined that most likely the beams would be the limiting factor in the design. Additionally, columns are designed to carry loads associated with relatively large tributary areas in comparison of much smaller areas carried by the beams. Therefore adding a small amount of load to a beam would have a negligible effect on the columns.

The first step in analyzing the beams was each beam was found in the steel manual and based upon type, size, and weight per foot the associated maximum moment, φM_P, was found. Then, based upon this value including the length of the beam and its spacing, an allowable load was calculated in pounds per foot. Next, the various load cases were evaluated and the controlling one determined. Then based upon this resulting load, the beam self weight was subtracted as well as the proposed deck construction thereby giving the net allowable load that the beam in question could carry.

This same process was done for all the beams in the area influenced by the green roof as depicted by the green area shown below in Figure 9 Green Roof Area of Influence. A table was created to show what was described in the previous paragraph and can be found in Appendix K. A similar process was done to evaluate the girders that would in turn carry the load imposed by the green roof to the columns.

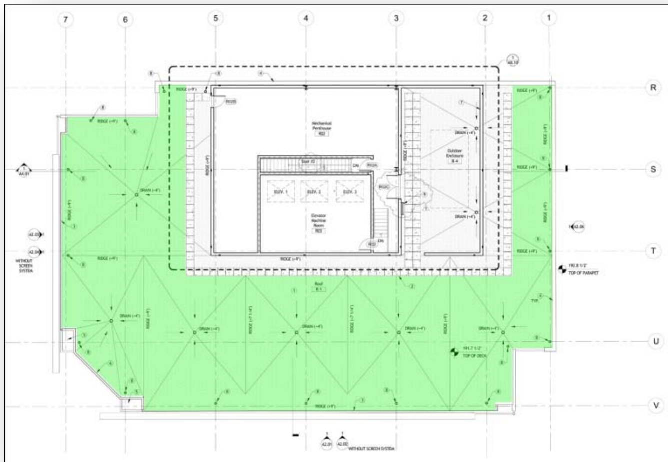

Figure 20 Green Roof Area of Influence

The resulting net allowable load was determined to be approximately 69 psf. In light of the recent snow fall that occurred in the DC area, the amount of snow that would cause the roof to collapse was then calculated. To do this a green roof system had to be selected. Based upon conversations with a representative from GreenGridRoofs, a four inch thick extensive modular green roof was selected. This system weighed in with a saturated weight of 22 psf. Based upon this weight and the carrying capacity of the roof structure, the following table was created.

Green Roof

Snow Water Equivalent		
SWE		Precip. (in.)
Typical 10-20% winter and 20-40% spring	10%	53.08
	20%	26.54
	30%	17.69
	40%	13.27
	50%	10.62
Water	100%	5.31

Notes:

†10% SWE when air temp. near 14°F

††20% SWE when air temp. near 32°F

†††100% SWE is Max distance from primary drain to secondary

Figure 21 Depth of Snow to Cause Roof Failure

This table shows how much snow in inches the roof could carry with the green roof taken into account. Snow Water Equivalent is used to determine how heavy snow is. It is a ratio of snow density with respect to water. Water weights 62.4 lbs/sf and based upon the temperature and age of the snow, a new weight can be calculated. One important factor is the air temperature at the time of the precipitation. If the air temperature is at 32°F then the SWE is 20% and when it is near 14°F the SWE is 10%. Therefore the two numbers of great importance in this table is 53.08 and 26.54. This means that the roof would fail somewhere between 26 inches and 53 inches. This becomes a great concern when considering the amount of snow that Washington DC received this year. In addition, the number to the right of 100% SWE or water is the maximum distance between the primary drain, the soil, and the secondary or overflow drain.

