

THE PENNSYLVANIA STATE UNIVERSITY
5TH YEAR THESIS

Thesis Proposal

Alternative Methods Analysis

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2175 K STREET NW
WASHINGTON DC
12/15/2009



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 '11
 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.



Executive Summary

This proposal is intended to serve as an outline for the research and analyses proposed for the spring semester portion of senior thesis. The following topics have been identified based upon critical industry issues, the current state of the economy, and the diminishing properties of the atmosphere. The underlying theme for the following areas of emphasis is energy and energy usage in buildings. According to the United States Green Building Council, in the United States alone, buildings account for 72% of electricity consumption, 39% of energy use, and 38% of CO₂ emissions¹. This simple fact along with rising energy costs makes energy consumption a critical issue that affects all building owners.

Analysis I – Peak Energy Shaving

This analysis will look at methods of reducing peak energy usage. To do this, a study will be conducted that looks into using the building's backup generator to offset the energy consumption at peak hours of the day. In other words, this analysis will look into various ways to help levelize the buildings energy usage over the duration of the day. Besides using the building's backup generator, other strategies will be researched.

Analysis II – Alternative Roofing Types (Blue, Green and White)

This analysis will compare the pros and cons of three different types of roofing types, which are solar (blue), vegetated (green), and cool (white). This analysis will investigate the relative benefits of each system with respect to energy and thermal characteristics. With respect to energy, each roof type will be evaluated based upon the amount of energy it requires to be constructed versus how much energy it saves or, regarding the solar option, how much it generates. Additionally, each type will be evaluated based upon its thermal resistance or insulating properties.

Analysis III – Alternative Curtain Wall Design

This analysis will look into the benefits of customizing the curtain wall based upon the various building facades. This will attempt to determine the optimal configuration of curtain wall features to minimize thermal gain and glare, and to maximize occupant comfort. To do this, several technologies will be researched, including electrochromic window tinting and solar PV integrated windows.

Analysis IV – Energy Efficient Retrofits

This analysis will research various items within a building that consume more energy than necessary and determine the best course of action to remediate the situation. One example of this would be using LED light fixtures where standard fluorescent fixtures are used. This analysis will also look into the feasibility of using fiber optics to introduce natural daylight into areas where it does not typically reach.

¹ USGBC. <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1718>

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A. 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.

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 exiting 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 exiting 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 Corporation.

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.



Figure A.1 Rendering Provided By FOX Architects

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.

For more information, please refer to the following website <http://www.engr.psu.edu/ae/thesis/portfolios/2010/tmc5014> or clicking any of the following documents:

- [Building Statistics](#)
- [Technical Assignments](#)

B. Critical Industry Issue

Concerning 2175 K Street, very little effort was invested into reducing the building's energy consumption. This could be considered a major flaw given the current state of the economy and rising fuel costs. According to the United States Green Building Council (USGBC), in the United States alone, buildings account for 72% of energy consumption, 39% of energy use, and 38% of CO₂ emissions².

Another metric to evaluate the benefit of each analysis is the reduction in the building's carbon footprint. Carbon is one way of measuring a buildings impact on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced in our day-to-day lives through burning fossil fuels for electricity, heating and transportation³. This became a point of interest when the United States government introduced a tax on these sources of energy⁴.

In the following few pages, several analyses will be discussed, which all carry 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 could be applied to any number of projects.

With specific reference to Analysis IV – Energy Efficient Retrofits, interviews and surveys will be utilized to determine the extent of owner and contractor knowledge regarding the technologies stated within this analysis. Based upon the finding of such research, efforts could be adjusted to

² USGBC. <http://www.usgbc.org/DisplayPage.aspx?CMSPageID=1718>

³ Carbon Footprint. <http://www.carbonfootprint.com/carbonfootprint.html>

⁴ Red Green and Blue. <http://redgreenandblue.org/2009/03/15/carbon-tax-bill-introduced-in-us-congress/>

enhance the market penetration of these technologies and other similar ones. There are many benefits to be realized if this were to become reality.

