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Analyzing the LEED Certification & Energy Usage of the Peter Irving Wold Center

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Of the Peter Irving Wold Center

By

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ABSTRACT

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This report discusses the Leadership in Environmental & Energy Design (LEED) Gold certification of the Peter Irving Wold Center, located in Schenectady N.Y. The credits that the Wold Center achieved in the LEED process are discussed as well as what credits were not achieved. Each credit is described in detail and the feasibility of implementing the credits that were not achieved is considered. The feasibility of achieving Platinum certification is discussed. It is important to note that this analysis, while post-construction, is determining whether or not the building could have achieved Platinum certification during the planning and building process. A discussion of the shortcomings in the LEED credits assignment is included. Note that much of the information in this report is from LEED documents obtained from EYP, the engineering & architecture firm involved with the LEED certification of the Wold Center. Additionally, data from the Wold Center is compared to aggregate U.S. building data. The LEED certification is also compared to the Energy Conservation & Construction Code NYS 2010. Through these comparisons it is concluded that LEED certification is not an accurate prediction of the energy efficiency of the building, as compared to a non-LEED certified building. If a specific building system is directly addressed by a LEED credit, achieving this credit means that this building system will outperform a similar system in a non-LEED building. As a whole, LEED reflects only small pieces of the building's efficiency, rather than the entire building.

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Abstract

This report discusses the LEED Gold certification of the Peter Irving Wold Center, located in Schenectady N.Y. The credits that the Wold Center achieved in the LEED process are discussed as well as what credits were not achieved. Each credit is described in detail and the feasibility of implementing the credits that were not achieved is considered. The feasibility of achieving Platinum certification is discussed. It is important to note that this analysis, while post-construction, is determining whether or not the building could have achieved Platinum certification during the planning and building process. A discussion of the shortcomings in the LEED credits assignment is included. Note that much of the information in this report is from LEED documents obtained from EYP, the engineering & architecture firm involved with the LEED certification of the Wold Center. Additionally, data from the Wold Center is compared to aggregate U.S. building data. The LEED certification is also compared to the Energy Conservation & Construction Code NYS 2010. Through these comparisons it is concluded that LEED certification is not an accurate prediction of the energy efficiency of the building, as compared to a non-LEED certified building. If a specific building system is directly addressed by a LEED credit, achieving this credit means that this building system will outperform a similar system in a non-LEED building. As a whole, LEED reflects only small pieces of the building's efficiency, rather than the entire building.

Introduction & Background

Leadership in Energy & Environmental Design certification, or LEED certification, is issued by the United States Green Building Council, USGBC. Their mission is to promote sustainable living and infrastructure for the next generation. LEED certification is a stamp on how environmentally friendly a structure is. The concept of LEED, Leadership in Energy & Environmental Design, is to change the process for how buildings are designed, maintained, and operated. There are several categories of LEED certification as well as several levels of certification. The categories of certification are based on the type of construction. Examples of construction types include new buildings and major renovations, residential developments, and schools. The level of certification is determined by how many points the building is awarded for its environmentally friendly features. The credits are outlined by the USGBC (LEED).

The rating systems include new construction/major renovation, existing buildings operations/maintenance, commercial interiors, core and shell development, schools, homes, neighborhood development, and healthcare. The four levels of certification are Platinum, Gold, Silver, and Certified. The rating system used for the Peter Irving Wold Center in Schenectady, NY was the new construction and major renovations category. The Peter Irving Wold Center was dedicated in May 2011, and is LEED Gold certified. To determine the level of certification of the building, there are several categories, each containing credits that can be earned. These categories are sustainable sites, water efficiency, energy & atmosphere, materials & resources, and indoor environmental quality. Most credits are worth one point, and a total of at least 39 points needs to be achieved for LEED Gold certification. LEED Certification is achieved from 26-32 credits, Silver certification is 33-38 credits, Gold is 39-51 credits, and Platinum is 52

credits or greater. Additionally, the version of credits used for this project was V2.2 of LEED certification.

LEED certification is achieved through a complex application process. The project team, as referred to in this report, is the team of individuals that is responsible for submitting the LEED paperwork and working towards LEED certification. The LEED committee then reviews this paperwork and determines whether or not the credit will be granted. The project team decides which credits will be pursued; just because a credit is pursued does not necessarily mean that it will be granted. The LEED review team must determine whether the building has met the credit requirements adequately. In this discussion, each point will be addressed in regards to the Peter Irving Wold Center.

According to the USGBC, the average cost to certify a LEED project is approximately $2,000. There are several costs associated with LEED certification, including a cost for each credit and varying charges based on the floor space. The charges are summarized in Table 1, as they would apply to the Wold Center. These charges are for Gold, Silver and Platinum level members, and are for a building project from 5,000-50,000 square feet, as the Wold Center contains approximately 11,500. The total cost in the table represents the cost of the LEED certification for the Wold Center (Registration).

Table 1: Cost of LEED certification, as applied to the Wold Center

Step	Cost
Registration	$ 900
Precertification Review	$ 3,250
Design & Construction Review	$ 2,250
Appeals, Per Credit (x2 credits)	$ 500
Total	$ 7,400

There are several reviews that occur in the process of LEED certification, in order to make sure the credits being granted are adequately met by the structure. These reviews include, at a minimum, a preliminary design review and preliminary construction review. A final design review and a final construction review can be added as well, if there are additional credits to be pursued. For the preliminary design review, an application is submitted stating the rating system the project team would like to be considered under (new building construction for the Wold Center). Additionally, they indicate what credits they anticipate receiving. The LEED review team then indicates which credits were approved based on the supporting documentation provided. The final design review may be pursued by the project team if they wish to resubmit paperwork for credits they were denied during the preliminary design review.

The preliminary construction review is designed to investigate the credits that have not been granted to the building. The project team can accept the results of this review, or choose to have a final construction review. The LEED committee indicates the credits that were accepted and those that were denied. The final construction review (if

pursued) is the last change for the project committee to have their credits accepted, unless they would like to appeal a credit. If a credit is not accepted during the design review, additional paperwork can be submitted and this credit will be reinvestigated during the construction review (Application). The Wold Center achieved certification in April of 2012. The building was completed in early 2011 for use (Wold Center).

In an effort to quantify the performance of buildings that are LEED certified, the water system, photovoltaic solar system, total carbon footprint and total energy cost of the Wold Center were compared to data from the 2010 Buildings Energy Data Book. This book is issued by the U.S. Department of Energy and includes statistics on residential and commercial building energy construction. This book is released by the Building Technologies Program, which is a part of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy. The data book contains aggregate information on buildings in the U.S., including federal buildings, residential buildings, and commercial buildings. It also includes information on energy availability, water supply and energy codes & standards (Buildings).

This paper analyzes the differences between LEED certification and the Energy Conservation & Construction Code 2010 for New York State (ECCCNYS 2010). ECCCNYS 2010 is the building code for New York State that addresses designing and construction energy efficient building. Several building systems are addressed, including mechanical systems, lighting systems, ventilation systems, heating and cooling systems, etc. Chapter five is the chapter that refers to commercial buildings, as opposed to residential buildings, and that was the chapter used in this analysis (2010).

In the data analysis & comparison section, the solar photovoltaic (PV) system is analyzed. This system harnesses the power of the sun and uses it to heat the water for the bathroom sinks in the Wold Center. Energy from the sun is converted into electricity in this system. Solar PV systems are composed of solar panels to convert the energy, an energy distribution system, and sometimes an energy storage device such as a battery. Batteries are used to store the energy produced by the sun during the day and are discharged at night (How).

In order to determine the production of the solar PV system, a sensor was installed in the loop in the Wold Center. The system used is from ONICON Inc., which is a company that develops flow and instrumentation equipment for these types of applications. The sensor used is a combination BTU and flow meter called the system-10-BAC BTU meter. The system is able to measure flow, energy and temperature data through one connection which lowers installation costs. Additionally, the unit is ready for installation upon delivery and uses only one manufacturer for all of the components, making accountability easy for the system's warranty. One of the specific applications listed for this unit is monitoring of university or campus buildings. This is also the system that is used to measure the flow rate and gallons used for the domestic water system in the Wold Center. The specification sheet can be seen in appendix 2.

Manual temperature sensors were also added to the solar PV loop. These thermometers were attached to the piping with Thermowell Model A-500. This piece is machined to attach to the pipe that the temperature is being taken from. The piece is designed to transfer the heat from the substance where the temperature is being measured to the thermometer as accurately as possible. These thermometers provide additional

temperature verification for the solar PV system. The specification sheet can be seen in appendix 3.

The kiosk is set up to take data from these sensors and output them to an external visual display on the first floor of the Wold Center. The internet allows for remote access to the system by Union College Facilities staff and by Technical Building Services, the company which built the kiosk software. The internet connects to the Union College Campus LAN which is connected to the local access system and the Sunnyview portal, which Facilities uses to track certain building systems for their own purposes. The Union College campus LAN connects to the ICONIX server and that connects to the Wold Center kiosk. This is how the data acquisition of the Wold Center is achieved.

Project Definition & Goals

For the first term of this project, my goal was to investigate the LEED credits achieved by the Wold Center for Gold certification. I was going to determine what features of the building were used to achieve LEED certification and how many points were achieved. I planned on determining the additional cost and feasibility of Platinum certification.

For the second term of this project, I investigated the energy usage of the Wold Center and compared these values to average energy loads, as well as compared the LEED certification to the ECCCNYS 2010. The question to be answered was how well does LEED certification predict an energy efficient building, as compared to non-LEED buildings. The Wold Center was used as proof to support my conclusion. In my second

term, I compared the water usage, solar PV generation, carbon footprint and energy cost of the Wold Center to building averages in order to determine how well the Wold Center performed as compared to similar buildings. The final deliverable for MER 498 was an analysis of the feasibility of Platinum certification, as well as an analysis of the energy usage of the Wold Center as compared to building averages. Using this information, I quantified the LEED certification and determine how much less energy, if any, LEED buildings use than non-LEED buildings. In my conclusions, I determined that Platinum certification is not feasible. Additionally, LEED certification does not ensure a more energy efficient building than a non-LEED building.

LEED Credits Achieved

The first category that was investigated was the sustainable sites category. The points to be earned in this category include construction activity pollution prevention, site selection, development density and community connectivity, brownfield redevelopment, alternative transportation of several forms, site development in several forms, stormwater management, heat island effect, and light pollution reduction.

The credit of construction activity pollution prevention was a prerequisite for all other sustainable sites credits and has no associated point value. This means that this “credit” did not contribute to the total number of points needed for certification, but was necessary as a prerequisite to earn other points in this category. In effect, this credit is mandatory. In order to earn this requirement, an Erosion and Sedimentation Control Plan for the construction of the project must be developed in compliance with the most

stringent requirements by law (either federal or local codes). The intent of this credit is threefold. First, it serves to prevent erosion and soil loss during construction. During construction, the ground is dug up and this dredged soil must be protected from erosion in order to be reused or replaced at the end of construction. Second, protecting this soil also keeps storm drains from being clogged if the soil is swept away with the rain. This erosion plan also protects the soil from scattering into the air. Third, the erosion plan prevents soil pollution in water and air, and ensures reuse of the soil.

The first credit to be earned in the sustainable sites category is the site selection credit. This credit has several criteria that must be met in order to be earned. In order to earn this credit, development cannot take place on any of the following land: prime farmland (as stipulated by the USDA), undeveloped land with elevation within 5 feet of the 100-year flood line, as stipulated by the Federal Emergency Management Agency (FEMA), land inhabited by any species that is state or federally threatened or endangered, land within 100 feet of wetlands, undeveloped land within 50 feet of a body of water that could support fish (consistent with Clean Water Act), or land which was previously public parkland. The 100 year flood lines developed by FEMA are those areas that have a 1% chance or higher of being flooded every year (Flood). Over 100 years, these areas are statistically likely to flood once.

For the case of the Wold Center, the selection of the site was pre-determined; that is, the site was not selected based on the criteria of a sustainable site. The site was selected based on the desired location and availability of land on campus. The fulfillment of the sustainable sites criterion was by coincidence. In addition to the building not being

placed on any of these types of land, the parking areas, roads, or additional infrastructure required for the building cannot be placed in these areas.

The intent of the development density and community connectivity credit is to develop on land that is close to residential areas and foster a spirit of integration among the environment, residential communities and urban centers. In order to achieve this credit there are two routes that can be taken. The first route is to build on a previously developed site and in a community with a minimum density of 60,000 square feet per acre, in order to add infrastructure to existing communities. The second route has several criteria; the first is to build within 0.5 miles of a residential zone with at least 10 units per acre. The second is to pick a location within 10 basic services and have pedestrian access between the building and the services. Some of the basic services that the USGBC recognizes are banks, places of worship, grocery stores, day cares, cleaners, fire stations, beauty salons, hardware stores, laundry mats, libraries, medical facilities, parks, pharmacies, restaurants, schools, supermarkets, theater, fitness centers and museums. Additional services can qualify that are not listed as well. In order to determine this credit, a 0.5 mile radius is generated from the main entrance of the building. The services in this area are then determined by what is within this circle *and* has pedestrian access to the building.

