ILLINOIS INSTITUTE OF TECHNOLOGY

2014 NATIONAL COMPETITION

NECA GREEN ENERGY CHALLENGE
MCCORMICK TRIBUNE CAMPUS CENTER
NECA IIT STUDENT CHAPTER REPORT

TEAM: SPRING 2014

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A brief video outlining our project can be found at http://tinyurl.com/m4w8aj3

B.1 PROJECT SUMMARY

B.1.1 Executive Summary

The *McCormick Tribune Campus Center* (MTCC) was constructed in 2003 in order to accommodate student activities for the Illinois Institute of Technology and Shimmer College. The building was designed by the famous Dutch architect Rem Koolhaas, who was chosen through a competition held in 1997-98. The building carries important architectural significance due to its relationship with Mies Van Der Rohe's vision, as it is the first planned addition to Mies' grand design of the campus. The Campus Center itself directly connects to one of Mies' buildings called The Commons. The main entrance also plays an homage to the founders of Illinois Institute of Technology, better known as the Founder's Wall shown in Figure B.1.1.

Figure B.1.1. Founder's Wall

Mission Statement

The Illinois Institute of Technology NECA student chapter selected the MTCC for the 2014 Green Energy Challenge. During the first phase of the project, an analysis of the existing conditions of the building was conducted by means of an energy audit. With the help of industry professionals and local electrical contractors, solutions for a retrofit were made to improve the building performance. A **total of $739,019 potential savings over a five-year period, with an initial investment of $405,662** was the result the retrofit solutions.

The building is inefficient and the opportunity to create energy savings was realized through improved lighting, metering, and alternate energy.

The building lighting system is uncontrolled so the lights operate almost on a 24-hour basis. The additions of occupancy and daylight sensors will eliminate this. The comprehensive lamp replacement will significantly reduce energy use. The **investment total is $63,638. The total five-year savings is $397,080, and the payback is 0.8 years.**

There is a real opportunity to install solar power. The southeast corner of the building has a 68,310 square foot roof area to construct a 60 kW photo-voltaic system. After grants and incentives, **the investment total is $147,750. Energy production per year will result in a total five-year savings of $84,375 and a payback of 8.7 years.**

Sub-metering and monitoring identifies areas of the building where energy consumption is high. Currently, the MTCC's energy use is monitored on a building level through the *smart-grid*. This level of monitoring can be improved to a level where the power consumption of each electrical distribution is looked into. The plan will implement a system that monitors each distribution and automates energy consumption. After initial installation **the investment total is $194,189 with a five-year savings of $235,000, and a payback of 4.1 years.**

B.1.2 Client Summary

Figure B.1.2. Armour Institute of Technology (1914)

Founded in 1890 as a polytechnic institute that would serve the local economy and help students in the Chicago area, Illinois Institute of Technology has grown dramatically into an institution with four campuses in the Chicago area and an international student population of over 6000.

At the time of building construction IIT and its affiliates had a an annual research volume of $140 million in areas that included fluid dynamics, aerospace, synchrotron radiation, environmental engineering and environmental law, polymer science and recycling, fuel cell and battery research, food safety and technology, and transportation and infrastructure.

Between 1938 and 1958 IIT's *College of Architecture, Planning, and Design* was headed by Mies van der Rohe. During these years, the school served as the center for development of the technologically inspired modernism that became identified with Chicago during the post war recovery. While serving as the head of the school, Mies was also commissioned to prepare a master plan for th 120-acre main campus and to design a number of buildings, culminating in the S.R. Crown Hall, the home of the College of Architecture. This group of buildings is now recognized as the largest complex of Mies-designed buildings in the world. An international campaign is actively working to restore the core Mies complex of academic buildings and celebrate the architectural importance of the Mies campus.

Maram Kittaneh is the Resource Efficiency Manager/Energy Efficiency from the Office of Campus Energy and Sustainability and is our direct client for the project. Maram and her staff work with the companies that supply automation and solutions to the university's energy opportunities. She is also the point person with all utility companies that supply the buildings on campus and reports directly to the Vice President of Sustainability.