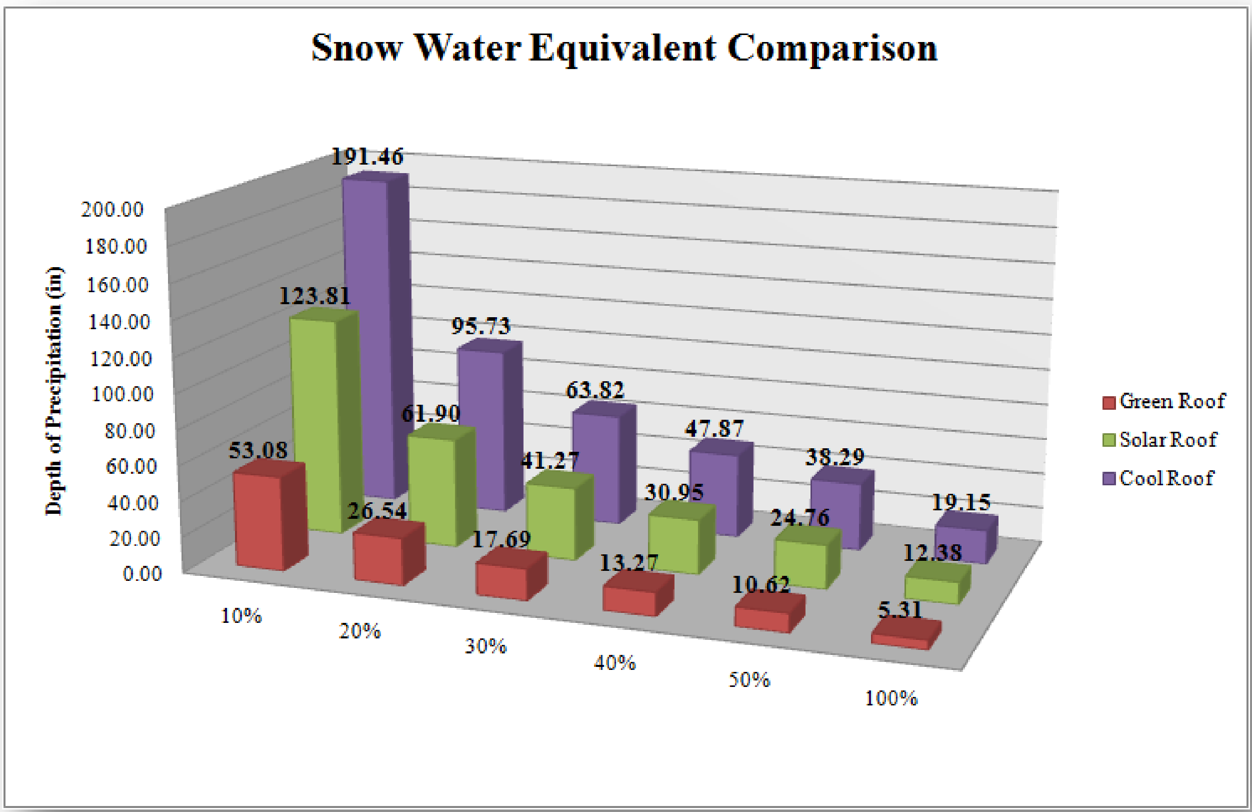

Figure 22 Snow Water Equivalent Comparison

Above in Figure 10 is a graph of the relative depths that cause failure for the three types of roof construction. In all three cases, the metal deck was selected so it was not the limiting factor, which thereby made the roof structure control. This was done to allow the number in the above figure to be able to be compared to each other. Based upon the recent snowfall in DC, one might choose to implement a solar roof or cool roof instead of a green roof but this was outside the scope of this analysis.

Potential Energy Savings

After it was determined that a green roof was plausible, the related energy savings were calculated. Due to the nature of modular green roofs, it was assumed that the modules would provide no thermal insulation thereby not affecting the overall R-value of the roof. This was done to make the estimate conservative. Additionally, because air can pass beneath the modules, a convection current could develop thereby mitigating any thermal insulation the modules might provide and consequently causing the estimate to be high.

To begin, the knowledge gained in AE 542 Building Enclosures was used. The relative heat transfers were calculated and are shown below in Figure 11 Energy Transfer. In addition, below that figure is another showing the relative thermal performance in Figure 12.

Energy Transfer			
	Base Case	Green Roof	Reduction
Heat Gain	381,524	17,791	95%
Heat Loss	871,773	648,394	26%
Total Heat Flow	1,253,297	666,185	47%

Figure 23 Energy Transfer Comparison

Thermal Performance												
		U		A		t_o		t_i				
Base Case	q(dot)=	0.05	x	5500	(	158	-	72	)	=	23,650	BTU/hr
Green Roof	q(dot)=	0.05	x	5500	(	86	-	72	)	=	3,850	BTU/hr

84% reduction

Figure 24 Thermal Performance Comparison

As shown in Figure 12, it was calculated that there would be approximately 84% reduction in the thermal gain that the building envelope would experience due to the change in roofing materials. When this number was converted to a total building envelope reduction, it turned out to be approximately 8.4%. Given the current electrical usage by the buildings mechanical system being 1,038,500 kWhr, this results in a reduction of 32,800 kWhr. When this amount is converted to a monetary savings, this value comes out to over $5,100, based upon $0.1543 per kWhr. This savings was only assessed for the summer months because the roof would only perform as indicated above during the summer, the green roof would have a negligible effect during the winter months. Again this is because it was assumed the modular nature of this system would have no effect on the overall R-value of the assembly.

Cost Analysis

After contacting the GreenGridRoofs representative, it was determined that the cost of the GreenGrid modules is approximately $13.00 per square foot on top of the cost of the substrate, being the concrete on metal deck, insulation, and roof membrane. In addition, the labor cost associated with the installation is approximately $3.00 per square foot; resulting in a total of $16.00 per square foot. When the labor and material costs for the concrete, metal deck up-charge from what was initially budgeted, and the formwork, this cost increases to $19.26 per square foot or $106,000. The previously mentioned costs, except for the GreenGrid costs, came from RS Means Costworks and were verified by the contractor on the project.

As previously mentioned, the cost savings amounted to $5,100 which results in a 20.9 year payback period, but an important note regarding this number is it does not take into account the financial incentives available from the government to promote the use of green technologies. If this route were to be investigated, this number would drop considerably, because there are a number of government funded programs to help the owner with the initial cost associated with green roofs. Below in Figure 13 Roofing Comparison is a comparison between the lifecycle costs associated with a standard EPDM roof and the proposed green roof.

Roof Type	Cost Per SF	Area	Cost	Life Expectancy	50 Year Cost	50 Year Savings	Payback Period	Relative Payback
EPDM	$ 11.00	5500	$ 60,500.00	12	$ 265,283.33	$ -	N/A	N/A
Green Roof	$ 19.26	5500	$ 105,924.36	50	$ 105,924.36	$ 252,814.60	20.9	7.4

Figure 25 Roofing Comparison

As shown in the above figure, when replacement costs are included in the payback period calculation, as shown by the relative payback, the time it takes for the initial cost to be recovered decreases to about 7.4 years. That equates to a 65% reduction in time, which makes this a viable option to incorporate into a project. As mentioned previously, as with the payback period decreasing when financial incentive are included, so would the relative payback period.

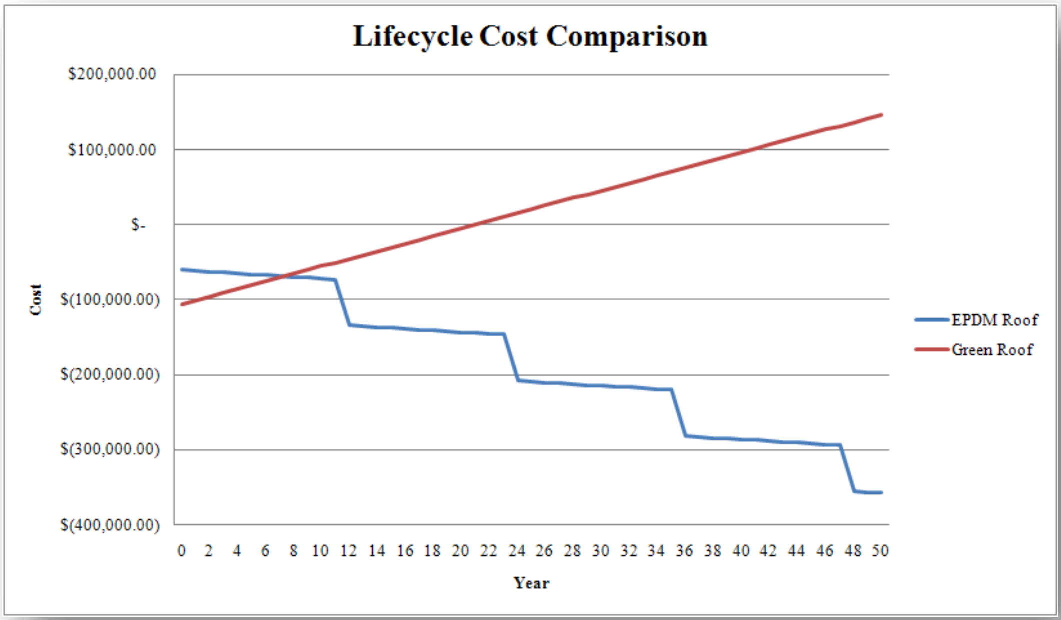

Figure 26 Lifecycle Cost Comparison (Base Roof vs. Green Roof)