This credit was earned by the Wold Center. The first option of this credit was not used to achieve this point, as the building was not built on a previously developed site. The second option for achieving the credit was taken.

Brownfield redevelopment was not a credit that was achieved by the Wold Center. This credit is intended to redevelop land that has an environmental threat and serves a two-fold purpose; first, it clears a land that is otherwise unusable and uses it as a location for a structure. Second, it does not require development of previously undeveloped land, which preserves the environment. As previously stated, this credit was not achieved because the location for the Wold Center was pre-determined and did not have the option to be built on a brownfield. In investigating Platinum certification, this credit will not be considered as a potential credit that can be earned.

There are several credits associated with alternative transportation. The first credit is public transportation access. This is intended to reduce pollution and encourage patrons to use public transportation as opposed to driving themselves. To earn this credit, the building must be within 0.5 miles of a commuter rail or subway, or within 0.25 miles of campus or public bus lines. This credit was earned because the Wold Center is within 0.25 miles of campus bus stops.

The second credit for alternative transportation is bicycle storage and changing rooms. To earn this credit, bicycle racks must be within 200 yards of the building entrance and changing rooms must be present for at least 5% of the building occupants. This credit was earned by the Wold Center.

The third alternative transportation credit is low emitting and fuel efficient vehicles. There are several options for this credit; first, low-emitting and fuel-efficient vehicles shall be provided, along with preferred parking, for 3% of building occupants. Second, preferred parking may be provided for 5% of building occupants. Third,

alternative-fuel stations shall be installed for 3% of total parking capacity of the site. Low-emitting and fuel-efficient vehicles are those classified with a minimum score of 40 by the American Council for an Energy Efficient Economy guide, or zero emissions vehicles. This credit was earned by the Wold Center for the purchase of fuel efficient vehicles in accordance with the first option for earning this credit.

The last alternative transportation credit is parking capacity. This credit also has several options that can be completed. The first option is to provide preferred parking for carpool vehicles accounting for 5% of overall parking capacity, and the parking size cannot exceed zoning requirements. The second option is to provide parking for less than 5% of building occupants. The last option is to provide no new parking. This credit was earned by the Wold Center because no new parking was added to support the building. Yet, this is slightly misleading because the campus already has several parking areas surrounding the building – it is just that no new areas were built. The intent of this credit is to limit the number of spaces available for parking and encourage building occupants to carpool, use public transport, or walk. Although this credit was earned, it does not necessarily accomplish its intent, as there is other parking available in the vicinity if the Wold Center.

The credit of protect or restore habitat was applied for but denied by the USGBC, and ultimately the Wold Center did not achieve this credit. The intent of this credit is to conserve natural areas and rehabilitate areas that are environmentally damaged. This credit has two options for fulfillment. The first option is for Greenfield sites (sites that have not been previously developed). This states that site disturbance cannot be more than 40 feet beyond the outside perimeter of the building. In other words, the construction

process cannot disturb the environment more than 40 feet from the site of the building. Additionally, site disturbances cannot exceed 10 feet away from utilities and walkways, 15 feet beyond roadways, and 25 feet beyond construction areas. The second option for attaining this credit is for previously developed sites. If the site has been previously developed, a minimum of 50% of the site area must be restored with native vegetation. For example, this can be fulfilled through a vegetated roof.

The Wold Center did not achieve the protect or restore habitat credit, although it was applied for. The project team stated that the site was previously developed but that 65% of the site area does not fall within the building footprint for the Wold Center. The lawn around the building was counted as part of the regrown area, but this cannot count under the credit guidelines if the lawn needs regular mowing and maintenance. Additionally, the cultivation of grass does not necessarily imply that there is any biodiversity or that there are native species present. The project team indicated that the grass was a mixture of native species but the lawn still required regular maintenance in order to be presentable to the campus. This is why the credit was ultimately denied to the Wold Center.

The site development credit to maximize open space was achieved by the Wold Center. The intent of this credit is to promote biodiversity through open space. There are several options to achieve this credit. First, the development footprint can be reduced or 25% more vegetated space can be planted than as stipulated by the zoning requirements. The second option is to provide vegetated space equal to the size of the building. This option is used if no local zoning requirements exist. The third option is to provide vegetated open space equal to 20% of the total building area. This option is used if there

is no open space requirement indicated in the zoning. This credit was achieved by the Wold Center using the third option. Vegetated open space was cultivated equal to 39% of the building square footage.

There are two credits associated with stormwater management: quantity control and quality control. These credits attempt to preserve the natural drainage system of the terrain and eliminate contaminates from potentially leaching into the groundwater supply. This is done by increasing on-site filtration and eliminating pollution from runoff. There are two cases for the quantity control credit. The first case applies where the existing imperviousness is less than or equal to 50%. Imperviousness is a measure of the impact development has on the landscape. It has two main contributing factors – buildings and roads. These structures are impermeable and restrict runoff, preventing natural flow of stormwater. Areas with existing imperviousness of less than 50% indicate less developed areas (The Importance). To achieve this credit, a drainage plan must be developed to prevent the peak runoff rate after building construction from exceeding the peak runoff rate from pre-construction. Where existing imperviousness is greater than 50%, a plan must be created to decrease the volume of runoff by 25%. This credit was not achieved by the Wold Center.

The stormwater quality credit attempts to limit the disruption of natural water flows, and is achieved by implementing a plan that treats 90% of the water runoff and filters it before returning it into the groundwater system. This credit was also not achieved by the Wold Center.

There are two heat island effect credits, the roof and non-roof credits. These credits are designed to reduce heat islands, which have negative effects on the surrounding environment. Heat islands are areas that are hotter than the surrounding environment. These occur in areas where there is a dense population and lots of greenhouse gases are emitted, often over cities. Heat islands increase energy demands in the summer months, increase greenhouse gas emissions and reduce air quality (Heat Island Effect). A heat island is defined as the thermal difference between developed and undeveloped areas. There are two options to achieve the credit for the non-roof heat island effect. The first is to provide cooling strategies for 50% of the construction area, including shade, reflective pavement materials and an open grid pavement system. In order to qualify as a reflective pavement material, the solar reflectance index (SRI) must be at least 29. The solar reflectance index is a measure of the ability to reflect solar energy into the atmosphere. Lighter colors have greater solar reflective indexes (Solar). The second option to achieve this credit is to place at least half the parking spots in shaded areas, under a roof with an SRI of at least 29.

The credit for heat island roof can be achieved by a few options. The first is to install a vegetated roof for at least 50% of the roof area. The second is to build a roof with at least 75% of the area having an SRI of at least 29 (Heat Island Effect - Roof). The third option is to combine a vegetated roof with reflective roof material using equation (1).

$$\frac{Area\ of\ SRI\ roof}{0.75} + \frac{Area\ of\ vegetated\ roof}{0.5} >= Total\ Roof\ Area \qquad (1)$$

The Wold Center earned the heat island effect, non-roof, but did not pursue the roof credit for the heat island effect.

The last credit available for site development is light pollution reduction. This credit is designed to minimize the light given off by the building, specifically during nighttime hours, improving the surrounding habitat. The credit has two associated parts: inside and outside lighting. The indoor credit involves reducing the light output from the interior with automatic lights that can be manually controlled after business hours. The interior requirement can also be achieved by having all interior lighting reflect on opaque surfaces before exiting through the windows. For exterior lighting, in a commercial/industrial area (as the Wold Center is located in), the lighting must be less 0.60 footcandles, horizontal and vertical, at the site boundary and less than 0.01 horizontal footcandles at 15 feet beyond the site. A footcandle is a measure of how much light is falling on one square foot of area. The light is measured in lumens, or light flux (What).

The Wold Center achieved the interior lighting requirement for this credit but did not achieve the exterior lighting requirement. This credit was targeted by the project committee but was denied during certification. During the initial design application, there was no submission of a lighting analysis for the required limits. This credit was pursued during a design application appeal, and was not granted because the lighting study showed the amount of light on adjacent academic buildings was beyond the requirements of this credit, as determined by the engineering & construction company, EYP.

There are 5 available credits associated with water usage. The first is water efficient landscaping – reduce by 50%. The credit is designed to limit the water usage for irrigation on the surrounding landscape. To achieve credit for this requirement, the potable water consumption must be decreased by 50% for irrigation based on the value for peak summer usage. This can be done by changing the vegetation present, increasing the efficiency of irrigation, using recaptured rainwater or recycled water, and using non-potable water for irrigation. This credit was earned by the Wold Center.

The second credit for water efficient landscaping is no potable water use or no irrigation. This credit is granted if an irrigation system is entirely eliminated. This can be done by installing landscaping that does not need water, or by using only recycled water or non-potable water for irrigation purposes. The Wold Center achieved this credit because no permanent irrigation system was installed, and the exterior lawn of the building was only watered during the initial germination phase (one year from completion of the building).

The innovative wastewater technologies credit is awarded for reducing the potable water consumed and, in turn, the wastewater generated. To earn this credit, there are two options. The first is the potable water usage must be reduced by 50%. The second is to treat 50% of the wastewater produced with on-site facilities. This credit was not achieved for the Wold Center, although it was applied for. The project team submitted calculations showing a 50% decrease in the potable water used, but it was in accordance with the wrong standards and did not accurately take into account the number of people in the building (the number was underestimated). Additionally, there was an error in the calculation for the use of the duel-flush toilets. New calculations were submitted and the

credit was applied for again. The credit was not granted because the toilet flush rate was not properly taken into account in the water use calculations.

There are two credits associated with water use reduction – one credit granted for a 20% reduction and one credit awarded for a 30% reduction. This credit is designed to maximize water efficiency and decrease the need for water. Both of these credits were achieved by the Wold Center. The total water usage of the building was decreased by 63.5% from the baseline design.

The energy & atmosphere category of the LEED certification has 17 credits associated with it. There are three prerequisites for this category. The first prerequisite for this category is to make sure the energy systems are installed and calibrated according to the performance requirements for the project, the construction documents and is in accordance with the design. This prerequisite has several categories that must be achieved. A commissioning team must be in place with no individuals that are directly responsible for the design or construction of the building. The design intent must be reviewed and verified. The commissioning requirements *must* be incorporated into the construction documents, to ensure the correct installation of the energy systems. A commissioning plan must be developed and used. The energy systems also need to be verified once they are installed and the functional performance must be evaluated. The training, operation, and maintenance for the systems must be documented. Lastly, a commissioning report must be completed. Commissioning is designed to reduce the energy usage and operational cost of energy systems, and ensures that the systems are working as designed. This prerequisite was met by the project team.

The second prerequisite is to establish a level of energy efficiency for the building in accordance with the standards set forth by the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc. and the Illuminating Engineering Society of North America, ASHRAE/IESNA, which are energy standards for buildings (Why). The last prerequisite is fundamental refrigeration management. This prerequisite prohibits use of CFC-based refrigerants in the HVAC and refrigeration systems for the building. This reduces ozone depletion and preserves the environment. This prerequisite was also met for the Wold Center.

Up to 10 credits can be earned for the optimization of the energy performance of the building. The number of points earned is based on the percentage improvement of building performance from the baseline standard set forth by the ASHRAE/EISNA. The percentage improvement is measured by the energy savings of the building. The Wold Center earned 5 points for this category, which means that the energy savings of the building is at least 24.5% greater than what is required to meet the requirement.

On-site renewable energy includes three potential credits that can be earned. This credit is designed to encourage the use of alternative energy to offset energy costs. The performance of the renewable energy systems is to be calculated and the more energy the renewable source contributes to the overall energy of the building, the more credits are earned. A 12.5% contribution of renewable energy corresponds to 3 points earned for this credit. The Wold Center earned no points, out of three, for this credit.

One credit can be earned for enhanced commissioning. This is earned if the following requirements are achieved in addition to the commissioning required as a

prerequisite for this category. First, a team (independent from design team) will review the design before construction plans are generated. Second, this team will review the construction documents in a similar manner. Third, this team will review the contractor documents. Fourth, a document is to be created with all of the commissioning information for the building. Fifth, a document to review the commissioning of the building with the operations and maintenance staff must be created. Last, a plan needs to be in place to review the commissioning systems and mitigate any issues after one year of building operation. The Wold Center did achieve this credit.