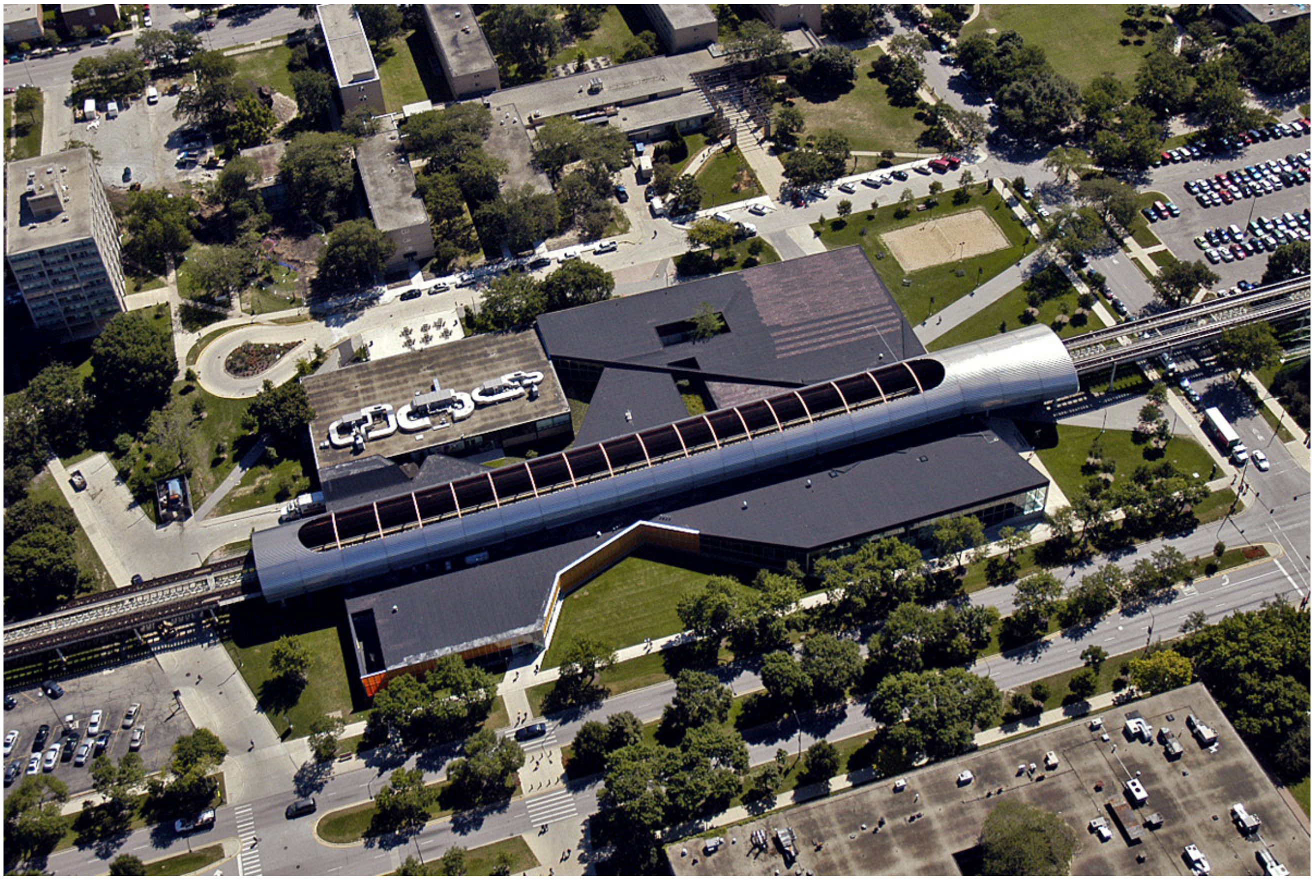


Figure B.1.2. Ariel View of MTCC

Role of the Facility

The building program seeks to balance the student needs with those of the surrounding community, as well as to generate enough traffic in the building to make retail enterprises economically viable.
Geographically McCormick Campus Tribune Center's main purpose is to unite the east and west sides of the campus, as they are separated by the Elevated train tracks and State Street. The Campus Center's main purpose is to provide students and visitors with experiences that extend outside of the classroom.
During the original building design Members of the Campus Center Planning Committee assisted Holabird and Root in facilitating group sessions. These meetings lead to the decision to emphasize relaxation and recreation over formal activities. The original programming study requested for 186,000 square free of space to include all of the desired building program. This had to be condensed down to 100,000 square feet due to estimated costs.

Given space constraints, the building committee decided that the Campus Center should not become an administrative building that essentially shut down during normal business hours. Administrative areas were significantly reduce to make room for other areas such as retail, food, programming, student organization, or recreational space. Cuts in these areas seemed to contradict the stated desire to have a facility that "lived" throughout the day.

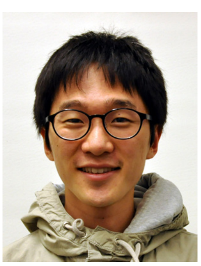
The building process defined by these constraints creates open circulation for both air and people that result in significant energy losses. We seek to optimize the efficiency of the building in terms of energy losses without compromising circulation and community value.

B.1.3 Team Resumes

Ivan Jose - Project Leader
Major: Architectural Engineering
Year: 4th
Interests: Building Performance, Energy Modeling, BIM
Experience: IPRO338 Fall 2013, IIT DOE Student Home Design Competition, KAIST Solar Decathlon Team 2010

June Young Park - Audit Team Leader
Major: Architectural Engineering
Year: 4th
Interests: Building Energy Modeling, Building Enclosure Design, Building Information Modeling
Experience: UNIFIL Construction Manager, IIT DOE Student Home Design Competition

Sima Mustaklem- Lighting Team Leader
Major: Architectural Engineering
Year: 4th
Interests: Sustainability and Building design , Building Information Modeling , Structures, and hanging out with freinds.
Experience: IPRO338 Spring 2014, IPRO328 Spring 2014, Welfare Association (Civil engineering Department).