The above figure, Figure 26 Lifecycle Cost Comparison (Base Roof vs. Green Roof) looks into the maintenance cost associated with both roofing types. Additionally, with regards to the single-ply EPDM roof, it was determined, based upon typical life spans of similar roofs in comparable climates, that the EPDM roof would need to be replaced every twelve years. Along the same lines, it was determined that typically, EPDM roofs require $0.20 per square foot in terms of maintenance cost.

Schedule Impact

One of the primary benefits, aside from the ability to store the modules in a nursery to allow for plant growth, is the relatively short time it takes to install such a system. Typical installation rates are between 3,000 sqft and 5,000 sqft per day. The representative from GreenGridRoofs expressed that some contractors push this number as high as 8,000 sqft per day, but this is the upper limit. With that being said, based on the size of this project being only 5,500 sqft, the installation of this system would only take one day and could easily be done on a Saturday thereby not having any impact on the schedule's substantial completion date. Thus no added cost associated with extending the general conditions, which amount to over $16,000 per day. The proposed installation plan taking place on a Saturday was confirmed with the general contractor on the job and was determined to be easily accomplished.

In terms of the necessary installation of concrete on metal deck, based on the amount of concrete, this activity could also take place over a weekend. Because the original design included metal roof deck, the act of changing this to composite metal deck would be a one-to-one change in terms of installation time. Thereby again having a minimal effect on the overall schedule.

Constructability Review

As discussed in the previous section, this system, based upon typical daily outputs and the overall size of this project, would be able to be installed within one day and thereby not affect the overall schedule. Along the same lines, this system is also relatively easy to install. Because this system uses the same substrate as would have been already installed, the only difference is pouring concrete on the deck and bolting down the GreenGrid modules. Because of this simple fact, it is anticipated that the addition of the green roof on this project would not pose any negative implications on the constructability of the project.

Conclusions

To summarize the findings of this analysis, the addition of a GreenGrid green roof would impose an additional $45,400, when compared to the original single-ply EPDM roof. The total cost of this system is $106,000, which includes both labor and material. In addition, the payback period is 20.9 years but when the original cost is factored in, the payback period drops to only 9.0 years. In other words, the owner would pay off the additional cost associated with the green roof in as little as 9.0 years. Based upon the expected life of the green roof, the owner could expect approximately four times the value of the roof in fifty years. After investigating the financial benefits of adding a green roof to the project as well as the numerous environmental benefits, this system was determined to be well worth the initial investment and the final recommendation would be to move forward with the proposed change.

In an effort to allow other building owners to compute the cost of the proposed change based upon the size of a different building, the cost per square foot based upon new construction area and total building area was computed and found to be $3.14 per square foot and $0.61 per square foot respectively.

MAE Requirement

The knowledge gained through several graduate level courses was applied throughout this analysis. With regards to the energy calculations, the course notes from AE 542 Building Enclosure Science and Design were used. This knowledge was specifically applied to this analysis in the section entitled "Potential Energy Savings." Here, the performance of the green roof was determined based upon thermal gain and these results were then compared to the performance of the base roof. In this analysis, the base roof was a built up EPDM roof which performed quite poorly in terms of thermal gain due to the dark color of the roof material.

In addition to AE 542, the knowledge gained through AE 572 Project Development and Delivery Planning was applied in a similar manner to how it was applied in the previous analysis. The course knowledge regarding lifecycle cost and payback period was applied to the above analysis.

Lastly, as with the previous analysis, AE 597D Sustainable Building Methods helped to structure this analysis and helped reinforce the overall theme of reducing energy consumption in buildings.

Curtain Wall Redesign Analysis*

**Note Regarding this Analysis*

The information needed for this analysis was obtained extremely late in the overall process of this report and therefore the information discussed within this section is only preliminary and is not complete.

Area of Potential Improvement

Another area identified as a place for potential improvement with respect to energy efficiency and reducing the electrical usage of the buildings is the curtain wall design. Most building envelopes consist of one system that covers all four elevations with minimal alterations. In some cases, as with the project in question, the building designer takes this one step further and uses the same design for three elevations and uses another system for the fourth.

Proposed Solution

This analysis looked at improving the thermal properties of the curtain wall and quantifying the resulting energy savings. In addition, another aspect that was investigated was the affect of changing the curtain wall in terms of reducing the initial cost of mechanical equipment.

Taking this one step further, a building integrated photovoltaic curtain wall was investigated to determine the potential benefits they have on the overall performance of the building. Based upon preliminary analysis, the southern facing façade could benefit from solar PV more than the other elevations. On the eastern and western façade, other systems could be used such as electrochromic tinting to reduce the amount of glare introduced into the space. This aspect was not investigated due to a delay in receiving the necessary information to complete the study.

Benefits

The primary benefit of changing the existing curtain wall design with the proposed one is in terms of the insulation properties of the new system. In terms of relative conductance values, the new system is approximately twice as insulating and thereby reduced the overall electricity use of the mechanical system.

With regards to the buildings integrated solar PV systems, the primary benefit is the generation of electricity, which can in turn reduce the electricity demand of the building saving the owner money over the life of the system. Based upon the limited amount of potential surface area that could receive solar PV integration, the feasibility of the system was addressed.

Drawbacks

Similarly, with most new technologies, they are more expensive to purchase and install. For this reason, the upfront costs of the system and lifecycle costs were studied, relative to the current system installed at 2175 K Street. Additionally, the payback period will need to be determined to help the owner determine if the system is worth the investment. Additionally, as with many "green" technologies, financial incentives exist for those who are willing to do the research. Part of this analysis was to conduct said research in an attempt to reduce the upfront cost that the owner would be facing if they should choose to implement such a system.