Enhanced refrigeration management is worth one credit in the energy & atmosphere category. There are two options to achieve this credit; first, do not use any refrigerants. Second, select refrigerants that contribute minimally to ozone depletion and global warming. To achieve the second requirement, a complex formula is used to determine the maximum threshold of refrigerant that can be used. The formula used is equation (2)

$$\frac{[GWPr*(Lr*Life+Mr)*Rc]}{Life}+\frac{[ODPr*(Lr*Life+Mr)*Rc]}{Life}x\ 10^5\leq 100 \qquad (2)$$

Where GWPr is the global warming potential for the refrigerant in pounds of CO_2/ton-year, Lr is the refrigerant leakage rate in percent, life is the equipment lifetime, Mr is the end of life refrigerant loss in percent, Rc is the refrigerant charge, and ODPr is the ozone depletion potential of the refrigerant (Enhanced).

The Wold Center earned this credit for enhanced refrigeration management by showing that the result from equation (2) was less than 100, at a value of 90.1. This credit is included in LEED certification to comply with the regulations set forth by the Montreal

Protocol. The Montreal Protocol on Substances that Deplete the Ozone Layer was an international document that was developed with the intent to stop the depletion of the ozone layer. This protocol was voluntarily ratified by several countries and the European Union, as they vowed to reduce their emissions of ozone-harming pollutants (The Montreal).

Measurement and verification applies as one credit towards the certification of the Wold Center. This was earned by creating and implementing a measurement and verification plan that lasts for at least a year after the construction of the building is complete. In order to receive this credit, the project team had to develop and implement a plan, but the plan did not have to complete at the time of submission for LEED certification.

Green power is the last credit available in the energy & atmosphere category. This is a credit that fosters the use of renewable technologies that do not harm the environment. To earn this credit, at least 35% of the electricity must be from renewable sources for at least 2 years. This credit was achieved by the Wold Center.

Materials & resources is the next category of credits, with a total of 13 credits attainable. There is one prerequisite for this category, storage & collection of recyclables. To receive this prerequisite, there must be easy access to recycling bins and there must be separated recycling for at least paper, cardboard, glass, plastic and metals. There must be a designated area for the collection and separation of these materials. The Wold Center completed this prerequisite. In the Wold Center, there are built-in recycling areas that

serve the purpose of collecting different types of recycling materials. In all other buildings on campus, blue bins are provided that stand alone.

There are three credits associated with building reuse. The first credit is achieved if 75% of existing surface area, including walls, floors, and roof, is maintained in an effort to reuse materials. For the Wold Center, this credit was not pursued. This is because the Wold Center was not built from a preexisting structure and was not eligible for this credit. This is true for the second and third credits as well. The second credit associated with building reuse is to maintain at least 95% of the existing walls, floor, and roof. The third credit is to maintain at least 50% of the interior non-structural elements, including doors, walls, interior floors, and fixtures.

Construction waste management has two credits associated with it. The first is to recycle or reuse at least half of the construction and demolition material used for the project. The second credit is earned if at least 75% of the material is reused or recycled. The Wold Center earned both of these credits. In order to prove this, a detailed plan was submitted by the project team to discuss what materials were being reused and where it was going (i.e. recycling plants).

Materials reuse has two credits associated with it. One credit is achieved if 5% of the materials used, by cost, are reused materials. The second credit is achieved if 10% of these materials are used. The exclusions to this are mechanical, electrical and plumbing components and specialty equipment for the building. Since these items are most likely designed and sized specifically for the building it would be hard to receive these

materials as refurbished. The Wold Center did not achieve either of the credits in this category.

The Wold Center did achieve both credits associated with recycled content. The first credit is earned if at least 10% of the materials used, by cost, are recycled materials. The second credit is earned if this percentage is 20% or above. To determine the value of recycled content, it is weighed and the weight is multiplied by the cost of assembly. This gives the recycled content cost that can be compared to the new material cost. The Wold Center had a total of 20.56% of materials that fit this requirement.

Two credits are associated with regional materials, and both were received by the Wold Center. Regional materials are defined as materials that are manufactured, extracted or reused from within 500 miles of the project. The first credit is obtained if 10% of the building materials are classified as regional materials. The second credit is earned if at least 20% of the material used is classified as regional. The Wold Center had a total of 26.16% of materials being regional material. The percentage is based on the cost of the material as compared to the overall cost of the building. If a material is only partially regional (for instance it is only manufactured and not extracted locally), the weight percentage of the material that is regional will be counted towards this calculation.

Rapid renewable material usage counts for one credit, and is achieved if 2.5%, by cost, of the total building material is rapidly renewable. Rapidly renewable materials are plants that are harvested and regrown within a 10 year life cycle. This includes bamboo flooring, cork flooring or insulation, soy spray-foam insulation, and wood flooring (NC-v2.2). The Wold Center did not achieve this credit.

The Wold Center received one credit for using certified wood in the project. To earn this credit, at least half of the wood products must be certified wood. Certified wood comes from forests that have standards for how to manage the production and harvesting of wood products. This credit is aimed at fostering responsible forest management. It is up to the discretion of the project team whether or not to include temporary construction materials in this calculation, but all permanent materials must be included.

The indoor environmental air quality credit has two prerequisites associated with it. The first is to establish a minimum indoor air quality in accordance with the local or federal requirement, whichever is more stringent. The second prerequisite is to control the exposure of the inhabitants to tobacco smoke. There are two options for this credit. First is to prohibit smoking in the building and have any smoking areas be at least 25 feet away from the building. This is the option that the Wold Center chose to achieve this prerequisite. The second option is to have designated smoking areas in the building and prohibit smoking everywhere else.

Outdoor air delivery monitoring was a credit that was not pursued by the Wold Center design team. This credit involves installing a monitoring system that can be controlled with feedback, in order to ensure the conditions of the air delivery are consistent with what they should be. The system, if installed, would sound an alert if the conditions varied by 10% from the desired conditions. The system must monitor the carbon dioxide concentrations in all densely occupied areas of the building. The Wold Center also did not pursue the increased ventilation credit. To achieve this, additional ventilation would be included, providing a more comfortable environment to building

inhabitants. For the Wold Center to achieve this, the ventilation rates would have to be at least 30% higher than the minimum standard required (Outdoor).

There are two credits associated with an indoor air quality plan; one before occupancy and one during construction. These credits involve implementing an air quality management plan during each of these times. For the construction phase, there are several criteria that must be met. First, air handlers must be used during construction and the filters must be replaced immediately after construction (and before occupancy), and absorptive materials must be protected from moisture damage. For the before occupancy plan, there are two options for completion. The first requires a minimum of two weeks between construction and occupancy to flush out the building with 100% outside air. The filters must be replaced after this flush out is complete. The second option to complete this credit is to perform an indoor air quality test according to the standards set forth by the USEPA. The Wold Center achieved both of these credits associated with indoor air quality plans.

There are four credits associated with low-emitting materials; one for adhesives and sealants, one for paints, one for carpet and one for composite wood. A low-emitting material is a material that does not substantially contribute to indoor air pollution and complies with the standards set forth by the LEED criteria. Each of these categories has a different set of standards that are required to achieve this credit. For the low-emitting wood credit, none of the wood material may contain urea-formaldehyde resin. The Wold Center achieved all four of these credits.

There is one credit associated with indoor chemical and pollutant source control. This credit is designed to minimize pollutants in densely populated areas. To achieve this credit, doorways must have systems in place to capture dirt and particulates from entering the building. Labs where chemicals are used must be physically separated from the rest of the building and have a required air ventilation rate of at least 0.50 cubic feet per minute per square foot. This credit was achieved by the Wold Center.

Controllability of lighting systems has one credit available. To earn this credit, the building must provide lighting control for at least 90% of building inhabitants to fit individual needs, as well as add controls for shared spaces to fit group preferences. This credit was earned by the Wold Center.

There is one credit associated with controllability of thermal systems to provide thermal comfort. This involves providing individual thermostat controls for at least 50% of the building inhabitants, as well as providing thermostats for shared spaces to fit group needs. This credit was achieved by the Wold Center.

There are two credits associated with thermal comfort: design and verification. The first credit involves designing the heating, ventilation and air conditioning, HVAC system to meet the standards for thermal comfort conditions for human occupancy set by the American Society of Heating, Refrigeration, and Air Conditioning Engineers, ASHRAE. The second credit associated is to implement a thermal comfort survey within 18 months of the opening of the building in order to assess the success of the thermal comfort system. Neither of these credits was pursued or awarded to the Wold Center.

The last credits in the indoor environmental quality category are associated with the percentage of daylight that enters the building during the day. The first credit is awarded if a glazing factor of 2% is achieved in 75% of all spaces, or at least 25 footcandles are achieved in 75% of all spaces where light is required. This can be done through calculation, simulation or measurement. The second credit is achieved if 90% of all spaces achieve the requirements set forth in the first credit. Neither of these credits was granted to the Wold Center.

The last category, with a total of five credits available, is the innovation & design process category. Four of these credits are very open-ended, which is different from the requirements of other credits. To obtain four of these credits, the project team must show that they went above and beyond in certain areas with the building design. The first credit was obtained by showing the educational value of the display cases and the kiosk in the Wold Center. The second credit was earned by showing the value that the building adds to undergraduate research, as it contains labs for many professors. The third credit was achieved for exceeding the exemplary performance limit in the water use reduction credit category. The last innovation in design credit was awarded for providing a space for USustain to meet and discuss initiatives to help promote sustainable living in the campus and the community. The last credit in the innovation & design category is awarded for having a LEED accredited professional as part of the design team. This credit was also awarded to the Wold Center. The last category of innovation & design is the only category where the Wold Center earned all of the possible points.

The Wold Center achieved 42 credits out of a possible 69. To achieve Gold certification, a minimum of 39 credits are needed. Therefore, the Wold Center had a

leeway of 3 credits – even if three of the credits applied for weren't granted, the building would still have Gold certification.

Platinum Certification

The first step in my analysis of Platinum certification was to rule out credits that were unattainable. The first credit is the redevelopment of a brownfield, as the building had a specific site it was designed for that is not a brownfield. The second credits are the daylight & views credits; one credit is awarded for a minimum amount of daylight in 75% of spaces, and the second credit is awarded for daylight in 90% of spaces. Because this building is attached to the Olin Center and Science & Engineering, it was being blocked by some of the existing structures. This blockage prevented these credits from being achieved. The last three credits that were not applicable to this project were the building reuse credits. The first credit states that 75% of existing walls, floors & roof must be maintained. The second credit is achieved if 90% of walls, floors and roof are maintained. The third credit is awarded if at least 50% of the interior elements are maintained. Although this project was on "previously developed land" as defined by the USGBC, there was no existing structure where this was built so these credits were not applicable. To start off, 6 credits of the 69 are not available for the Wold Center.

This leaves 21 credits that the Wold Center can be eligible to achieve that it did not achieve for Gold certification. The Wold Center needs 10 additional credits from the Gold certification to achieve Platinum certification. There were several credits that I did not have enough information to determine whether or not they would be attainable. I will

discuss each credit that was not achieved in order, and discuss whether or not it could have been attained.

There are two credits associated with stormwater design: both quantity and quality control. These credits were not pursued by the Wold Center because of the existing infrastructure in the area. The credits would require a plan for stormwater management that would require extensive routing around current buildings and follows the water to nearby bodies. These credits are not feasible, given the existing structure of the campus and the routing of the water that would have to occur.

The reduce heat islands: roof credit can be earned by the Wold Center if a vegetated roof was installed for 50% of the roof area.

The light pollution reduction credit could not be earned because of the lighting from the surrounding infrastructure. For safety reasons, the campus wanted to have the surrounding walkways well lit, and this did not meet the exterior lighting requirement.

The innovative wastewater technologies credit was pursued by the project team but was not granted. The issue with the calculations for this credit was the automatic flushing of the toilets. After these calculations were corrected, it was determined that this criteria would not have been met. In order to meet this, an on-site wastewater treatment plant could have been installed to treat 50% of the wastewater leaving the building.

The renewable energy credits, worth up to 3 points, would have been earned if the renewable energy systems accounted for 2.5% (1 credit), 7.5% (2 credits) or 12.5% (3 credits) of the total energy usage. The feasibility of achieving this credit cannot be determined without the energy loads from the Wold Center, which I will not have until

the second term of my project. The building currently has renewable energy systems in place, and these account for less than 2.5% of the energy usage of the building. Geothermal heating is used, as well as solar thermal heating and this accounts for a small fraction of the overall energy usage. Because of this information and the lack of data surrounding these credits, they will be neglected in determining Platinum certification.

There are ten credits available for optimizing energy performance. In order to earn a full 10 points, a 42% reduction in the energy usage must be shown through an energy simulation, using a baseline calculation based on the ASHRAE 2004 standards. Because I did not have access to the simulation loads due to proprietary issues, I was unable to determine the feasibility of improving the scoring in this category. The project team earned 5/10 credits for this category.