Jungsik Kim - Audit Team
Major: Architecture
Year: 4th
Interests: Building Sustainability, Architectural Design Theory
Experience: IIT DOE Student Home Design Competition, Q.C manager for ROKAF(Republic of Korea Air Force)

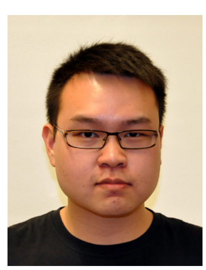
Charles Rivas - Schedule and Estimating Leader
major: Business/Psychology
Year: 5th
Interests: Efficiency, Sustainability, Teamwork, and Management
Experience: IPRO 338 Spring 2014

Fredrick Herringer - Project Leader
Major: Industrial Technology/Operations
Year: 4th
Interests: My faith and family, sustainability, construction project management, golf
Experience: IBEW Local 134 apprenticeship. 14 years of experience in commercial, residential, and industrial electrical construction. IIT-NECA student chapter officer.

David Edgren - Submetering Team Leader
Major: Civil Engineering
Year: 4th
Interests: Water and Wastewater Treatment, Hiking
Experience: Lab Manager for Water and Sewage Transformation Endeavor at Wheaton College, Summer Internship with HCJB Global in Rural Water Development

Joaquin Vera - Project Leader
Major: Industrial Technology/Operations
Year: 4th
Interests: Energy Management in High Rise Buildings, LEED Certified Retrofits, TED Talks,"Reinventing Fire" by Amory Lovins, Rocky Mountain Institute
Experience: IPRO338 Fall 2013, IBEW Local 701 Low Voltage Systems Technician, Communications Supply Corporation, UPS

Abhiroop Chattopadhyay - Sub-metering
Major - Electrical Engineering
Year: 4th
Interests : Electric Machine Design, Energy Conversion, Renewable Energy, Biking
Experience: IPRO 338 Fall 2013, Research Intern at Karlsruhe Institute of Technology



Name: Yoon Chye Lee- Solar Team Leader
Major: B. S. Chemical Engineering
Year: 3rd
Interests: Renewable energy and sustainability
Experience: IPRO 338 Spring 2014

B.2 TECHNICAL ANALYSIS 1: Energy Audit/Benchmark

Overview: Perform an energy system assessment of the MTCC for lighting, cooling, and ventilation operations, and compare the results with a similar building.

Results:
1. MTCC is not a high energy efficient building. Additional insulation is recommended to improve the performance.
2. MTCC is in need of a more efficient lighting control system.
3. MTCC requires submetering systems to monitor energy use and limit the consumption of low priority systems.
4. Alternative energy sources such as solar panels can help improve efficiency.

B.2.1 Assessment of the Energy System

Lighting

According to the MTCC light fixture plan, **thirty-five different types of fixtures were found**. High consuming fixtures were identified and analyzed for possible retrofit solutions.

A majority of the lights are on 24 hours every day. Table B.2.1 shows existing fixtures with their monthly energy consumption.

To research the lighting performance of the MTCC, various Illuminance levels were measured at different locations. The levels were recorded both vertically and horizontally with a foot-candle.

According to measurements, the overall lighting performance in the MTCC meets the minimum functional requirement. However, several areas, such as the computer station, the cafeteria, and the bathroom were lacking proper illumination for their task. Because of the poor feedback from students in these specific areas, lighting systems with higher illuminance levels are highly suggested. Other areas, such as the Commons, were using excessive lighting energy since **all the lamps were turned on regardless of sufficient daylight coming into the space.** [Table B.2.2]

Fixture	#	Watt	kWh/mon	%
Auditorium	173	**43250**	2595	6.19
Hallways	311	13995	13219.2	**31.53**
Fixture 1	56	5264	3790.1	9.04
Fixture 2	71	5325	3834	9.14

Table B.2.1. Major Contributing Lighting Fixtures

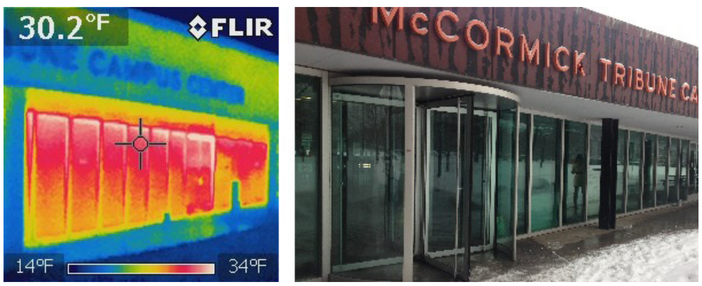
Location	Illuminance level	
	Vertical	Horizontal
Entrance	**20**	**35**
Coffee Shop	27	11
Cafeteria	**7**	**3**
Ping-Pong Table	5	3
Computer Station	**1**	**2**
Orange Corridor	22	48
Commons	29	14
7-11	32	34
Bridge	7	10
Study Zone 1	26	22
Sitting Area 1	10	4
Sitting Area 2	12	7
Bathroom	**9.3**	**4.6**