C. Proposed Analyses

To address the theme of reducing energy consumption in buildings, the following areas of interest were identified. Within each area, several key topics will be discussed. The topics are as follows; the proposed solution, the potential benefits to the building and the occupants (if any), the potential drawbacks that might make the solution less appealing, the necessary research, the methodology, any preliminary tools needed to analyze the feasibility and outcomes associated with the proposed solution, and the expected outcome of the analysis.

Each analysis will vary in terms of key features but all will be related back to overall cost and energy savings in terms of payback period. To reduce the payback period associated with each proposed solution, financial incentives will be explored. These could be incentives from the Federal Government or the State Government.

Additionally, each analysis will have a component that identifies how each of the proposed solutions will affect the project schedule, either shortening or extending the substantial completion date. Along the same lines as schedule reduction, each analysis will address value engineering and constructability review.

To see a breakdown of how effort will be distributed in each of the four areas of interest, being research, value engineering, constructability review, and schedule reduction, refer to the section “E. Weight Matrix” on page 18.

Analysis I – Peak Energy Shaving

Proposed Solution

The first analysis being proposed is one that will investigate the area of peak energy saving. 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 others. Two additional strategies worth looking into could be ice storage and photovoltaics (PV). The ice storage system could be used to offset the energy consumed by the mechanical system when cooling the building to the desired temperature. Likewise, the PV system could offset the electricity load of the building.

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 levelizing the electricity demand which would be a cost savings to the electric utility. A great deal of efficiency is lost when a utility has to ramp down a power plant. If more effort was invested in levelizing the electricity demand from buildings, the power plants would be able to run at optimal efficiency, thereby electricity would cost less. Additionally, the nation is starting to realize the power of the sun and other sources of renewable energy. This is why photovoltaics will be explored in the following analysis. Please refer to “Analysis II – Alternative Roofing Strategies” for more information.

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. To supplement the beneficial results of this section, a few of the other technologies will be researched. Additionally, because some of these technologies have more in terms of an upfront cost, research into financial incentives will be explored.

Research

The research component of this analysis will investigate the potential technologies that could be used in obtaining the end goal of reducing the building’s energy consumption. Additionally, if the decided strategies have a substantial first time cost associated with them, financial incentives will be explored.

Methodology

- Research strategies of reducing peak demand
- Evaluate alternatives
- Calculate energy savings and carbon footprint
- Investigate financial incentives
- Identify synergies with other systems
- Evaluate schedule impact
- Perform a constructability review
- Summarize findings

Preliminary Tools to be Used

- Energy10
- Carbon Footprint Calculator
- Professors and colleagues

Expected Outcome

The expected outcomes from this analysis would include positively effecting the energy consumption of the building while creating a guide for other projects to use to evaluate potential energy savings.

Analysis II – Alternate Roofing Types

Proposed Solution

Another possible area of energy saving is with respect to the roof of the building. The standard roofing material for many years has been asphalt. The problem with asphalt is it absorbs a large amount of energy and holds it. It later 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, also known as the heat island effect. Additionally, the standard roofing systems tend to breakdown in sunlight, which leads to periodically replacing the asphalt on the roof.

Several different roofing types have been introduced to help combat the negative characteristics of hot applied asphalt roofs or other similar types. The three that will be investigated in this analysis will be solar panels (blue), vegetated (green), and cool (white). With respect to vegetated or green roofs, two subtypes will be explored, which are extensive and intensive.

Each type will be evaluated based upon energy consumption and thermal characteristics. 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. Additionally, with respect to the solar roof, the energy generated will be included. In terms of thermal characteristics, thermal resistance, “R-Value”, will be considered. Finally, absorption will be addressed in an effort to reduce or eliminate the heat island effect.

Benefits

Each system inherently comes with associated benefits. Green or vegetated roofs can significantly reduce the amount of stormwater 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.