The two credits associated with resource reuse could have been achieved with an additional cost. The same can be said for the outdoor air delivery monitoring system, the increased ventilation system, and the thermal comfort credits associated with design and verification.

The rapidly renewable material credit could have been achieved but would not necessarily have reduced the overall environmental impact of the building. If these materials were used, they would need to be replaced or require maintenance sooner than traditional materials. Because of this, I will not count this credit towards Platinum certification.

Based on these credits, a total of 9 could have been added to the Wold Center. Several other credits I did not have enough information to examine whether the credits

could have been improved. With the information that I had available to me, LEED Platinum certification was not a feasible option or the Wold Center.

Data Analysis & Comparisons

The data used in this section of the report is from the kiosk located on the first floor of the Wold Center. The data that will be summarized here will be the solar photovoltaic system, or solar PV system, the water usage, total energy usage of the building, carbon footprint, and the lighting levels on each floor.

The first analysis will be of the water system. Figure 1 shows the average usage of water per hour each day.

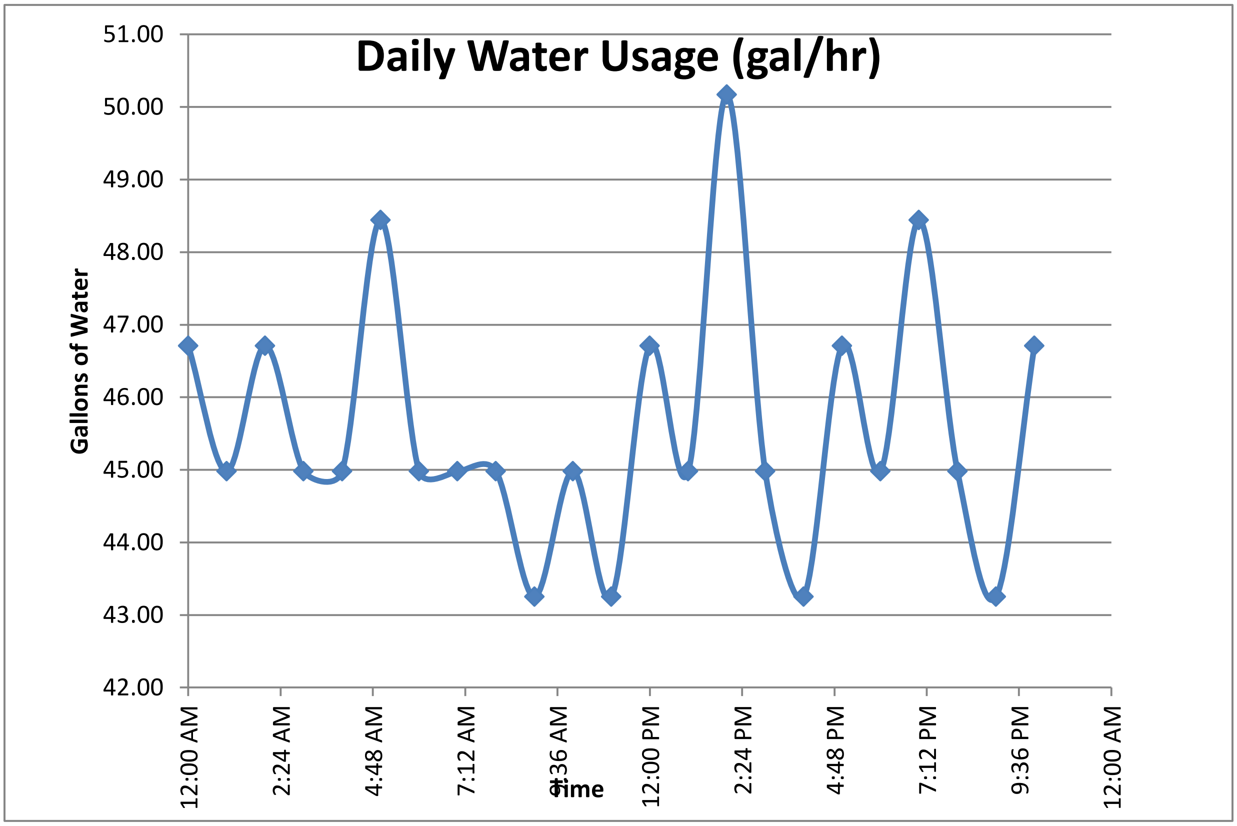

Figure 1: Daily water usage of the Wold Center.

Figure 1 shows that the peak water usage occurs in the afternoon, although the load is fairly constant throughout the day. Figure 2 shows the chilled water usage per hour each day.

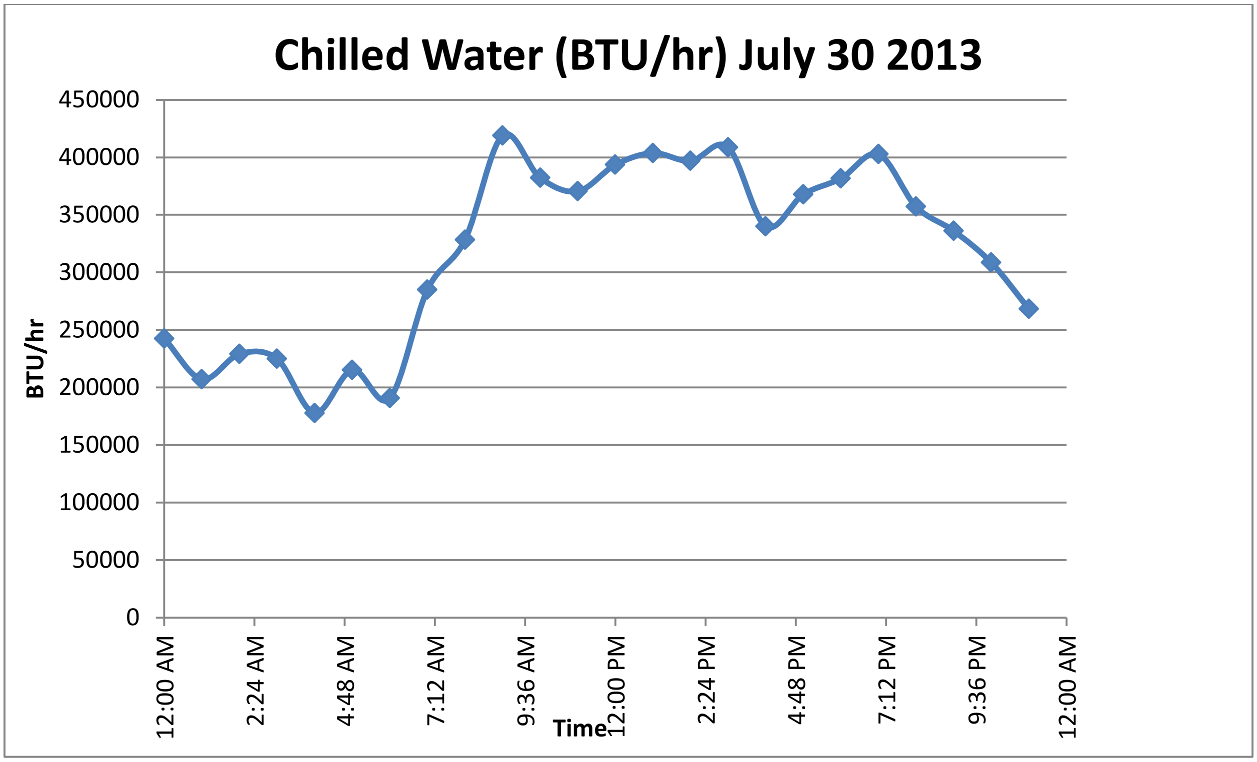

Figure 2: Chilled water usage of the Wold Center.

Figure 2 shows that the highest demand for chilled water is during the morning, around 9:00am, through the afternoon, around 3pm. This does not match directly with the data shown in figure 1, which reflected the peak water usage only in the afternoon. This means that the chilled water system is used at different times than the general water system. One reason for this is that the labs or the Starbucks may use chilled water for various reasons, making the demand higher in the morning when lots of customers are at Starbucks and students are in lab. The overall water may peak in the afternoon due to a high number of students in the building at this time, therefore using the bathroom and the water fountains.

In the water efficiency category of LEED certification the Wold Center achieved four out of five credits. One would assume that this means the Wold Center has a fairly

efficient water system as compared to other buildings, and uses less water on a daily basis. In order to determine if this is true, the average daily water usage of the Wold Center was compared to other buildings as described in the 2010 Buildings Energy Data Book. Two types of buildings were used to compare: college campus buildings and office buildings. The data book contained statistics on the average water usage (gal/day) per square foot of building. Multiplying these numbers by the square footage of the Wold Center yielded the comparative data. Figure 3 shows the average usage of the Wold Center as compared to the averages for other types of buildings in the U.S. (2010 Buildings).

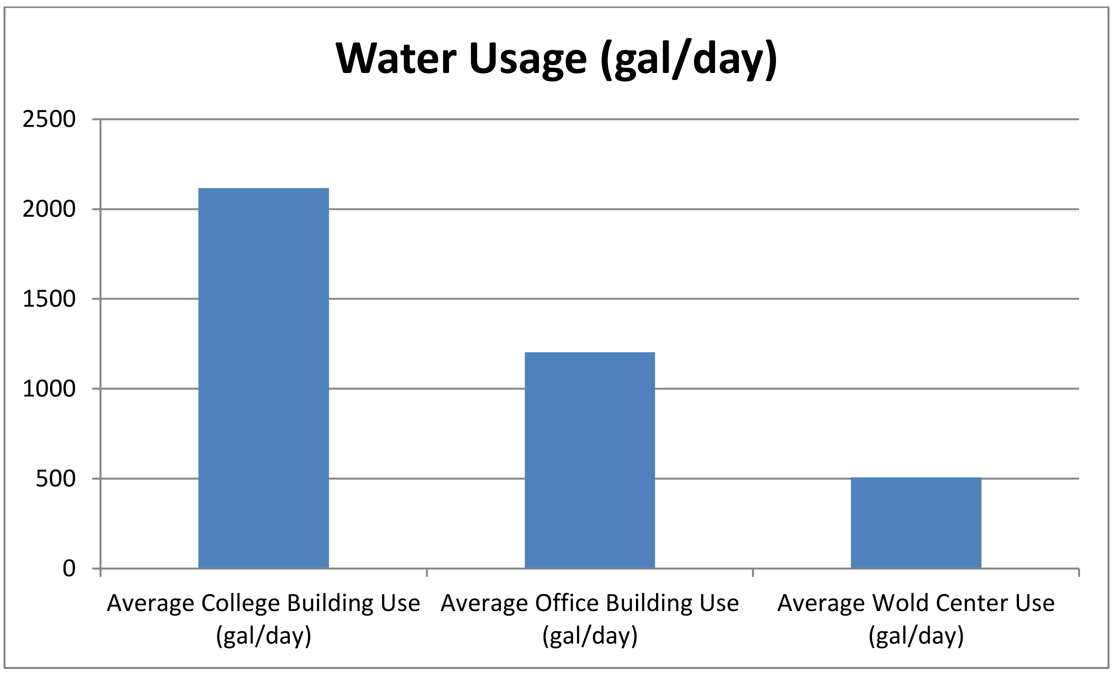

Figure 3: Water usage of the Wold Center compared to averages for other buildings.

Figure 3 shows that the average daily water usage for the Wold Center is less than 50% of the average office building use and less than 25% of the average college building use.

This shows that the Wold Center is more efficient than comparable building averages in terms of water usage. In the case of the water efficiency category, the LEED certification has been verified by the Wold Center; the building achieved four out of five credits in this category and does perform more efficiently than non-LEED buildings.

The second system to be analyzed is the solar PV system. Figure 4 shows the average hourly production of the PV system.

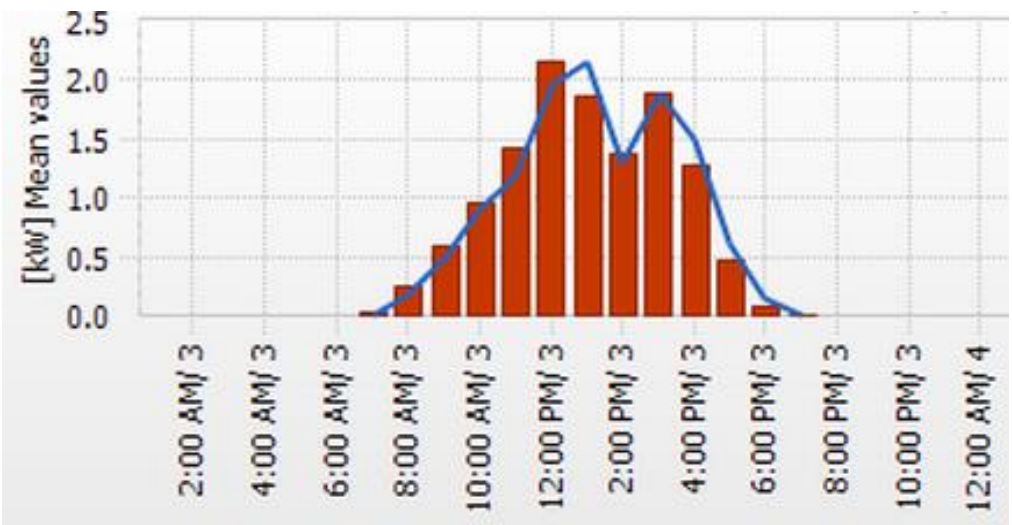

Figure 4: Average daily production of the solar PV system.