Table B.2.2 Illumination Level for Existing Fixtures

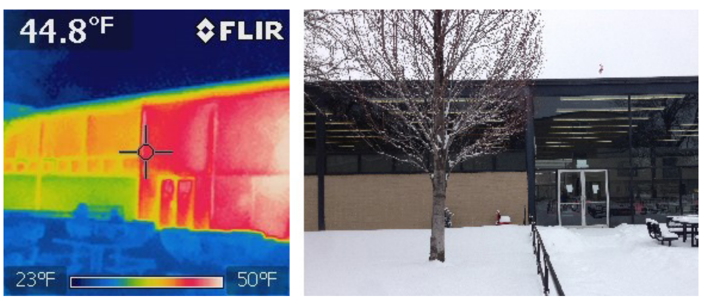
Heating, Cooling, and Ventilation

Photos taken 01/25/2014 18°F Outdoor Temperature

<West Facing Wall>



<South Facing Wall>



<East Facing Wall>

Figure B.2.1. Infrared photos of MTCC exterior

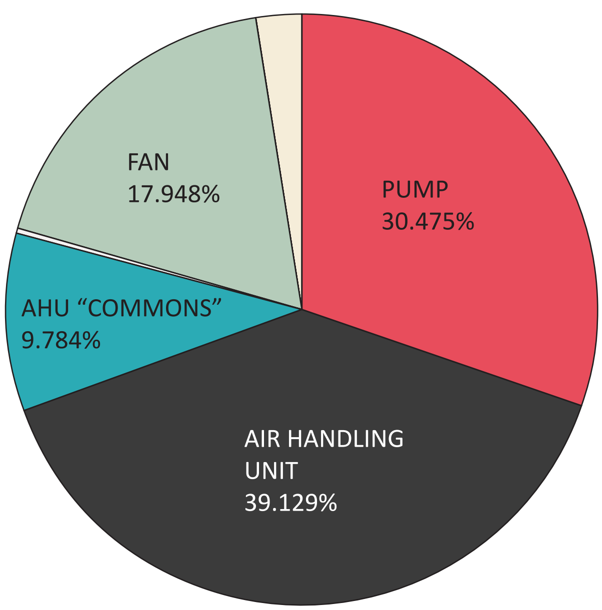


Figure B.2.2. Energy Distribution in MTCC HVAC

The MTCC is a mostly passive building in terms of HVAC energy requirements. The heating and cooling source for MTCC is provided by a centralized system. This system contains self-controlled boilers and cooling units, located in other buildings around the campus.

The heating source is generated in the main residence hall known as MSV, east of the MTCC. The heating requirements for the MTCC is provided by a pipe system connected from the source to the ducts in the MTCC. These ducts are controlled by variable frequency drives, or VFDs. The cold water for cooling is fed from the Engineering 1 building northwest of the MTCC. Because of the centralized system, it is difficult to consider retrofitting solutions for the MTCC.

Instead of attempting to improve the air handling and cooling systems, other ways to improve the MTCC's energy efficiency are considered. Large improvements can be made on the building envelop. **Thermal images indicate the buildings poor energy performance in the winter time.** [Figure B.2.1] The large differences in temperature between the building's exterior walls and the ambient temperature indicates a lot of the energy being used by heating the building and being lost due to the building envelope's inefficient thermal insulation.

The HVAC system of MTCC is automated by using the *Siemens Apogee Automation System*. This allows the user to control building systems from a computer, and also notifies a client of any incidents in the system.

The electric machineries of the system, such as fans, motors, and pumps, are responsible for circulating the air inside the building. [Figure B.2.2] shows how the energy is distributed and which of these systems requires the most energy use