Subsequently, solar roofs also have their benefits. One type of solar is solar thermal, which uses the sun's energy to heat a medium which can then be used to heat water for use within the building. This system would have very limited application on 2175 K Street, therefore it will not be analyzed. On the other hand, solar photovoltaic or solar PV collects the sun's 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.

The third type of roof that will be investigated 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 sun's 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.

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. Therefore, this analysis will need to determine if the existing structure can support the weight of a green roof.

Additionally, with respect to a solar roof, substantial first time cost is associated with this system. This aspect will be addressed within this analysis along with the possibility of financial incentives to offset this cost.

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, this might be the case. This analysis will determine which system will work best given the current conditions.

Research

This analysis will require research into each type of roof with respect to design characteristics and performance data. Because this project is located in Washington DC, weather data will need to be collected to create a baseline from which each system will be evaluated against. Additionally, as mentioned above, if any upfront costs exist, research into financial incentives will need to be conducted to help eliminate or offset these costs.

Methodology

- Research each 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 (lifecycle cost analysis)
- Determine schedule impact
- Conduct constructability review
- Summarize findings

Preliminary Tools to be Used

- Energy10
- STADD or similar structural program
- Professors and colleagues
- Equipment Manufactures

Expected Outcome

This portion of the analysis was designed to determine which system, if any, could be 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 each roof type and establish an estimated cost and performance.

Analysis III – Alternative Curtain Wall Design

Proposed Solution

Another area for potential improvement with respect to energy efficiency is the curtain wall design. Most building envelopes consist of one system that covers all four elevations with minimal alterations. Some buildings take this one step further and use the same design for three elevations and use another system for the fourth. Being proposed here is to customize each elevation according to its given conditions to ensure optimal performance. The basis for this concept results from each of the four elevations receiving differing amounts of solar exposure thereby requiring each system to be designed independently.

Additionally, technologies such as solar PV integrated windows and electrochromic window tint will be investigated to determine the potential benefits that each have on the overall performance of the building. Based upon preliminary analysis, the southern facing façade could benefit from solar PV more than the northern facing façade. On the northern façade, electrochromic tinting might be appropriate to reduce the glare introduced into the space. Additionally, research will need to be conducted to determine if these systems can be installed in the same location to benefit from the positive characteristics of each. In other words, can a solar PV film be installed on the exterior side of the electrochromic tint so the occupant can block some of the sun while maintaining maximum exposure to the solar photovoltaic film; thereby allowing the occupant to adjust the light level within the space without diminishing the output of the solar collector.

Lastly, the current design of the buildings solar louver system will be analyzed to determine the relative benefit to the overall performance of the system. This analysis will need to first create a baseline of the current conditions then evaluate the performance of the proposed solution.

Benefits

The primary benefit, as with all solar PV systems, is electricity generation, which can in turn reduce the electricity demand of the building saving the owner money over the life of the system. Based upon the amount of potential surface area that could receive solar PV integration, the feasibility of the system will need to be addressed. Along the same lines, the primary benefit of electrochromic window tinting can enhance occupant comfort and reduce thermal gain within the space. This then reduces the thermal loads the mechanical system would need to be designed to handle.

Drawbacks

Similarly, with most new technologies, they are significantly more expensive to purchase and install. For this reason, a financial model will need to be created to determine the upfront costs of each system, relative to the current system installed at 2175 K Street, and then compared to the lifecycle cost of each. 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 will be 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 will need to be done on possible manufactures of such technologies. Additionally, research into possible financial incentives will be necessary if there is substantial upfront cost associate with the above mentioned technologies.

Methodology

- Research potential products
- Determine feasibility of each technology
- Determine synergies that can be gained through combining these technologies
- Establish baseline of existing design
- Calculate the cost and savings associated with each system
- Compare cost and savings to baseline
- Identify schedule impacts
- Perform constructability review and identify potential issues that could come up during installation

Preliminary Tools to be Used

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

Expected Outcome

As addressed throughout this section, determining the overall success of this analysis would be 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.