Figure 4 shows that the highest production occurs between the hours of 10AM and 4PM, with smaller production occurring in the early morning and late evening. During the evening hours when the sun isn't shining the system does not produce power, which is confirmed by the graph. It is important to note that the production of the system is heavily affected by cloud cover. In figure 4, at the hour of 2PM, the sun was probably clouded and that is why the power for the system dipped during this time. Figure 5 shows the production in kilowatt-hours of the system during the months of 2013. On a cloudy

day, figure 4 would have a peak generation of approximately 1-1.5kWh but maintain the same shape.

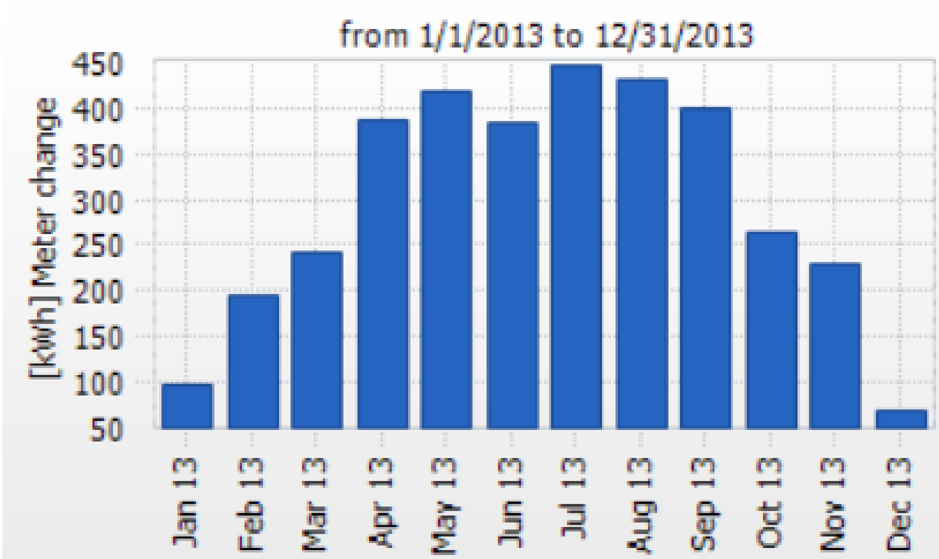

Figure 5: Monthly production of the PV system during 2013.

In examining figure 5 it becomes clear that the PV system performs best during the late spring, summer, and early fall months. In 2013 the months of April through September show significantly higher productions than the other months. It should be noted that June 2013 is lower than one would expect given the trends of the surrounding months. This is most likely due to a cloudy June during 2013. Figure 6 shows the total energy usage of the Wold Center.

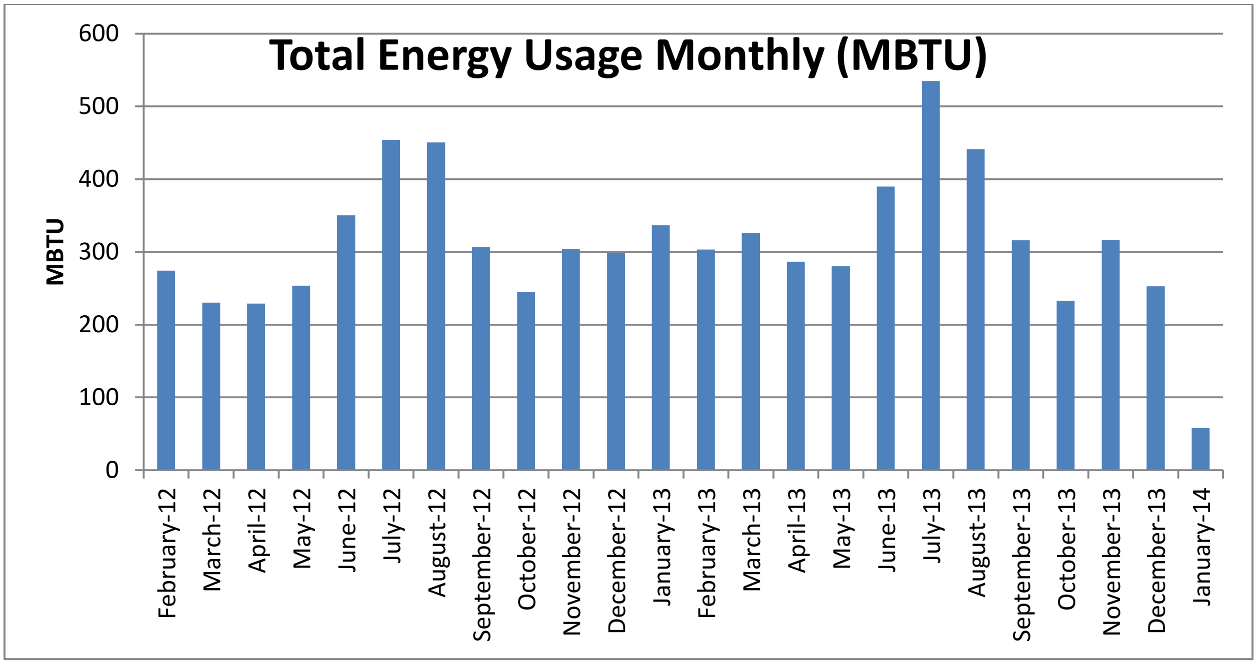

Figure 6: Energy usage of the Wold Center monthly.

Figure 6 shows that the highest energy demand is during the summer months of June, July, and August. January 14 has a low value for the energy usage because the January data did not include the entire month of January during 2014. Figure 7 shows the carbon footprint of the building over the same range of time.

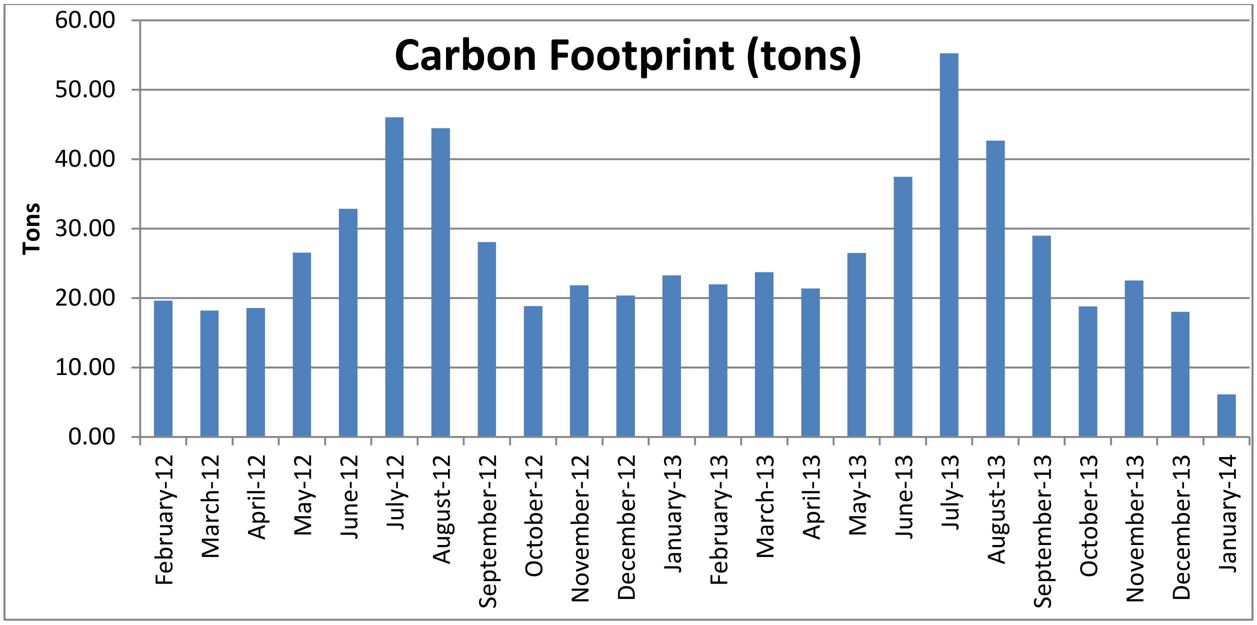

Figure 7: Carbon footprint of the Wold Center shown monthly.

Figure 6 and figure 7 show very similar trends. The highest carbon footprint is during the summer months, which corresponds to the highest energy usage. The months with the smallest energy usage also have the smallest carbon footprint.

In order to determine what percent of the building's energy demand is from renewable sources, it is necessary to know the overall energy demand of the building. The average energy demand of the building is 322MBTU/month. The average production of the PV system is 295kWh/month, which is approximately 1MBTU/month. The PV system accounts for approximately 0.3% of the overall energy demand for the Wold Center. The average commercial building has approximately 0.7% of its overall energy demand supplied from renewable sources. This was calculated based on the average commercial building energy demand and the average commercial building renewable energy consumption values taken from the 2010 Buildings Energy Data Book. This

shows that the Wold Center does not perform as well as non-LEED buildings in the renewable energy category. In this calculation, it was assumed that the only renewable energy is coming from the PV system. I did not take into account the geothermal system that is used to provide heating and cooling because the geothermal system is not only tied to the Wold Center, it is tied to the library as well. The data from the kiosk measures the overall geothermal system, not the geothermal energy only entering the Wold Center. I assumed that the Wold Center received a negligible amount of energy from the geothermal system for this calculation to calculate the worst case scenario.

The Wold Center did not achieve any LEED credits for renewable energy sources. To earn credits for this category, at least 2.5% of the building's energy demand must be provided by renewable sources. In analyzing the renewable energy of the Wold Center and determining it was less than the average commercial building. This verifies the denial of the LEED renewable energy credit. If the Wold Center performs below the average commercial building for renewable energy usage, it should not be earning a LEED credit for renewable energy (and it did not).

So far, in examining the water system and PV system, the LEED credit system has been verified. The water system performed significantly better than similar buildings and it achieved many credits in the water efficiency category. The PV system did not provide a substantial amount of energy for the overall building, and the Wold Center performed worse than similar buildings and did not receive a LEED credit for renewable energy. Now, the overall energy usage of the building will be taken into account.

The energy usage of the Wold Center can be compared to the average energy of a commercial building based on fuel costs. The fuel costs for the Wold Center were calculated given the average electrical costs for Union College and the total energy demand of the building. The energy provided by the solar PV system was subtracted from the total demand of the Wold Center for this calculation, yet the geothermal system was neglected for reasons previously stated. The average cost for electricity for Union College, according to Union College Facilities, is $0.09/kWh in 2014. Multiplying this value by the overall energy demand for a year, the total cost to run the Wold Center is approximately $100,000. According to the 2010 Buildings Energy Data Book, the average utility cost for a commercial building is $2.51/sqft (2010 Buildings). Multiplying this by the square footage and converting $2009 to $2014 assuming an 8% interest rate yields a utility cost of approximately $40,000. According to the data for the average commercial building, the cost to run the Wold Center should be much lower based on the square footage. This indicates that the Wold Center is using more energy than the average commercial building per square foot, or a gross difference in utility cost across geographic regions.

The U.S. Energy Information Administration provides the data shown in Table 2 (U.S. Energy).

Table 2: Average electricity costs by U.S. region.

Region	Commercial Building Energy Cost ($/kWh) December 2013
New England	$ 0.15
Middle Atlantic	$ 0.12
East North Central	$ 0.09
West North Central	$ 0.08
South Atlantic	$ 0.09
Easy South Central	$ 0.10
West South Central	$ 0.08
Mountain	$ 0.09
Pacific Contiguous	$ 0.11
Pacific noncontiguous	$ 0.10
Average	**$ 0.10**

Table 2 shows that New England does pay higher than the average region for electricity costs, yet Union College pays only $0.09/kWh, which is less than the national average for electricity costs. This data shows that the cost to run the Wold Center is higher than the average U.S. commercial building because the Wold Center uses more electricity, not because electrical costs are higher (U.S. Energy).