Submetering and Monitoring

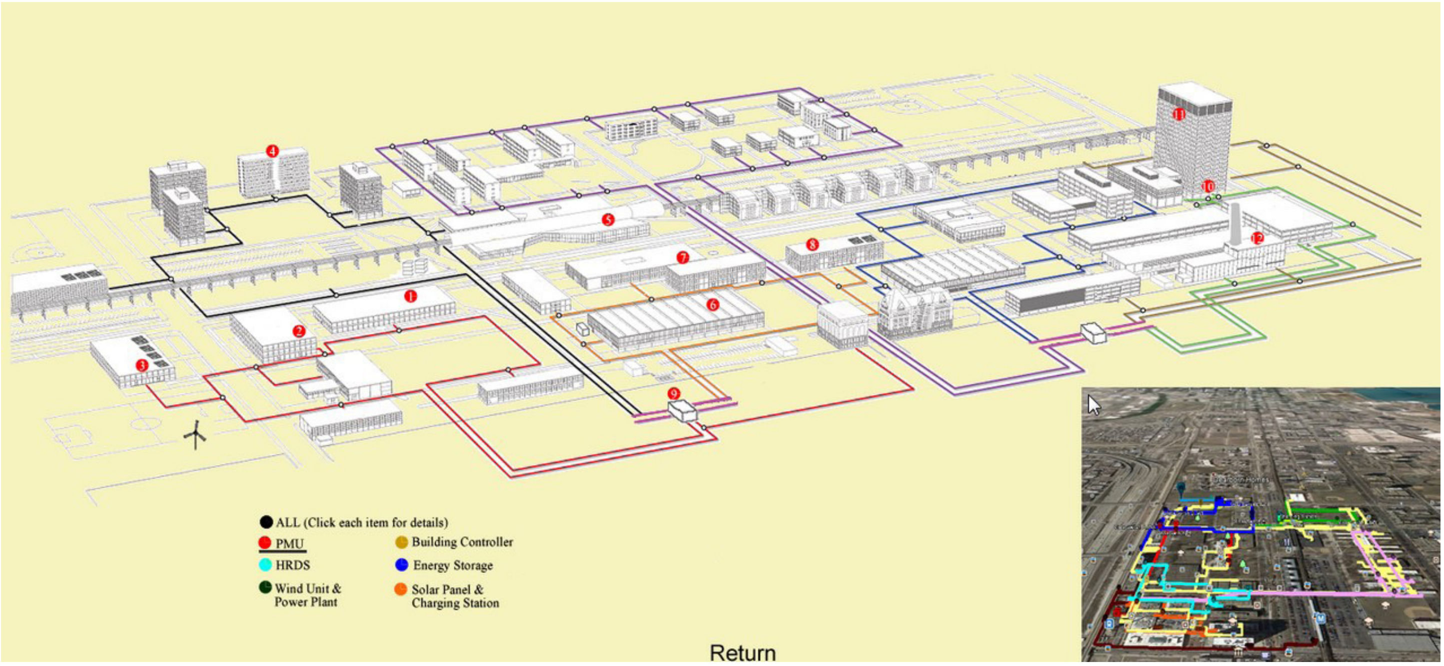


Figure B.2.3. Micro-grid at Illinois Institute of Technology

The micro grid at the Illinois Institute of Technology, shown in Figure B.2.3, is part of a research program named the Perfect Power System and is the only one of its kind in Illinois. This system allows real-time building data to be recorded and monitored through a network of power distribution loops throughout campus with the capability of providing a redundant power source to campus buildings within the micro-grid. It also has the ability of operating independently of public utility should a power interruption arise. Furthermore, the micro grid can isolate itself from the public grid and generate up to 70% of its demand when the campus breaches its pricing bracket due to usage during hours of peak demand.

- Two digital meters, that are integrated into the campus's network of utility meters, measures electrical usage in MTCC. They feed information to the campus metering network server.
- A Phasor Measurement Unit (PMU) is connected to the load side of the MTCC's main transformer measuring and monitoring, in real time, characteristics of the AC waveforms such as Voltage, Current, and Phase Angle.
- The PMU's are part of a similar design to the digital meters in that there is a network of them throughout the campus's micro grid power distribution system.

B.2.2 MTCC Energy Use Analysis and Benchmark

In order to understand the MTCC's energy use relative to its size and functionality, a similar facility that has already been thoroughly analyzed was used as a benchmark. The Herman Miller Marketplace located in Michigan was selected to make comparisons. The qualifications for this building as a benchmark are listed as follows:

1. MTCC and HMM are located in the same climate zone (northern Illinois and Michigan)
2. The buildings have relatively similar square footage (120,000 sqft and 95,000 sqft)
3. The interior layout of the buildings are similar as well as the construction materials of the facade.
4. The buildings were constructed in the same year (2003).
5. HMM has achieved LEED Gold certification from U.S. Green Building Council. Because the building is recognized as a successfully-designed green building, HMM would be a perfect platform to find examples in how to improve the MTCC's energy efficiency.

Figure B.2.4. Herman Miller Marketplace, MI

Figure B.2.5. HMM Interior

Lighting

Herman Miller Marketplace was able to achieve the LEED Gold certification by implementing a number of green strategies into their building systems. The green strategies used in lighting are listed in Table B.2.3. From this list, the HMM lighting systems begin to distinguish themselves from the MTCC. High considerations were taken into creating efficient lighting, significantly reducing the amount of energy consumption. While the HMM building invests in high efficiency light lamps and daylighting and automated control systems, the MTCC does not. Because of the similarity of the two buildings, **The MTCC can use HMM as a model and incorporate their green strategies into the building.**

	Green Strategies (HMM)
Daylighting	An open floor plan for sufficient daylighting
	Use atrium for daylighting
	Use large windows and high ceilings
Light Levels	Design for no more than 1.0 watts/ sqft
	Use different task and ambient lighting
Light Sources	Use high-efficiency lamps
	Use metal halide lamps

Table B.2.3.Green Strategies in lighting (HMM)

Heating, Cooling, and Ventilation

	Green Strategies (HMM)
Non-solar cooling loads	Use operable windows
High-performance windows and Doors	Optimize Energy Performance of glazing systems
	Windows' u-factor less than 0.32
Heating systems	Locate heating equipment in an accessible place for maintenance and service
Roof Insulation	Design roof system with consistent thermal integrity

Table B.2.4. Green Strategies comparison in heating, cooling and ventilation (HMM)

The comparison of green strategies in cooling/heating shows that the MTCC does not have enough green strategies in terms of heating and cooling. The reason of the poor performance is mainly due to the weak envelope system. According to the measurement, the U-factor of MTCC's curtain wall system is more than 1.00, while it has to be limited less than 0.32 in HMM. [Figure B.2.6.]