Research

To ensure the optimal performance of the designed system, research was done on possible manufacturers of such technologies. Additionally, research into possible financial incentives was done due to the substantial upfront cost associates with the above mentioned technologies.

Methodology

- Establish baseline of existing design
- Research performance data of super insulated curtain walls and PV integrated systems
- Calculate the cost and savings
- Evaluate impact of new system on mechanical system
- Evaluate schedule impacts
- Perform constructability
- Summarize Findings

Preliminary Tools to be Used

- Energy10
- Manufacturers Data
- Professors and colleagues
- Contacts made at the 2009 PACE Roundtable
- Autodesk Revit and Ecotect

Expected Outcome

As addressed throughout this section, the key factor that determined the overall success of this analysis was reducing the energy consumption of the building and to add value without substantially adding cost. Additionally and possibly most importantly, improve the quality of the working environment for the building occupants and improve their productivity.

Description of Existing System

The existing curtain wall under investigation is located on the south and west elevations. In addition, because the scope of the project is to all three floors to the existing buildings, this analysis looked at the effect of changing the two aforementioned elevations on the new three floors.

The curtain wall on the south and west elevations is a unitized system that is one story in height and is exterior glazed. The glazing has a U-value of 0.31 BTU/hr-ft^2-^{o}F. In addition, this system was determined to cost approximately $100 per square foot. Typical curtain wall costs are usually closer to $80 per square foot, as indicated by the general contractor on the project, but due to the limited size of the project being only 7,700 square feet, the price was slightly elevated.

Description of Proposed Changes

After contacting several companies, the one chosen is a German company entitled Schuco USA, who generously supplied product guides and other such literature to aid in my product selection. The selected product is a unitized system that is one story in height and is an exterior glazed system. This system in these terms is the same as the existing design in an attempt to minimize drastic changes which would then affect the overall cost of installation. Because this was minimized, it was determined that the difference in installation costs would be negligible and the existing mounting clips and support steel would be sufficient.

The proposed system differs greatly in one aspect and this is in terms of U-value. As previously mentioned, the existing system has a U-value of 0.31 BTU/hr-ft^2-^{o}F. The proposed system, Schuco FW 50+.SI, has a U-value of 0.8 W/m^2-^{o}K and when this is converted to imperial units, it was computed to be 0.14 BTU/hr-ft^2-^{o}F. In other words, the new system is over twice as efficient in terms of insulation. This is because Schuco has developed a new solution that they have termed as a “super insulation” solution. To estimate the cost of this new system, $110 per square foot was assumed

In addition to being super insulating, this system can be converted to a building integrated photovoltaic system, as shown in the image to the right. In this analysis, the relative benefit of adding this feature was assessed. The photovoltaic panels can be incorporated into the vision glass in the form of semitransparent collectors or in the non-vision glass as translucent collectors. This analysis will look the relative benefits of incorporating just the translucent collectors in the non-vision glass and the

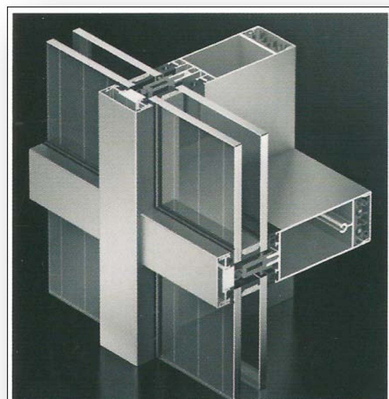

Figure 27 Schuco FW50+.SI Curtain Wall System (Image Provided by Schuco USA)

effects of including the semitransparent collectors in the vision glass. Based upon the incorporation of the two different systems of collectors, the following cost per square foot was estimated. For the proposed curtain wall system with translucent collectors only in the non-vision glass, or about 20% of the system area, a cost of $130 per square foot was estimated. When this system was expanded to include the collectors in the vision glass, the cost increased to $160 per square foot. These number are only estimated, when the manufacturer was contacted to determine the added cost, they could not be reached and therefore could not verify the accuracy of the above numbers.

Energy Savings

Based upon discussion with the building owner, it was determined that the building used approximately 1,730,000 kWhrs a year. In addition, it was assumed that the mechanical system uses approximately 60% of this total load or about 1,040,000 kWhrs. When this is broken down per floor, this number becomes 130,000 kWhrs or 10.8 kWhrs per square foot floor area.

The following table shows the reduction of electricity usage based upon each proposed change.

Design	Electricity Usage (kWhrs)	Savings (kWhrs)	Savings ($)
Existing	1,427,884.62		
Glazing Redesign	1,260,561.22	167,323.39	$25,818.00
Non-Vision Only	1,254,519.94	173,364.68	$26,750.17
Both Collectors	1,240,578.50	187,306.11	$28,901.33

Figure 28 Summary of Proposed Changes

As shown by the existing design, when the building usage pre construction is extrapolated to include the new construction, the electricity usage of the mechanical system would increase to almost 1,427,885 kWhrs. When the super insulated curtain wall design is factored in, this number decreases to 1,260,561 kWhrs or a reduction of by 167,323 kWhrs. When the solar collectors are incorporated into the non-vision glass, this number is further reduced by 6,041 kWhrs or 1,254,519 kWhrs in total. To further reduce this number, when the vision glass collectors are included, this number reduces by 13,941 kWhrs or 1,240,579 kWhrs in total. Please see above for the associated cost savings that correspond to each proposed change.

Cost Comparison

After the cost savings were calculated, the associated payback periods were calculated and are shown in the below figure.