Analysis IV – Energy Efficient Retrofits

Proposed Solution

One method of reducing energy usage within buildings is to replace inefficient 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 exiting portion of the building in the near future. This adds precedence to this area of analysis. These fixtures 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 interest 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 will need to be done to verify these claims and to investigate the feasibility of using such a system.

An additional are of potential energy savings 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. A simpler route could be to purchase a smart power strips for each office that houses a computer. 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.

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.

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.⁵⁶ 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.⁷⁸ 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%.⁹

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

⁵ L. Edwards, P. Torcellini, (2002), *A Literature Review of the effects of Natural Lighting on Building Occupants*, NREL

⁶ *Journal of Property Management*, (January 2000)

⁷ *Green Building Council*, www.usgbc.org

⁸ *Australian Commercial Building Sector Greenhouse Gas Emissions 1990–2010*, Australian Green House Office

⁹ Parans. <http://www.parans.com/Products/Benefits/tabid/1080/language/en-US/Default.aspx>

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 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.

Research

As mentioned in the previous few sections, a great deal of information is needed and it will hopefully be found through research and contacting the manufactures of these systems. Research into fiber optics in terms of using it as a lighting system within a building is critical to determine if such a system is even possible and even if so, financially feasible.

Methodology

- Determine feasibility of a fiber optic lighting system
- Investigate fluorescent currently installed on project
- Determine energy savings through installation of LED fixtures
- Calculate upfront cost and payback period for LED fixtures
- Compare installation time between fluorescent and LED fixtures to determine potential schedule impacts
- If fiber optics prove to be a possibility, conduct similar activities as outlined above
- If fiber optics prove to be improbable, explore alternate solutions

Preliminary Tools to be Used

- Professors and collogues
- Product Manufacture's
- Industry Professionals
- Contacts made at the 2009 PACE Roundtable

Expected Outcome

The primary goal of this analysis is to provide factual evidence to the owner of 2175 K Street or other building owners in an attempt to persuade them to utilize these alternate lighting strategies in an effort to reduce energy consumption and in turn reduce electricity costs associated with lighting. Additionally, reducing wasted electricity in the form of heat will have a positive effect on the sizing of a building's mechanical system. The systems within a building are all interdependent; making a change to one can have an effect on them all.

D. Expected Outcome

As discussed within each of the four proposed analyses, the overall goal for this research is to reduce the amount of energy consumed by buildings in the form of electricity. One outcome of saving electricity is reducing operating cost or lifecycle cost. If money can be saved in one area, it allows for more money to be invested in improving other areas. Going one step further, if a building consumes less electricity, power plants won't need to burn as much fossil fuels and therefore reduce the amount of CO₂ and other greenhouse gases that are released into the atmosphere. This cannot alone prevent the progression of global warming but every bit counts and the more people are aware of the ways to accomplish the goal, the more the market will develop for such technologies. There is only one Earth... we need to start taking better care of it.

E. Weight Matrix

The purpose of the following weight matrix is to illustrate how time and effort will be distributed among the different analyses proposed in the previous sections.

Description	Research	Value Eng.	Const. Rev.	Sched. Red.	Total
Analysis I	5%	5%	5%	0%	15% ✓
Analysis II	10%	10%	10%	5%	35% ✓
Analysis III	10%	10%	15%	5%	40% ✓
Analysis IV	5%	5%	0%	0%	10% ✓
Total	30% ✓	30% ✓	30% ✓	10% ✓	100% ✓
	(10 to 30%)	(10 to 30%)	(10 to 30%)	(10 to 30%)	(100%)

Figure E.1 Work Breakdown

To help distribute effort accordingly, the time and effort was divided into several categories. Such categories are research, value engineering, constructability review, and schedule acceleration. The effort needed in these areas varies based upon the analysis at hand.

With regards to Analysis I – Peak Energy Shaving, the breakdown is as follows: 5% on research, 5% of value engineering, 5% on constructability review, and 0% on schedule reduction. These percentages were based upon the anticipated amount of effort needed in each category. Concerning the schedule, if the primary means of satisfying the goal of this analysis is using the backup generator, it would have no affect on the overall project schedule.