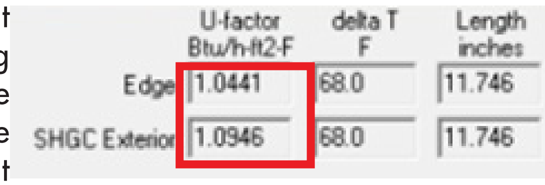


Figure B.2.6. MTCC Envelope Analysis

As a result of this energy loss, the HMM uses significantly less amount of electricity shown in the comparison of the two buildings' annual electricity bills. MTCC was is 2 million kWH of electricity a year while HMM is using 1.3 million kWH a year.[Table B.2.5, B.2.6] Despite the fact that MTCC is 15% larger than HMM in square footage, MTCC is using 54% more amount of electricity.

MTCC Energy Use	
Month	Energy Usage (kWH)
June 2012	181,550
July 2012	187,810
August 2012	187,800
September 2012	182,000
October 2012	180,230
November 2012	164,210
December 2012	150,420
January 2013	160,680
February 2013	150,870
March 2013	162,570
April 2013	162,700
May 2013	160,730
Billing Year Total	2,031,570

Table B.2.5. MTCC Electricity Metering Data

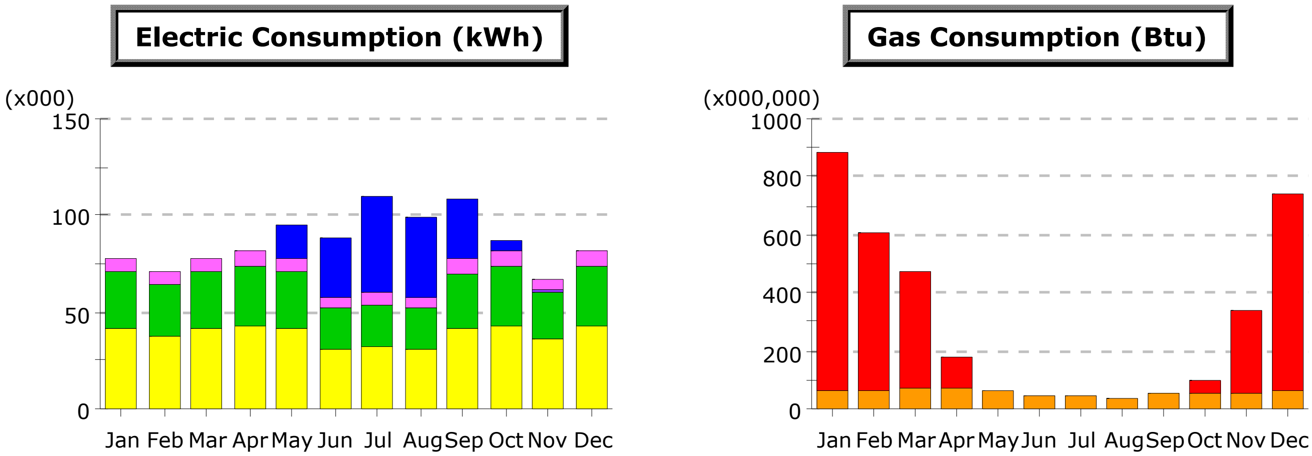
HMM Energy Use	
Month	Energy Usage (kWH)
January 2004	105,500
February 2004	101,840
March 2004	97,760
April 2004	97,120
May 2004	107,600
June 2004	110,640
July 2004	146,960
August 2004	143,280
September 2004	120,800
October 2004	106,480
November 2004	88,640
December 2004	87,520
Billing Year Total	1,314,240

Table B.2.6. HMM Electricity Metering Data[1]

[1]Data courtesy of Zeeland Board of Public works

EPA Benchmarking Tool

Figure B.2.7 MTCC Annual Energy Consumption



Since there is no objective comparing tool, an energy analysis was conducted based on the ENERGY STAR rating system which is a suggestion from US Environmental Protection Agency(EPA). Once a user enters building operation data in Portfolio Manager, it computes the typical intensity of energy source usage for a building of a similar type.

Portfolio Manager calculates an estimate of the building's actual source energy use intensity by converting the utility meter data to an estimate of source energy use: it multiplies electrical energy by a factor of 3.34 to account for energy loss in the conversion of primary energy and its transmission and distribution to the point of use. Finally it multiplies natural gas by a factor of 1.047 to account for losses in the delivery process.

To obtain energy consumption data of MTCC building, we implemented eQUEST (A building modeling software) to obtain results of monthly gas and electrical consumptions. [Figure B.2.7] As a last step this program exports a rating score for each of the buildings. These tools allows a comparison of the two buildings in a consistent manner.