Design	Initial Cost	Cost per SF	Incentives	Annual Savings	Net Cost	Payback	Net Added Cost	Payback
Existing	$ 769,470.00	$ 100.00						
Glazing Redesign	$ 846,417.00	$ 110.00	$ 13,850.46	$ 132,641.08	$ 699,925.46	6.1	$ (69,544.54)	0.0
Non-Vision Only	$ 1,000,311.00	$ 130.00	$ 46,850.46	$ 138,682.36	$ 814,778.18	6.4	$ (31,638.82)	0.0
Both Collectors	$ 1,231,152.00	$ 160.00	$ 46,850.46	$ 152,623.79	$ 1,031,677.75	7.4	$ 262,207.75	1.7

Figure 29 Cost Comparison by Design

As shown in the above figure, the net costs are greatly affected when federal and state incentives for sustainable technologies are incorporated. The initial payback period of the glazing redesign, only incorporating the super insulated curtain wall, the payback is only 6.1 years. This is the amount of time needed to recover the initial costs based upon the annual savings of the proposed change. When this number is compared to the existing design, the payback period is less than one year. This is partially because of the electricity savings and partially because of the federal and state financial incentives for incorporating sustainable technologies into design. When similar logic is applied to the other two designs, the payback periods are as follows, 6.4 years when collectors are incorporated into the non-vision glass only and 7.4 years when collectors are also incorporated into the vision glass. Upfront cost associated with both systems is recovered within the first year. With that being said, the feasibility of incorporating solar collectors into the vision glass is yet to be determined. Without discussing this with the manufacturer, it was assumed that this is not practical.

Design	Initial Cost	Added Cost	Annual Savings
Existing	$ 769,470.00		
Glazing Redesign	$ 846,417.00	$ 76,947.00	$ 132,641.08
Non-Vision Only	$ 1,000,311.00	$ 230,841.00	$ 138,682.36
Both Collectors	$ 1,231,152.00	$ 461,682.00	$ 152,623.79

Figure 30 Initial Cost versus Added Cost Summary

The table above was created to quickly show the initial cost and added cost associated with the going from the existing design to each of the three proposed designs.

Please refer to Appendix O for more information on the calculations discussed within this section. In addition, the outlines for the associated federal and state financial incentives can be found in Appendix P.

Schedule Impact

Based upon the conducted research, the proposed system weighs approximately the same as the existing system. This is because the added thermal performance is due to a film applied to the individual lites of the insulating glass unit and thereby adding a negligible amount of weight. After this was determined, it was assumed that the existing clips and support steel needed for the existing design would be sufficient to support the new system and be adequate to transfer the loads from the curtain wall into the building structure.

In addition, because this system is unitized, if incorporating solar collection was decided upon, the wiring needed would be installed in the factory where the units are assembled. Therefore there would be no time added in association with wiring the solar collectors. The only time would be to connect these collectors to the needed inverters and wiring these inverters into the electrical system of the building. Without discussing this facet with the manufacturer, this area is relatively unclear.

The final conclusion in terms of schedule impact is, if the owner were to decide upon only changing the curtain wall to the super insulated system, there would be no impact on the overall construction schedule. If it were decided to implement solar collectors, there would be an impact to the schedule but due to the limited time associated with this analysis, this duration was not determined.

Constructability Review

As discussed in the previous section, if the owner were to decide to implement a system that included only the super insulated curtain wall, there would be no impact on constructability. This is because the existing system design is very similar to the proposed system in terms of size, height, weight, and installation. To further increase the thermal performance of the system, a triple pane system could be used but this would have a significant impact on constructability in terms of system weight. Because the triple pane system weights significantly more, the mounting clips and support steel would need to be redesigned and the associated cost would thereby increase.

Consequently, if the owner were to decide upon implementing a system of solar collectors, as previously mentioned, there would be more challenges when it comes to the installation of the system. For example, the electrician would need to work with the curtain wall installer to properly connect the curtain wall panels to the necessary inverters and subsequently the electrical system of the building. Without having discussed these components with the various manufacturers, an exhaustive list of constructability challenges could not be compiled. Again, this area of the analysis was effected by the delay encountered early in the timeline of this report, if the delay wouldn't have occurred, more would have been done to be more thorough on this section.

Areas for Future Research

As discussed throughout this analysis, there were numerous sections that were affected by the delay encountered at the beginning of this report and thereby suffered in terms of completeness. Some areas that could use more attention in terms of research and investigation are the specifics of the solar collectors in terms of cost and installation. Based upon the amount of time that was able to be dedicated to this analysis, it was done as thorough as possible. After the needed information was received, there was only a few weeks to conduct this analysis.

Conclusion

Based upon the assumptions needed to allow for the completion of this analysis, it was concluded that the safest change would be to incorporate the super insulated glazing design. To reach the numbers associated with this design, minimal assumptions were necessary thereby increasing the accuracy of this portion of the analysis. After all calculations were completed, the following table was created to summarize the costs of each design change in terms of the new floor area associated with the construction and the cost in terms of the total floor area of the building.

	Cost per SF New Construction		Cost per SF Total Building Area	
Design	Base	Increase	Base	Increase
Existing	$21.98		$4.40	
Glazing Redesign	$24.18	$2.20	$4.84	$0.44
Non-Vision Only	$28.58	$6.60	$5.72	$1.32
Both Collectors	$35.18	$13.19	$7.04	$2.64

Figure 31 Resulting Square Costs by Design

As shown in the above figure, based upon the total floor area added to the building during construction, the glazing redesign would only add $2.20 to the cost. In addition, when the added cost is compared to the total floor area of the building, this total drops to $0.44. In other words, if the owner were to add $2.20 per square foot to the rent that the new tenants had to pay, changing the façade to the one previously discussed would result in the owner recovering all of the associated upfront costs of the change in design. Another way for the owner to recover all costs associated with the upgrade in façade, the owner could increase rent for all tenants by $0.44.

Subsequently, as previously mentioned, the final conclusion of this analysis is the safest change would be the one that incorporated the super insulated Schuco FW 50+.SI curtain wall design.

MAE Requirement

With regards to the above analysis, several graduate level course were involved in the development of this analysis and the included subcategories. In terms of the energy calculations and savings, these were made possible due to the knowledge gained in AE 542 Building Envelope Science and Design. This equations and design principles were implemented throughout this analysis. More specifically, the energy transfer equations and applicable principles were used to determine the amount of energy transfer through the existing curtain wall and subsequently, through the new super insulated curtain wall design.

In a similar fashion to the other analysis, this analysis involved substantial upfront costs associated with the proposed design change. For this reason, a lifecycle cost analysis and payback period analysis was performed to determine how quickly would the owner recover the added cost and begin to see a benefit in terms of decreased electrical demand and utility bills. This was made possible through the knowledge gained in AE 572 Project Development and Delivery Planning.