Consequently, Analysis II – Alternative Roofing Strategies, the breakdown is as follows: 10% on research, 10% of value engineering, 10% on constructability review, and 5% on schedule reduction. Based upon preliminary investigations, this analysis is going to require more effort in comparison to Analysis I. This analysis involves potentially changing the roofing materials

therefore more effort was placed upon value engineering, constructability review, and schedule reduction.

Subsequently, Analysis III – Alternative Curtain Wall Glazing has the following breakdown: 10% on research, 10% of value engineering, 15% on constructability review, and 5% on schedule reduction. Because this analysis involves making changes to the curtain wall system on the building, more effort was placed on conducting a constructability review to ensure the changes are feasible and possible within the scheduled timeframe. If this is not the case, if the changes cause an increase in the schedule, an attempt to justify the added time will need to be addressed.

Finally, Analysis IV – Energy Efficient Retrofits, the following breakdown exists: 5% on research, 5% of value engineering, 0% on constructability review, and 0% on schedule reduction. As previously stated, the primary purpose for this analysis is to identify several applicable products that could be applied to 2175 K Street as well as other projects that have the greatest effect on the energy consumption. For this reason, research and value engineering are the primary areas of emphasis for this analysis.

These percentages are only an estimation in an attempt to evenly distribute time and effort where needed.

Appendix A - Breadth Studies

Structural Analysis (Analysis II)

2175 K Street provides for a challenging arena for the application of an alternate roofing type. The proposed three types of roofs to be analyzed are solar, vegetated, and cool. Each type has a different weight per square foot associated with it. Seeing as how 2175 K Street consists of adding three floors onto an existing building, additional loads are critical. To allow for the existing structure to carry the newly imposed loads caused by the new structure, steel reinforcement or carbon fiber, depending on location, was utilized. With this in mind, any additional load imposed by an alternate roofing type would need to be calculated. To ensure the proposed solution is feasible, a structural analysis will need to be conducted.

Mechanical Analysis (Analysis III)

In an attempt to reduce unwanted thermal gain and increase energy efficiency, Analysis III will look into customizing the building facades based upon their orientation and sun exposure. Additionally, different types of glazing will be explored to further reduce unwanted thermal gain. The two proposed solutions to this facet of the analysis is using electrochromic window tinting and/or PV integrated glazing. One way to determine the success of the analysis in terms of beneficial outcomes is the effect the changes have on the building's mechanical system. Therefore, the results, in terms of reduced thermal gain, will be incorporated into a redesign of the building's mechanical system.

MAE Requirement

The skills and knowledge attained through a number of graduate level classes will be used to enhance the quality of analysis conducted. Additionally, the classes will help to create compelling arguments of the findings of such analyses. Such classes are AE 542 – Building Enclosure Science and Design, AE 572 – Project Development and Delivery Planning, and AE 597D – Sustainable Building Methods. Concerning AE 542, the knowledge gained through this course could be applied to the curtain wall analysis proposed above. Additionally, AE 572 can be used to create more thorough financial models which will result in more compelling results. Finally, the knowledge gained in AE 597D will serve as the basis for all of the research involving this proposal.

Appendix B - Spring Semester Schedule

January				February				March					April						
4 Jan 10	11 Jan 10	18 Jan 10	25 Jan 10	1 Feb 10	8 Feb 10	15 Feb 10	22 Feb 10	1 Mar 10	8 Mar 10	15 Mar 10	22 Mar 10	29 Mar 10	5 Apr 10	7 Apr 10	12 Apr 10	19 Apr 10	26 Apr 10	30 Apr 10	
Winter Break	Peak Energy Shaving																		
			Alternative Roofing																
						Alternative Curtain Wall Design													
											Energy Efficient Retrofits								

- Analysis I Peak Energy Shaving
- Analysis II Alternative Roofing
- Analysis III Alternative Curtain Wall Design
- Analysis IV Energy Efficient Retrofits
- Breadth I Structural Analysis
- Bredth II Mechanical Analysis



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