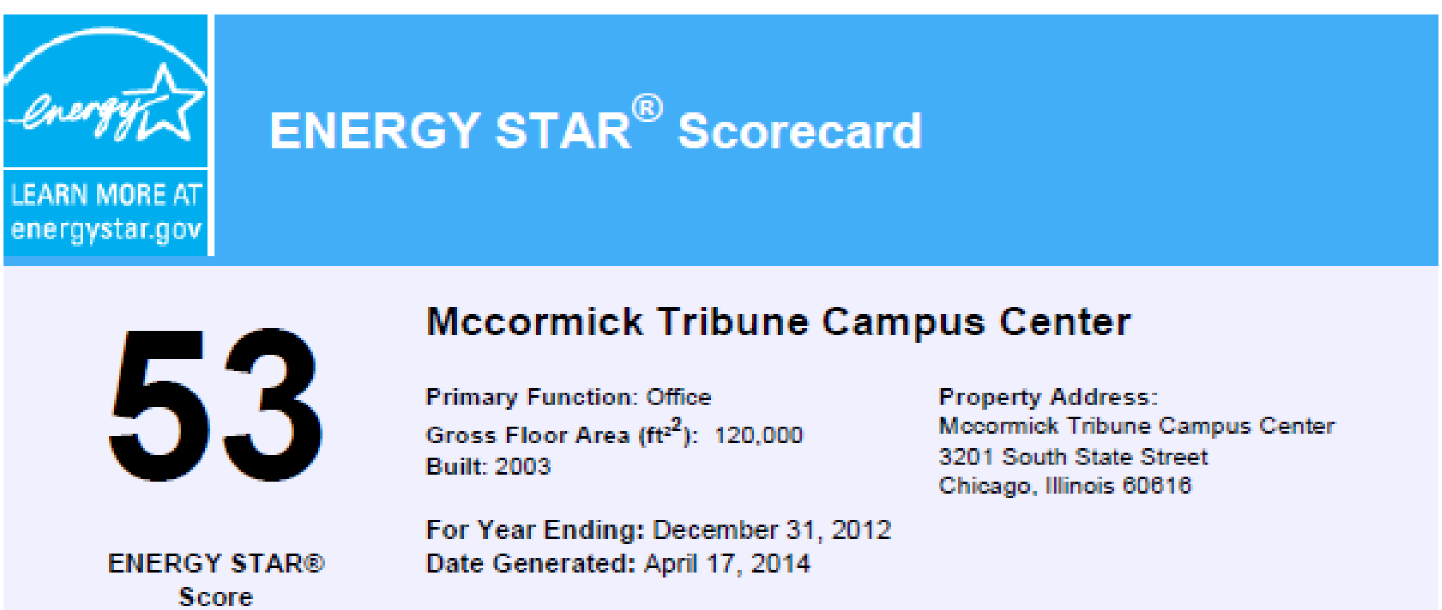


Figure B.2.8 MTCC ENERGY STAR RATING

Herman Miller Market place is performing well in terms of energy conservation. It is certified as LEED Gold. Both MTCC and HMM have similar geometries, climate condition, and built in the same year. However the buildings are polar opposites when it comes to energy consumption. Based on the AIA journal[2], **HMM got 75 points as ENERGY STAR rating system which is much more than 53 points scored by the MTCC.** [Figure B.2.8, 9]

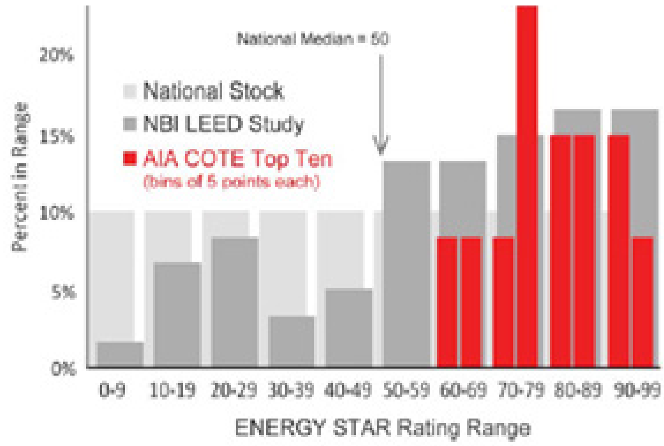


Figure B.2.9 Energy Star Rating Statistics

B.2.3 Key Observation and Recommendations

Observations

1. **Building enclosure** [Figure B.2.10]**:** The MTCC is primarily composed of glass with steel framing. Therefore, it consumes a significant amount of energy compared to other buildings. By the calculation of heat loss equation, it loses 2,231,870 Btu per hour through wall enclosures.

Figure B.2.10 Building Enclosure

2. **Lighting:** The lighting systems in the facility are performing ineffectively [Figure B.2.11]. The lack of automated lighting control management causes a waste of lighting energy during the day-time. MTCC wastes a lot of electricity that could be saved with a proper management plan.