Lastly, as discussed in the previous analyses, this analysis topic was heavily influenced by the knowledge gained in AE 597D Sustainable Building Methods.

Smart Power Strips Analysis

Area of Potential Improvement

Another major area of electricity usage that typically goes un-noticed is the electricity associated with running computers during non-work hours. A typical building that is operated for eight hours per day and forty hours per week is only in use for less than 25% of the time, yet many computers are left running or are placed into a standby mode during off hours. Given the current state of the economy, building owners have begun to place a great deal of effort to reduce the phantom loads associated with buildings. The primary focus seems to be lighting systems and mechanical systems because they are the major consumers of electricity in a building but as will be discussed in this section, computers and monitors use a substantial amount of electricity.

Proposed Solution

One method of reducing energy usage within buildings is to replace inefficient systems or install efficient retrofits to existing buildings. This type of work is increasing in popularity given the current state of the economy. As with many building owners, the owner of 2175 K Street has plans to renovate the existing portion of the building in the near future. This adds precedence to this area of analysis. These features could also be incorporated from the start of a project if considered early enough. One potential area of focus could be on the lighting system within the building. Currently the building uses standard 2' x 2', 2' x 4', and linear fluorescent light fixtures. One possibility of potential improvement could be to replace these relatively inefficient fixtures with more efficient LED fixtures. These fixtures are available in many of the standard sized fluorescent fixtures and the installation is quite similar as well, which make the use of such fixtures quite appealing.

Another area of potential savings is in the use of fiber optics to introduce natural daylighting into spaces where it was not possible before. Because this system would use the sun's energy, the only cost would be to purchase and install the system, there would be very little cost associated with the operation of such a system. Research would need to be done to verify these claims and to investigate the feasibility of using such a system and to determine the extent of any necessary backup systems in the case of a cloudy day.

An additional area of potential energy savings, and the focus of this analysis, could be the implementation of a system to manage plug loads. One potential solution to the problem is to install a system by Convia that can manage lighting loads and plug loads by implementing technology to assist in the goal of saving energy, but this could have substantial upfront costs associated with it. Instead a simpler route could be to purchase a smart power strip for each office that houses a computer and monitor. These power strips have the ability to kill power to designated outlets based upon the power state of the computer. This would require the computer to be turned off, or placed in sleep mode, at night which can be programmed into the computer to do so automatically at a certain time each day.

Lastly, occupancy sensors can be incorporated to turn off all or a portion of the light fixtures within each office to further reduce energy consumption.

Sticking with the theme of keeping first time costs to a minimum, the focus of this analysis was to determine the cost savings associated with implementing a relatively inexpensive system to manage plug loads within the building. To do this, as mentioned above, power strips with demand controlled outlets were investigated. These power strips are relatively new to the market and can greatly reduce phantom loads in a building. To do this, one outlet is the master, in most cases this would be a computer, and there are several controlled outlets that are turned off when the computer is powered down. This can be used to turn off monitors and other peripheral components. Additionally, to maximize the potential energy savings, utilizing the "sleep" or "hibernate" function of computers would allow it to automatically, based upon scheduled times, power down while saving the current state of the computer. This has two benefits. First, because the computer powers down, the other components will be turned off by the power strip thus saving electricity. Second, the computer, when using said functions, saves the computer's current state to allow the user to continue work with little disruption.

Benefits

As addressed in the previous section, LED light fixtures are more energy efficient when compared to standard fluorescent fixtures. An additional area of cost savings is in terms of lamp replacement. The standard LED has a life that far exceeds the life of a fluorescent lamp. Another beneficial characteristic that was already mentioned is in terms of fixture configurations. Many standard fluorescent fixtures have LED fixtures of the same size. This helps to lower the complexity associated with installing these fixtures. It is expected that through research into this product, more benefits will be discovered and noted accordingly.

Similarly, fiber optics could prove to be a valuable addition to commonly accepted lighting practices. Because the source of the energy is the sun, this technology should account for a great deal of savings if a system can be installed. As mentioned previously, the only costs associated with this technology is purchasing and installing it. Additionally, there are no lamps to replace, just tendons to be cleaned. Another beneficial property of fiber optics comes in terms of transmission loss. Light travels very efficiency through fiber optic lines. With decreased transmission loss comes increased efficiency. As with LED fixtures, there are potentially more benefits that could be discovered through research.

Another key area of potential benefit regarding introducing natural light into office buildings is the health benefits for the occupants. Based upon some initial research, according to studies done by Parans, illuminating interior spaces with sunlight can increase productivity by 6 to 16%. Another way to look at this is 1% productivity increase equals the total energy cost in offices.[7][8] Similarly, property value increases significantly when the space is enhanced by introducing natural daylight. With regards to sustainability and energy, electric lighting represents 40 to 50% of the energy consumption in commercial buildings which accounts for 25 to 30% of the emission of greenhouse gases generated by such buildings.[9][10] Consequently, incorporating this system for half of the building's lighting system can lower energy costs by 20 to 25% and reduce emissions by 10 to 15%.[11]

Finally, as mentioned above, this analysis focused solely on an inexpensive solution for reducing phantom loads within a building by investigating the benefits of controlled power strips. The other methods discussed were only to invoke thought on the topic of energy efficient retrofits.

Drawbacks

Based upon conversations with colleagues, the primary disadvantage associated with LED fixtures is heat. When discussing fluorescent lamps, heat is emitted from the filament within the lamp that creates the visible light. On the other hand, with LEDs, the lamp is quite cool but the ballasts can get very hot. After discussing this with a panel at the 2009 PACE Roundtable held at The Pennsylvania State University, this is not the case or, at least, does not present any problems associated with installation or operation. Additionally, with most new technologies, there is a premium associated with purchasing these fixtures. Therefore, a financial analysis will need to be conducted to determine the relative payback period for these fixtures. Another potential drawback facing 2175 K Street is if the LED ballasts' require a voltage other than 208Y120.