This can be confirmed by comparing the carbon footprint of the Wold Center with the average carbon footprint for a commercial building. The yearly carbon footprint for the Wold Center, normalized for square footage, is 0.3tons/sqft. Overall carbon dioxide emissions commercial buildings in the U.S. for year 2010 amounted to 1074 million

metric tons. The total square footage of commercial space in 2010 was 78,800 million square feet. Based on these values from the 2010 Buildings Energy Data Book, this shows that average commercial building emits 0.013tons/sqft. The Wold Center is much higher than average, showing that the building uses more energy than the average commercial building.

This section has compared the Wold Center to building averages from the 2010 Buildings Energy Data Book. It is important to discuss the assumptions in this analysis, as they limit the validity of the comparison. The Wold Center was compared to the average U.S. commercial building, although the Wold Center is not a commercial facility. The reason that this was chosen is because it is the most similar to the Wold Center in size and functionality as compared to a residential building, federal building, or medical building. Additionally, this book was issued in 2011. The Wold Center energy usage data was taken in the years 2012-2014. This discrepancy was not necessarily accounted for and may cause slight variations in the calculated values. Lastly, an uncertainty analysis was not performed on this data because neither the Wold Center data nor the data book had any uncertainties listed for the values.

LEED vs. ECCCNYS 2010

The LEED certification and the New York State building code were compared to determine similarities and differences. First, I will describe the ECCCNYS 2010 and then discuss the overlap with the LEED credits. Chapter five is the section of ECCCNYS 2010 that discusses commercial energy efficiency, and will be discussed here.

Chapter five first addresses the insulation values that are necessary for the building. The climate zones are listed for New York State, which consist of climate zone 4, 5, and 6. Specification values for insulation listed for group R and all other buildings. Group R buildings are those that contain sleeping accommodations but not for medical treatment or correctional purposes. Group R includes R-1 buildings and some R-2 buildings. Group R-1 is a residential building that does not host occupants for more than 30 days (i.e. a hotel). Group R-2 includes permanent occupancies with more than two apartments, or units. Minimum thicknesses are provided for the windows and minimum thermal resistances (R values) are given for these components as well.

After the code discusses insulation and fastening requirements for walls, windows, and doors, it addresses the openings for exhaust equipment and specifications for ventilation, and then discusses building mechanical systems. In calculating the heating and cooling loads, the code specifies that a building must follow the procedures describes by the American Society of Heating, Refrigeration, and Air Conditioning Engineers, ASHRAE, and that the ASHRAE HVAC *Systems and Equipment Handbook* must be followed when designing the ventilation systems. Several equations are provided in order to determine a minimum efficiency for the HVAC system of a specific building. Additionally, several different types of air conditioners are addressed, including air cooled, through-the-wall air cooled and water and evoraporatively cooled air conditioners. Specifications are given for various types of heat pumps, warm air furnaces, snow melt systems, boilers (gas and oil fired), condensing units, and water chilling packages. Each of these types of systems have several different kinds classified in each one and ECCCNYS 2010 addresses all possible systems including exceptions. Lastly, the

code discusses pipe insulation values, water heating, electrical power, and lighting systems. The lighting controls are described in detail as well as exceptions to these rules.

The LEED certification credits do address some of the same things that ECCCNYS 2010 addresses. A comparison of the categories addressed can be seen in table 3.

Table 3: Comparing LEED certification with ECCCNYS 2010. Note that '-' indicates that category was not addressed in the document. The abbreviations following the LEED credits indicates which category the credit is listed in.

Category	**LEED**	**ECCCNYS 2010**
Insulation Requirements	Credit 7.1/7.2, E&A	Section 502
Wall Thickness Requirements	-	Section 502
Exhaust Openings	Credit 1/2, IEQ	Section 502
HVAC Equipment Performance Requirements	Credit 1, E&A	Section 503
Thermostat Controls	Credit 6.2/7.1/7.2, IEQ	Section 503
Minimum Efficiencies for Cooling/Heating Systems	Credit 1, E&A	Section 503
Minimum Pipe Insulation	-	Section 503
Fan Power Limitations for HVAC Systems	Credit 1, E&A	Section 503
Water Heating	-	Section 504
Light Reduction Controls, Automatic Light	Credit 6.1, IEQ	Section 505

Shutoff		
Exterior Lighting Controls	Credit 6.1, IEQ	Section 505
Daylight Zone Control	Credit 8.1/8.2, IEQ	Section 505
Lighting Power Allowance for Exterior	Credit 8, SS	Section 506
Calculation Software Tools	-	Section 506
Water Reduction	Credit 1.1/1.2/3.1/3.2, WE	-
Renewable Energy/Green Power	Credit 2/6, E&A	-
Recycling Construction Materials	Credit 1.1/1.2/1.3/2.1/2.2 M&R	-
Regional Materials	Credit 5.1/5.2, M&R	-
Low-Emitting Materials	Credit 4.1/4.2/4.3/4.4, IEQ	-

In examining table 3, it is clear that there is overlap between the LEED certification and the building code in New York State. A major difference between the two is that LEED addresses a lot of categories that are not addressed by the building code, such as the presence of green power, the reduction of wastewater, and an emphasis on green power and renewable energy. These things do not necessarily have direct impact on the functioning of the building, which is why they are not included in the NYS code, but they have value to the USGBC as they reflect a building that does not harm the environment. A major difference between the two is that the LEED credits value protecting the surrounding area of the building much more than the code.

The credits that do overlap between the LEED certification and building code are more specifically addressed in the building code. For instance, the insulation requirements in the building code have pages of specifications, while LEED certification only has two credits that address something similar to this.

It is important to note that LEED certification and the building code serve two different purposes. LEED is meant to be a comprehensive measure of the building and its surroundings, to determine whether or not the building is harming the surroundings more or less than other buildings.. The building code makes sure that all aspects of the building are not going to be extremely detrimental to the environment but focuses *only* on the buildings thermal systems. This is why following the ECCCNYS 2010 is a much more specific; since all buildings must follow this code, it must outline all possible scenarios, exceptions, and systems that a building will have. The LEED certification, governed by the USGBC, is only outlining exemplary performance and it is required that the state building code will already have been met. This is why the credits are less specific and address different things than the building code.

LEED Certification Shortcomings

In my research of the LEED certification criteria, I came across a few issues with some of the credit descriptions. For instance, the green power credit has two criteria that can be used to determine the baseline electricity usage. To achieve this credit, the project team could pick the lower of the two criteria for a baseline energy usage, as the credit description does not say the more stringent of the two has to be used. If I were to change

the credit description I would include that the more stringent of the two suggestions must be used, to make sure that the green power estimate is a conservative estimate rather than a liberal estimate. This wording is used in some of the other credits and I do not know why it is not applied here.

The water usage credit also requires a baseline water usage to be calculated in accordance with the Energy Policy Act of 1992. These calculations are left up to the project team. I see a slight conflict of interest here for the project team. If they are trying to prove that their building saves a certain percentage of water, there is a tendency to overestimate the baseline usage while underestimating the new planned water usage of the building. This is a problem that occurs with a number of the credits. The LEED professionals do review these calculations, but it is still possible for the project team to slightly exaggerate the numbers. The same issue arises for the optimizing energy performance credit. To obtain all ten credits for this, an energy simulation must be performed on the whole building. These energy simulations require lots of assumptions and can be tailored to output a certain percent in energy reduction. This category is worth an extremely high number of credits compared to other categories, which poses a conflict of interest to the project team.

Additionally, there are certain credits that have a distinction between newly developed land and previously developed land. The Wold Center was considered previously developed land, although there was no existing structure on this plot immediately prior to the building of the Wold Center. For instance, the site development credit to protect or restore habitat has two options: one based on previously developed sites and one for virgin sites. In this case, the requirements differ for each. I could not

find a distinct definition of what is considered previously developed by the USGBC in regards to LEED certification. The same point can be made for the definition of new structures. This is a point of dispute and should be better defined by the USGBC.

Another issue that I have with the LEED certification is that almost all credits are based on projected calculations or plans that are in place, not actual data that is acquired from the building. The only exception to this that I found is the credit for measurement and verification of the thermal comfort systems, which requires a survey to be conducted 6-18 months after the building is opened to the building inhabitants. Extensive calculations are required, and in some cases receipts, to prove that the credits were achieved, but these calculations are on a theoretical level. I personally think more weight should be given to *proving* that the building is performing to its standards after construction is complete. Once certification is complete, a structure does not need to be re-certified or verified again.

There are also certain credits that conflict with one another. For instance, the thermal comfort credits for at least 50% of the individuals in the building to have their own temperature controls have a detrimental effect on the credits allocated to optimize energy performance. Additionally, there are credits that are “green” in theory, but in the long run, may not make sense. For instance, the rapidly renewable material credit seems like a good idea because the materials can be replaced relatively quickly. Yet, in the long run, these materials wear much easier and need to be replaced more quickly, which means a higher long term cost and a less “green” building than was initially intended.

One major shortcoming of the LEED certification process is that the credits to achieve certification are consistent across the world. Buildings worldwide are LEED certified in very different climates using the same criteria, but the climate severely affects the performance of the building. For instance, in a drier climate it may be more important to emphasize water conservation. The generic credits associated with LEED do not address the important issue of building climate.

For these reasons, it is important to consider all aspects of a green building, rather than just designing a building to achieve the highest certification. A building should not necessarily be designed to meet these requirements, but to have the least impact on the environment as possible. Unfortunately, due to the nature of these requirements, most buildings that are built to achieve LEED certification are centered entirely on these requirements and do not necessarily take into account factors outside of the credit description. Overall, LEED certification does not predict energy efficiency of the building. Instead, the specific credits address how efficient certain systems must be. A more holistic approach may be beneficial for the USGBC if they are concerned with the energy efficiency of the building.

Obstacles

The first obstacle that I encountered during this project was obtaining the relevant information in regards to the LEED certification credits. General information on the credits is available through the USGBC website, but much of the specific information in regards to the credits is proprietary. This information is not readily available to the

public. It is usually only accessible by the parties interested in achieving LEED certification.

To mitigate this issue, I was put into contact with EYP, the architecture and engineering firm for the Wold Center. I asked if they could provide additional information in regards to the Wold Center and the credits that were received. They did provide some information but were unable to provide the specifics for the credits obtained. For instance, many credits that are being pursued need to have lengthy calculations and/or studies to show that the building will achieve the credit requirements. These studies were carried out by the construction company and/or EYP. These calculation spreadsheets were not available to me. In some cases, for instance in the energy efficiency of the building (worth up to 10 credits), this lacking data made it nearly impossible to determine the feasibility of Platinum certification with the Wold Center. If I did not know the base calculation, I could not perform additional analysis. Because of this, I could not complete my analysis on Platinum certification exactly how I had planned.

In order to determine the feasibility of Platinum certification, I examined each credit for its applicability and feasibility of implementation in regards to the Wold Center. Based on these criteria, I determined that Platinum certification was not a feasible option for the Wold Center.

In planning for the second term of my project, I asked EYP if I could have access to the energy simulations they ran to predict the energy loads of the building. There were two issues with this: first, the energy simulations are proprietary. Second, these

simulations are not meant to predict the actual loads of the building, but rather serve a relative purpose to compare features between simulations. In other words, these simulations are not meant to predict actual loads but serve the purpose of comparing how adding different features to the building will affect the energy loads of the building. For these reasons, it was not possible for me to obtain the data, nor to use it as a basis for comparison.

After the first term of my project, I began to look into the data on the energy loads of the Wold Center. I hoped to start gathering data on the performance of the Wold Center fall term so I could gather over 2-3 seasons, as opposed to one season in the winter. In my investigation, I discovered that the Wold kiosk had several errors in logging data. The kiosk is the touch screen located on the first floor of the Wold Center near the display cases. It is there to inform visitors about the Wold Center, and it includes data on the energy usage of the building. The screens that show the energy usage include the main energy display, air handling units, chilled water usage, domestic water usage, electricity usage, geothermal, lighting, natural gas, solar PV, solar thermal, steam heating, and water heaters 1 and 2. Many of the screens just listed were not logging data. This means that there was an issue with the sensor gathering the data or with the software designed to log the data and transfer the data to the kiosk display. A lot of this data was not logging correctly and it was determined this was a software issue rather than a hardware issue.

For the second term of my project, I used data from the kiosk to compare the energy loads of the building to current energy standards or simulations. This meant that the kiosk needed to be working before I could start the second term of my project.

Technical Building Services, TBS, is the company that set up the kiosk software and is able to make changes to it. I had approximately 10 meetings throughout the fall term to arrange for these changes to be made. I applied for and received a Green Grant through Union College in order to pay for some of the changes. I have been working with Meghan Haley-Quigley as the sustainable coordinator in facilities, and Professor Doug Klein of the environmental science and policy department, as well as the TBS contact to fix the software.