Changing topics, one major issue with using fiber optics and relying on the sun for light comes with the existence of water, primarily in droplet form when many come together to form clouds. Clouds, when they pass in front of the sun, block the emitted light and cause variations in the amount of light output, and because of this, research will need to be conducted to determine if there is anything that has been developed to mitigate this risk. If nothing exists, it must be determined if there are any uses currently for fiber optic lighting

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[7] *L. Edwards, P. Torcellini, (2002), A Literature Review of the effects of Natural Lighting on Building Occupants, NREL*

[8] *Journal of Property Management, (January 2000)*

[9] *Green Building Council, www.usgbc.ord*

[10] *Australian Commercial Building Sector Greenhouse Gas Emissions 1990–2010, Australian Green House Office*

[11] Parans. http://www.parans.com/Products/Benefits/tabid/1080/language/en-US/Default.aspx

within buildings. Another constraint linked to fiber optics is the turning radius of the tendons. In order to transmit enough light to make this system feasible, it is assumed, that there would need to be either a large number of tendons or the tendons would need to be quite thick thereby further reducing the flexibility. Again, research into this technology should help to clarify these topics as well as many others.

Lastly the primary drawback to using the proposed system of smart power strips is it requires the programming of each computer to go to sleep or hibernate based upon a predetermined schedule. In the case of this project, one tenant in particular might resist this change and would be against someone entering their space to set up this feature on their computers due to the heightened security of their space. That being said, the building owner could inform them of how to make the necessary changes and provide them with the equipment so that they could have one of their technicians perform the work.

Research

To ensure the success of this analysis, several areas or factors needed to be researched. First, research needed to be done to find an inexpensive system that could be used that would ensure minimal upfront costs to maximize the return on investment. In addition, the quantity and types of computers used by the tenants needed to be determined to properly calculate the electricity savings associated with this change.

Methodology

- Contact Owner/Tennant to obtain typical computer specifications
- Determine energy usage of typical computer and other components
- Calculate energy savings and associated cost
- Create guide to explain benefits for use on other projects
- Investigate Constructability and Schedule
- Summarize Findings

Preliminary Tools/Resources to be Used

- Building Owner and Tenants
- Product Manufacturers
- Microsoft Excel
- Adobe Photoshop (Summary Guide)

Expected Outcome

The primary goal of this analysis was to provide factual evidence to the owner of 2175 K Street or other building owners in an attempt to persuade them to utilize this strategy in an effort to reduce energy consumption in buildings and in turn reduce electricity costs associated with plug loads. Lastly, as mentioned above, a guide will be created to summarize the findings of this analysis to aid other building owners in making a similar system work for them.

Typical Energy Usage

Based upon the results of the aforementioned research, it was determined that the typical computer used by the tenants was a Dell Optiplex. This is a standard desktop configured to work well in business applications. After finding a comparable system on Dell.com, it was determined that the computers used at 2175 K Street consumed approximately 235 watts and the monitors consumed another 22 watts. After these values were established, the total amount of energy saved could be calculated.

Energy Savings and Upfront Cost

As previously mentioned, the typical computer consumed 235 watts and the monitor consumed another 22 watts. Considering a typical workday spans only eight hours, it was determined that, based upon a forty hour workweek, the computers were being operated only forty hours out of 168. This computes to over 6,600 hours a year that the computers would be turned on but not used. What most people don't realize is if a computer is put into standby mode, the most common idle state for a computer, this does not reduce the amount of electricity consumed or the reduction is negligible. With that being said, the following calculations were performed to determine the total electricity savings per year that could be expected at 2175 K Street, please refer to Figure 19 Savings Associated with Smart Power Strips.

Power Usage		
Workday		
Used	8	hrs per day
Not Used	16	hrs per day
Weekend		
Used	0	hrs per day
Not Used	24	hrs per day
Total Uptime		
	40	hrs per week
Total Downtime		
	128	hrs per week
	6,656	hrs per year
Computer Setup		
Desktop	235	watts
Monitor	22	watts

Figure 32 Savings Associated with Smart Power Strips

Electricity Usage			
Desktop		1,564.16	kWhr
Monitor		146.43	kWhr
Electricity Rate			
	$	0.1543	
Unit Savings			
Desktop	$	241.35	per year
Monitor	$	22.59	per year
Number of Computers			
		400	
Total Savings			
Desktop	$	96,539.96	per year
Monitor	$	9,037.78	per year
	$	105,577.74	per year
Building Lifespan			
		50	years
Grand Total			
Desktop	$	4,826,998	
Monitor	$	451,889	
	$	5,278,887	
Initial Cost			
	$	29.99	
Payback Period			
		0.11	years
		1.36	months

Figure 33 Savings Associated with Smart Power Strips (Continued)

As shown in the previous figure, the total annual savings was computed to be approximately $106,000, which works out to $263.94 per unit. Considering the average life of a business computer is approximately three to five years, the savings associated with the use of smart power strips could be used toward the purchase of the new computer. In other words, when it would be time for a new computer, the smart power strip saved between $760 and $1,300, which would greatly offset the cost of the new computer.

The following graph, Figure 21 Net Value of Smart Power Strip, shows the initial cost in relation to a five year return on investment.