To start the kiosk renovation, I met with Professor Klein and Meghan to go over what was wrong with the kiosk. We went through the screens and classified the changes as phase I or phase II. The phase I changes were critical to the functionality of the kiosk, as necessary for my project. These changes included fixing the output spreadsheets from the kiosk (making sure they weren't registering 0 for all time) in all of the necessary categories. This not only helps me, as I now have access to the raw data files, but it helps the campus by improving the functionality of the kiosk. Before I began my project, many of the energy usage screens on the kiosk were not populating correctly. At the end of this project, these screen issues will be fixed.

The phase II changes are not directly related to my project but were determined by myself and Professor Klein to be necessary to full understanding of the kiosk. Phase II changes include changes that will improve the educational value of the kiosk, as opposed to the direct functioning. These changes will include (but are not limited to) definitions and diagrams on various screens to make them clearer to the user, as well as informative blurbs about various types of energy used (for instance, what is geothermal energy?)

These phase II changes will improve the educational value of the kiosk for the campus, although they are not necessarily a direct deliverable of my project.

At the end of the fall term, the software updates were in the phase I stage. TBS had been on campus for a few days to make updates to the kiosk. The phase II changes had not yet begun to occur, as some problems arose. TBS is the company that installs the software and makes changes to fit the needs of the customer, Union College in this case. The software is produced by a company called ICONIX. According to TBS, there are some road blocks occurring in changing the interface of the ICONIX software to improve the functionality of the system. These changes are not necessarily something they will be able to do on their own.

During the second term of my project, more issues were uncovered with the kiosk software. The TBS services technician had difficulty contacting representatives from ICONIX to determine the best way to fix the kiosk. Because this system was built specifically for the Wold Center and is not in use anywhere else, there is no easy solution to fix the problems occurring. There is a delay in fixing the kiosk because Union College is not working directly with the party that has built the base software. At this point, Union College has asked TBS for a recommendation on whether the software can be fixed in the desired ways within a reasonable budget. If not, the system will need to be replaced. I will continue to work on finding the solution to the software issue during the spring term.

I was only able to use minimal data from the kiosk during the second term of my project, as a lot of the data was missing in places. If data does not span a significant amount of time and a number of seasons, it is not representative of the full function of the

building system. For this reason, I was only able to use data to draw conclusions from a few of the building systems in the Wold Center. I used this data to compare to data from the 2010 Buildings Energy Data Book. In my analysis I made several assumptions about the Wold Center, for instance that the Wold Center was more similar to an office building than a K-12 schooling building. Making these assumptions posed an obstacle because sometimes it was difficult to determine which assumption is the best one to make. The validity of my assumptions directly affects the quality of my analysis. The assumptions made in the data comparisons are outlined in the data analysis & comparison section.

Accomplishments & Future Research

During the fall term I completed background research on the USGBC and LEED certification. I determined the credits the Wold Center achieved to receive LEED Gold certification. Additionally, I investigated the remaining unearned credits and determined that it was not feasible to have pursued and/or achieved Platinum certification.

During the winter term, I used the kiosk data available to compare the systems of the Wold Center to similar buildings. I also compared the LEED certification criteria to the ECCCNYS 2010. Combining the information obtained from each of these analyses, I have concluded that LEED certification does not necessarily reflect a more energy efficient building when compared to a non-LEED building. The exception to this is that if a specific system is addressed by a LEED credit, for instance the "water reduction" credit, whether or not the credit was achieved will accurately predict whether that system will perform better than non-LEED certified buildings. Major weaknesses of the LEED

certification include the same rating system for different climates and the heavy emphasis on the surroundings of the building.

During the spring term, I will continue to address the phase II changes to the kiosk. Union College should receive a recommendation from TBS in the near future regarding the kiosk system. If the system is kept in place, I will work on making the changes to the system before June 2014, as well as put together a document explaining how the kiosk works. If the system is going to be replaced, my green grant funding will go towards purchasing and setting up another system.

Future research in this subject could include comparing the performance of LEED certified buildings in different climates and determine if there are substantial differences. Additionally, it would be helpful to know the number of LEED certified buildings by state and worldwide to determine if climate would play a factor in achieving LEED certification. In continuing research, additional building systems and utilities should be compared to data from the most recent Buildings Energy Data Book to determine if there are further discrepancies.

Acknowledgements

I would first like to acknowledge my adviser, Professor Cortez, for her help and guidance throughout both terms of my project. I would also like to acknowledge Professor Klein and Meghan Hailey-Quigley for their help on my green grant proposal and kiosk changes.

Damian Brewka and Sarah Stein from the engineering & architecture firm for the Wold Center, EYP, also provided valuable information on the LEED certification of the Wold Center, which helped in my analysis.

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Appendix 1: Outline of important meeting dates

9/26/13: Meeting with Steve Hassett from facilities to discuss extraction of the kiosk data.

9/29/13: Meeting with EYP representative Damian Brewka, one of the mechanical engineers for the project. We discussed resources available for the project and issues of proprietary information. Damian gave me Sara Stein as the LEED contact for the project.

9/31/13: Meeting with Professor Klein to discuss the desired changes to the kiosk.

10/3/13: Meeting with Meghan Haley-Quigley, Professor Klein, TBS Representative to discuss the desired kiosk changes. We were told that their rate to fix the program is $1,200/day.

10/4/13: Meeting at EYP with Damian Brewka to discuss proprietary issues more thoroughly. As opposed to corresponding over the phone or via email, I drove to EYP to meet him personally.

10/7/13: Meeting with Sara Stein from EYP to discuss LEED credits achieved by the Wold Center.

10/8/13: Meeting with Professor Klein to discuss the Green Grant application.

10/10/13: Meeting with Professor Klein to record the changes to be made to the kiosk. I then organized the changes into the phase I and phase II changes and presented this document to the TBS representative.

10/23/13: Meeting with TBS representative, Professor Klein, and Meghan to go over phase I changes. TBS representative has been working on the issue for a few days and gave us an indication of what was feasible and what was not.

1/12/14: Meeting with Meghan to get a status update on the changes that occurred over break with the kiosk.

2/7/14: Meeting with Meghan to obtain sensor information on the kiosk.

2/20/14: Meeting with Professor Klein to share sensor information

3/5/14: Presentation to senior environmental science & policy majors on my senior project.

Appendix 2: System-10-BAC Btu Meter Specification Sheet from Union College Facilities

• SYSTEM-10-BAC BTU METER •
BACnet MS/TP COMPATIBLE

ONICON INCORPORATED

DESCRIPTION

The System-10 BTU Meter provides highly accurate thermal energy measurement in chilled water, hot water and condenser water systems based on signal inputs from two matched temperature sensors (included) and any of ONICON's insertion or inline flow meters (ordered separately). The System-10-BAC-MS/TP provides energy flow and temperature data on a local alphanumeric display and to the network via the BACnet communications MS/TP driver. An optional auxiliary input is also available to totalize pulses from another device and communicates the total directly to the BACnet MS/TP network.

FEATURES

BACnet Compatible Serial Communications - Provides complete energy, flow and temperature data to the control system through a single BACnet MS/TP network connection, reducing installation costs.

Simple Installation and Commissioning - Factory programmed and ready for use upon delivery. All process data and programming functions are accessible via front panel display and keypad.

Single Source Responsibility - One manufacturer is responsible for every aspect of the energy measurement process ensuring component compatibility and overall system accuracy.

N.I.S.T. Traceable Calibration with Certification - Each Btu measurement system is individually calibrated using application specific flow and temperature data and is provided with calibration certifications.

Precision Solid State Temperature Sensors - Custom calibrated and matched to an accuracy better than ±0.15° F over calibrated range.

Highly Accurate Flow Meters – ONICON offers a wide variety of insertion and inline type flow measurement technologies including turbine, electromagnetic and vortex sensing. Each type offers unique advantages depending on the application. All ONICON flow meters are individually wet calibrated and designed to operate over a wide flow velocity range with accuracies ranging from ±0.2% to ±2.0% of rate depending on the model.

Complete Installation Package - All mechanical installation hardware, color coded interconnecting cabling and installation instructions are provided to ensure error-free installation and accurate system performance.

APPLICATIONS

Chilled water, hot water and condenser water systems for:

- Commercial office tenant billing
- Central plant monitoring
- University campus monitoring
- Institutional energy cost allocation
- Performance/efficiency evaluations
- Performance contracting energy monitoring

ORDERING INFORMATION

The System-10 BTU Meter is sold complete with temperature sensors and standard thermowells. Flow meters are purchased separately.

ITEM #	DESCRIPTION
SYSTEM-10-BAC MS/TP	System-10 BTU Meter BACnet MS/TP compatible
SYSTEM-10-OPT1	Add for 6" and larger pipes
SYSTEM-10-OPT2	Add for 2.5" - 3" copper tube
SYSTEM-10-OPT3	Add for 4" copper tube
SYSTEM-10-OPT4	Upgrade to outdoor thermowells (pair)
SYSTEM-10-OPT5	Upgrade to hot tap thermowells (pair)
SYSTEM-10-OPT8	High temperature sensors (over 200°F)
SYSTEM-10-OPT9	Add one analog output
SYSTEM-10-OPT10	Add four analog outputs
SYSTEM-10-OPT11	Auxiliary pulse input
Choose from the following flow meters:	
F-1100/F-1200	Insertion Turbine Flow Meter (1 1/4" - 72")
F-1300	Inline Turbine Flow Meter (3/4" - 1")
F-2000 Series	Full Bore Vortex Flow Meter
F-3000 Series	Full Bore Electromagnetic Flow Meter
F-3500	Insertion Electromagnetic Flow Meter (3"- 72")
Refer to catalog for flow meter installation kits. Consult with ONICON for additional flow meter types.	

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PROCESS CONTROL EQUIPMENT
3GF5

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06-10

SYSTEM-10 BTU METER SPECIFICATIONS

CALIBRATION
Flow meters and temperature sensors are individually calibrated followed by a complete system calibration.
Field commissioning is also available.

ACCURACY
Differential temperature accuracy ±0.15° F over calibrated range
Computing nonlinearity within ±0.05%

PROGRAMMING
Factory programmed for specific application
Field programmable via front panel interface

MEMORY
Non-volatile EEPROM memory retains all program parameters and totalized values in the event of power loss.

DISPLAY
Alphanumeric LCD displays total energy, total flow, energy rate, flow rate, supply temperature and return temperature.
Alpha: 16 character, 0.2" high; Numeric: 6 digit, 0.4" high

OUTPUT SIGNALS
BACnet MS/TP Points List

Name	BACnet Object Type	Units
Total Energy	Analog Value	Btu, kW-hrs or ton-hrs
Energy Rate	Analog Input	Btu/hr, kW or tons
Total Flow	Analog Value	gallons, liters or meters³
Flow Rate	Analog Input	gpm, gph, mgd, l/s, l/m, l/hr or m³/hr
Supply Temperature	Analog Input	°F or °C
Return Temperature	Analog Input	°F or °C
Delta-T	Analog Input	°F or °C
Energy Total Reset	Binary Value	Not applicable
Flow Total Reset	Binary Value	Not applicable
Auxiliary Input Total	Analog Value	Pulse Accumulator
Auxiliary Input Reset	Binary Value	Not Applicable

Baud Rate: 76,800, 38,400, 19,200 or 9,600 bps
Optional Interval Data Logging:
This option provides up to 24 hours of rate and total data logging in 15 minute intervals. Data includes date/time stamp, measured value & scaling factors when appropriate.
Isolated solid state dry contact for energy total:
Contact rating: 100 mA, 50 V
Contact duration: 0.5, 1, 2, or 6 sec

ONICON INCORPORATED

Optional Analog Output(s): 4-20 mA, 0-10 V or 0-5 V
One or four analog output(s) available for flow rate, energy rate, supply/return temps, or delta-T.

LIQUID FLOW SIGNAL INPUT
0-15 V pulse output from any ONICON flow meter

TEMPERATURE SENSORS
Solid state sensors are custom calibrated using N.I.S.T. traceable temperature standards.
Current based signal (mA) is unaffected by wire length.

TEMPERATURE RANGE

Liquid temperature range:	32° F to 200° F
Optional liquid temperature range:	122° F to 302° F
Ambient temperature range:	-20° F to 140° F

MECHANICAL

Electronics Enclosure:
Standard: Steel NEMA 13, wall mount, 8"x10"x4"
Optional: NEMA 4 (Not UL listed)
Approximate weight: 12 lbs

Temperature Thermowells:
Standard: 1/2" NPT brass thermowells (length varies with pipe size) with junction box
Note: 6" pipes and larger require SS thermowell option.
Optional:
- 1/2" NPT stainless steel thermowells
- Outdoor junction box with thermal insulation
- Hot tap thermowells with isolation valves are available in plated brass or stainless steel.

ELECTRICAL

Input Power*:
Standard: 24 VAC, 50/60 Hz, 500 mA
Optional: 120 VAC, 50/60 Hz, 200 mA
230 VAC, 50 Hz, 150 mA
*Based on Btu meters configured for network connection without the optional analog outputs

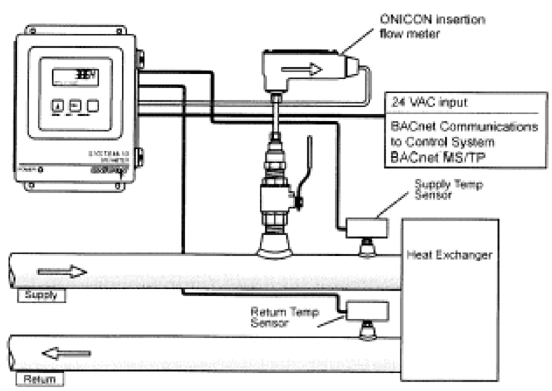
Internal Supply:
Provides 24 VDC at 200 mA to electronics and flow meter

Wiring:
Temperature signals: Use 18-22 ga twisted shielded pair.
Flow signals: Use 18 - 22 ga - see flow meter specification sheet for number of conductors.

Note: Specifications are subject to change without notice.

TYPICAL SYSTEM-10-BAC-MS/TP INSTALLATION

Insertion turbine flow meter shown. Any ONICON flow meter may be used with the System-10 BTU Meter. Consult with ONICON for additional flow meter types.



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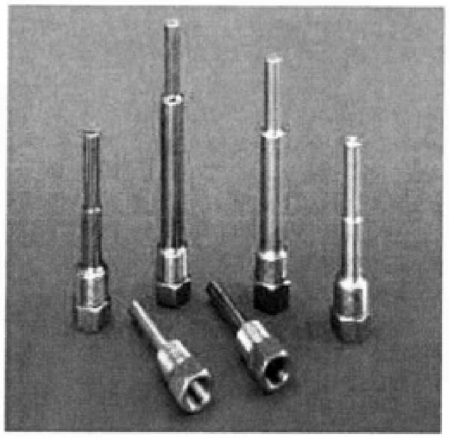
Appendix 3: Thermowell Model A-500 Specification Sheet from Union College Facilities

Thermowell
Model A-500



- **4", 6", 8" and 12" lengths**
- **Brass or stainless steel material**
- **Machined from a single piece**
- **Withstands up to 3000 psig pressure**
- **3/4" external with 1/2" internal or 1/2" external with 1/4" internal thread options**
- **A-505 Thermal Compound eliminates condensation**
- **Excellent thermal conductive synthetic paste**
- **No particle migration or fluid separation**
- **High working temperature with no evaporation or hardening**

The A-500 Thermowell is machined from a single piece of brass or stainless steel to provide a rugged and leak proof well for MAMAC temperature sensors. Each A-500 Thermowell is precisely machined to 0.255" bore to provide a tight fit for our standard 1/4" O.D. probe. This feature also significantly enhances the thermal transfer from the media to the temperature sensor.

The external and internal threads are machined to meet published specifications exactly, and each well is individually inspected to insure thread integrity. Hexagon wrench flats are provided to assist in installing the well in the pipe. Other thermowells that incorporate dissimilar metals like brass and copper which are welded/soldered together are susceptible to leaks caused by thermal shock. In HVAC applications, the temperature of the media may change rapidly and due to different coefficient of thermal expansion, a welded/soldered thermowell may leak. The A-500 Thermowell has a single piece construction and, as a result, is immune to leaks which may be caused by thermal shock or weak welds.

The MAMAC A-500 Thermowell is available in 4", 6", 8" and 12" lengths to handle pipe diameters from 4" to 24". The Thermowell has an industry standard 3/4" NPT external with a 1/2" NPT internal thread or a 1/2" NPT external with a 1/4" NPT internal thread.

With more than four length options, brass and stainless steel material choices, two external thread and two internal thread options, solid leak proof one piece construction, and precision machining enable the A-500 Thermowell to reliably accommodate all HVAC immersion temperature sensing applications.

In order to improve thermal transfer and to eliminate condensation forming within the Thermowell, MAMAC Systems offers a high grade Thermal Compound for the A-500 series Thermowell. The A-505 Thermal Compound is a synthetic, ester based white homogeneous paste, filled with heat conductive metal oxides, providing efficient thermal conductivity with negligible bleed and evaporation loss even at high working temperatures. A-505 exhibits no particle migration, fluid separation or hardening. Unlike silver oxide thermal compounds which may react with the temperature sensor probe in the presence of contaminants, the A-505 is totally inert and does not exhibit catalytic behavior between the probe material and the Thermowell.

The A-505 Thermal Compound has a specific gravity of 2.9 at 77°F, service temperature of - 40°F to 392°F, and thermal conductivity exceeds 19.0×10^{-4} (calories/ cm^2/° C/sec/cm). The A-505 Thermal Compound is available in conveniently packaged 1 oz. syringes. We highly recommend using the Thermal Compound with the A-500 Thermowell to insure that there is no condensation within the Thermowell and to improve the heat transfer from the media to the temperature sensor.

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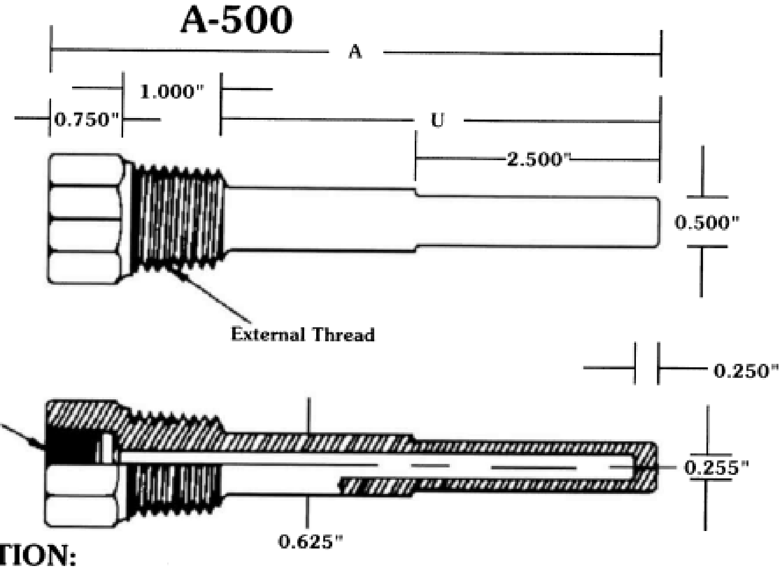
A-500

	A	U
A-500-1 (4")	4 1/4"	2 1/2"
A-500-2 (6")	6 1/4"	4 1/2"
A-500-3 (8")	8 1/4"	6 1/2"
A-500-4 (12")	12 1/4"	8 1/2"



ORDERING INFORMATION:
THERMOWELL:

A-500 — LENGTH — THREAD SIZE — MATERIAL

LENGTH	THREAD SIZE	MATERIAL
1) 4"	A) 3/4" NPT External	1) Brass
2) 6"	1/2" NPT Internal	2) Stainless Steel
3) 8"	B) 1/2" NPT External	
4) 12"	1/4" NPT Internal	

THERMAL COMPOUND:

A-505 (1 oz./28gm. Syringe)

The MAMAC Systems warranty covers parts and labor for 2 years from date of shipment. MAMAC Systems reserves the right to change any specifications without notice to improve performance, reliability, or function of our products.

A Complete Line of Control Peripherals From a Single Source

MAMAC Systems is the only manufacturer offering more than fifty products to satisfy all temp, humidity, pressure, flow, light, speed or any other DDC controls application. MAMAC's complete line of control peripherals is available in over two thousand different configurations of supply voltage, output, range and enclosure type to make our products guaranteed compatible to all HVAC controls, industrial automation and COGEN systems worldwide.

Single source accountability, liberal 2 year warranty, worldwide service and technical support, competitive pricing, accumulated experience or more than 10,000 installations are some of the benefits offered by MAMAC Systems

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Appendix 4: Summary of LEED Credits achieved by the Wold Center

Category	Credit Description	Credit # Possible	Pursued by Wold Center	Achieved by Wold Center
Sustainable Sites	Construction Activity Pollution Prevention	Prerequisite	-	-
Sustainable Sites	Site Selection	1	Yes	Yes
Sustainable Sites	Development Density and Community Connectivity	1	Yes	Yes
Sustainable Sites	Brownfield Redevelopment	1	No	-
Sustainable Sites	Alternative Transportation" Public Transportation Access	1	Yes	Yes
Sustainable Sites	Alternative Transportation: Bicycle Storage and Changing Rooms	1	Yes	Yes
Sustainable Sites	Alternative Transportation: Low-Emitting and Fuel Efficient Vehicles	1	Yes	Yes
Sustainable Sites	Alternative Transportation: Parking Capacity	1	Yes	Yes
Sustainable Sites	Site Development: Protect or Restore Habitat	1	Yes	No
Sustainable Sites	Site Development: Maximize Open Space	1	Yes	Yes
Sustainable Sites	Stormwater Management: Quantity Control	1	No	-
Sustainable Sites	Stormwater Management: Quality Control	1	No	-
Sustainable Sites	Heat Island Effect: Non-Roof	1	Yes	Yes
Sustainable Sites	Heat Island Effect: Roof	1	No	-
Sustainable Sites	Light Pollution Reduction	1	Yes	No
Water Efficiency	Water Efficient Landscaping	2	Yes	Yes
Water Efficiency	Innovative Wastewater Technologies	1	Yes	No
Water Efficiency	Water Use Reduction	2	Yes	Yes

Energy & Atmosphere	Fundamental Commissioning of the Building Energy Systems	Prerequisite	-	-
Energy & Atmosphere	Minimum Energy Performance	1	No	-
Energy & Atmosphere	Fundamental Refrigerant Management	1	No	-
Energy & Atmosphere	Optimize Energy Performance	10	Yes	5 of 10
Energy & Atmosphere	On-Site Renewable Energy	3	No	-
Energy & Atmosphere	Enhanced Commissioning	1	Yes	Yes
Energy & Atmosphere	Enhanced Refrigerant Management	1	Yes	Yes
Energy & Atmosphere	Measurement and Verification	1	Yes	Yes
Energy & Atmosphere	Green Power	1	Yes	Yes
Materials & Resources	Storage and Collection of Recyclables	Prerequisite	-	No
Materials & Resources	Building Reuse	1	No	No
Materials & Resources	Building Reuse, Non-Structural	1	No	No
Materials & Resources	Construction Waste Management	2	Yes	Yes
Materials & Resources	Recycled Content	2	Yes	Yes
Materials & Resources	Regional Materials	2	Yes	Yes
Materials & Resources	Rapidly Renewable Materials	1	No	-

Materials & Resources	Certified Wood	1	Yes	Yes
Indoor Environmental Quality	Minimum IAQ Performance	Prerequisite	-	-
Indoor Environmental Quality	Environmental Tobacco Smoke (ETS) Control	Prerequisite	-	-
Indoor Environmental Quality	Outdoor Air Delivery Monitoring	1	No	-
Indoor Environmental Quality	Increased Ventilation	1	No	-
Indoor Environmental Quality	Construction IAW Management Plan: During Construction	1	Yes	Yes
Indoor Environmental Quality	Construction IAW Management Plan: Before Occupancy	1	Yes	Yes
Indoor Environmental Quality	Low-Emitting Materials: Adhesives and Sealants	1	Yes	Yes
Indoor Environmental Quality	Low-Emitting Materials: Paints and Coatings	1	Yes	Yes
Indoor Environmental Quality	Low-Emitting Materials: Carpet Systems	1	Yes	Yes
Indoor Environmental Quality	Low-Emitting Materials: Composite Wood and Agrifiber	1	Yes	Yes
Indoor Environmental Quality	Indoor Chemical and Pollutant Source Control	1	Yes	Yes
Indoor Environmental Quality	Controllability of Systems: Lighting	1	Yes	Yes
Indoor Environmental Quality	Controllability of Systems: Thermal Comfort	1	Yes	Yes

Indoor Environmental Quality	Thermal Comfort: Design	1	No	-
Indoor Environmental Quality	Thermal Comfort: Verification	1	No	-
Indoor Environmental Quality	Daylight and Views: Daylight 75% of Spaces	1	No	-
Indoor Environmental Quality	Daylight and Views: Views for 90% of Spaces	1	No	-
Innovation and Design Process	Innovation in Design	4	Yes	Yes
Innovation and Design Process	LEED Accredited Professional	1	Yes	Yes