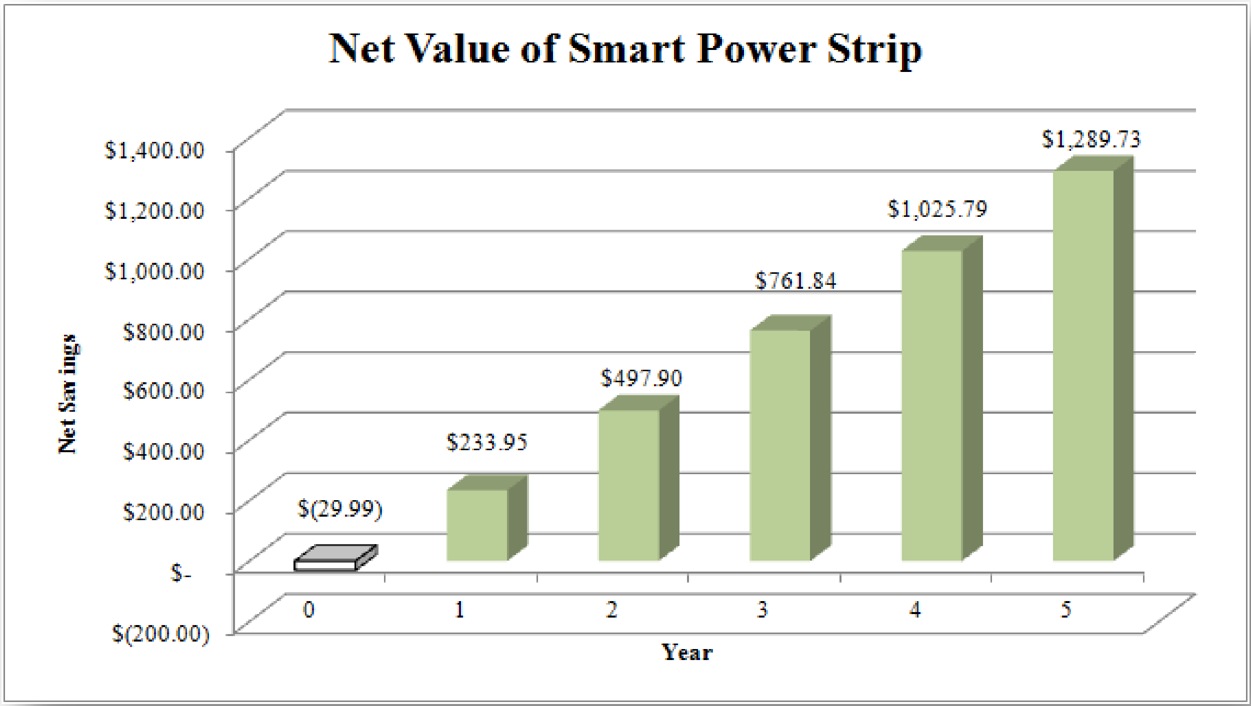

Figure 34 Net Value of Smart Power Strip

Constructability Review

The necessary installation associated with this analysis includes a technician entering each office and programming the computer to cause it to enter a sleep or hibernate mode based upon a predetermined schedule. In addition, at the same time, the person would need to plug in the computer to the master outlet and the monitor and any other peripherals into the controlled outlets. Based upon the current and intended tenants, these activities could prove challenging due to the type of tenants. Currently, there are several tenants of government entities that have heightened levels of security. Because of this extra sense of secrecy, these tenants might be opposed to a stranger entering their space. If this is the case, the building owner could provide these tenants the necessary equipment and other needed information and they can make their own arrangements to ensure the installation of such equipment be properly installed.

How-To Guide

Below is the guide, as discussed earlier, that could be used to persuade other building owners to incorporate a smart power strip system similar to the one discussed above.

Figure 35 Savings Guide

Schedule Impact

As previously discussed, this proposed addition would have no effect on the construction schedule of the project. This is because all that is needed to implement the proposed solution would be to go to Best Buy or another such store and purchase the power strips and install them. The install would only take a few minutes per computer. The majority of the time needed for installation would be waiting for the elevator to arrive to transport the person to the next floor. Additionally, this solution would require someone to go to each computer and set it up to go to sleep or hibernate (depending upon what release of Windows operating system is being used) when not in use.

Conclusions

Based upon the savings discussed previously, the conclusion had been made that this is most definitely a plausible solution to save money in an office building setting. In addition, this solution could be implemented on other building types. For example educational settings where the students are only on the computers for a limited time each day. Lastly, at a minimum, this plan could be used solely to offset the cost of new computers that would be faced by the building tenants. Or this could be implemented by the building owner to help reduce the cost of the electricity bills associated with their building.

In an effort to allow other building owners to compute the cost of the proposed change based upon the size of a different building, the cost per square foot based upon new construction area and total building area was computed and found to be $0.36 per square foot and $0.07 per square foot respectively.

MAE Requirement

The topics discussed within this analysis were founded by the knowledge gained in AE 597D Sustainable Building Methods. This analysis followed the overall theme of reducing building energy consumption that was a direct result of the information encountered as a result of completing the previously mentioned course.

Additionally, a lifecycle cost and payback period analysis was conducted to determine the time it would take for the owner to recover their initial investment and begin to receive positive feedback from such a change as discussed within this analysis.

Final Words

The below figure is a summary of energy savings, added cost, cost savings, payback period, and the grand totals for all four analyses discussed within this report.

Overall Summary of Proposed Solutions

Energy Savings Summary			
Backup Generator		2,163,200	kWhrs
Green Roof		32,769	
Glazing Redesign		167,323	
Smart Power Strips		684,237	
		3,047,529	kWhrs
Added Cost Summary			
Backup Generator	$	549,412	
Green Roof	$	105,924	
Glazing Redesign	$	76,947	
Smart Power Strips	$	11,996	
	$	744,279	
Cost Savings Summary			
Backup Generator	$	135,308	*
Green Roof	$	5,056	
Glazing Redesign	$	132,641	
Smart Power Strips	$	105,578	
	$	378,583	
Payback Period Summary			
Backup Generator		4.06	years
Green Roof		20.95	
Glazing Redesign		6.07	
Smart Power Strips		0.11	
Grand Totals			
Energy Savings		3,047,529	
Added Cost	$	744,279	
Cost Savings	$	378,583	
Payback Period		1.97	

* Backup generator savings takes into account the cost of fuel

Figure 36 Overall Summary of Proposed Solutions

Based upon the payback periods associated with each of the above proposed changes to the project, the overall payback period was found to be just under two years. If the owner were to choose one of the suggested improvements to implement on a future project, based upon upfront costs, annual cost savings, and payback period, the recommendation is to investigate further the glazing redesign. After all numbers were compiled and results assessed, this analysis posed the best figures in terms of the aforementioned categories.

Subsequently, the Smart Power Strips analysis proved beneficial for an owner who is not considering renovation or construction but needs a way to reduce building electrical loads without requiring extensive analysis. Along the same line, the results of this analysis could be applied by a building tenant to offset the cost of new computers every few years.

The following table is a summary of the associated costs per square foot of the outlined recommendations discussed for each analysis based upon new construction area and total building area.

Cost per Square Foot	New Construction	Total Building
Backup Generator	$16.31	$3.17
Green Roof	$3.14	$0.61
Glazing Redesign	$2.28	$0.44
Smart Power Strips	$0.36	$0.07
	$22.09	$4.29

Figure 37 Cost per Square Foot Summary

The analyses contained within this report are not intended to be exhaustive in nature but a strong beginning to what could prove to be some very beneficial changes to the way the industry and building owner think about their projects.

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