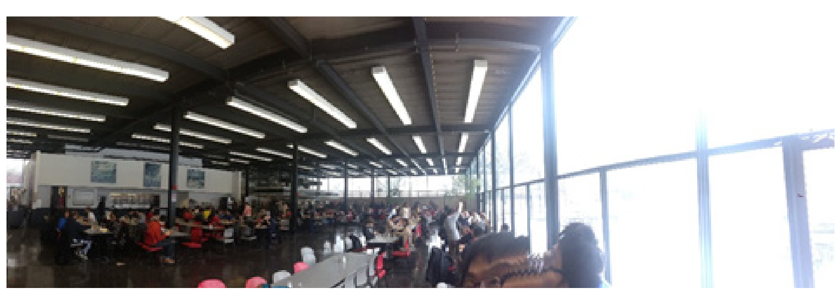


Figure B.2.11 Poor Lighting Control

[2]The American Institute of Architects

3. **HVAC:** Since the HVAC system was operated by other buildings' power facilities (Engineering 1 building for cooling, MSV for heating), the MTCC consumes more energy than a normal building which has similar HVAC system. It loses extra energy because those connections among buildings are not well insulated.

Recommendations

1. **Wall insulation:** To prevent heat loss through wall, some additional attachments on the wall is suggested. Since the MTCC primarily uses a curtain wall system, the best way to improve the thermal performance of the building would be to reduce the U-Value of the fenestration system. One possible retrofit improvement would be to implement a double-skin facade[Figure B.2.12], or glaze the windows with a low-emissivity coating.

2. **Curtain wall:** A new type of curtain wall system is suggested. The steel mullions which are the frame of curtain wall should be coated by other thermal insulated material. Also single layer window system should be replaced by Vacuum insulation double glass system which has higher insulation.

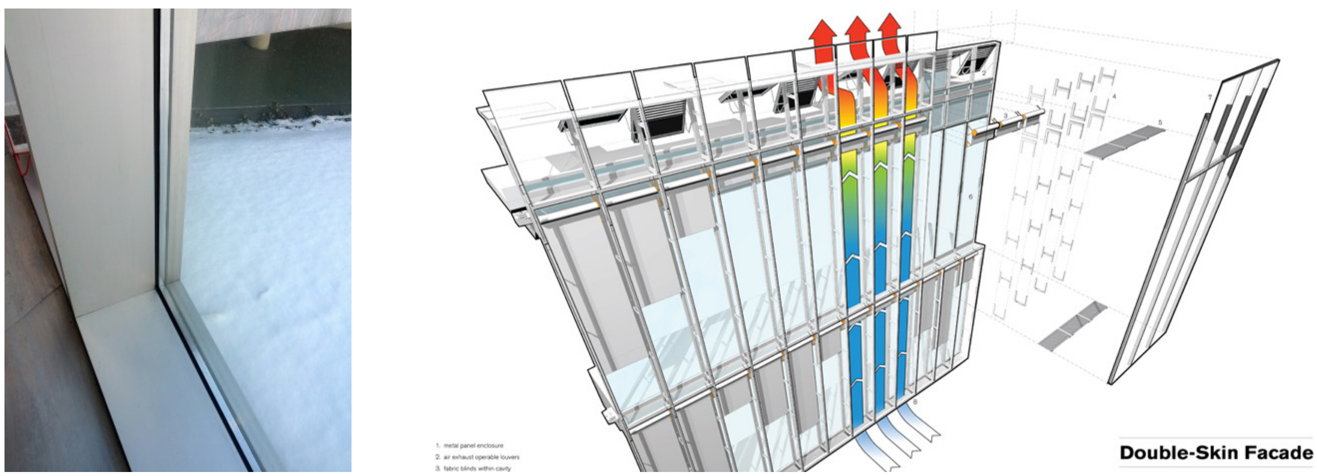


Figure B.2.12Curtain Wall System

3. **Lighting:** The building needs to implement an automated control system for daylighting and occupancy in areas where it would be beneficial [Figure B.2.13]. Because of the large amount of daylight penetrating the building, it would be best to take advantage of it. Also, current lamps or bulbs should be replaced with high efficiency lamps to reduce the power consumption of the lighting system.

Figure B.2.13 Lighting System

4. **Power:** Alternative energy sources must be integrated into the MTCC in order to increase the building performance. The MTCC is located in the Southside of Chicago, so utilizing wind power and geo-thermal heat pumps are not the most attractive alternatives. Implementing a solar power source would provide the best option for increasing the efficiency.

B.3 TECHNICAL ANALYSIS 2: Lighting Retrofit

Overview: This section includes an assessment of the MTCC lighting system. The recommendations include improved lighting efficiency and the reduction of the wattage draw.
Results: $397,080 savings over five-years.
Benefit: Increased lighting controls, reduction in energy consumption and maintenance costs.

B.3.1 Assess Space and Make Recommendations

The MTCC can increase lighting efficiency and reduce energy consumption. It is the hub for all student activity. The building is open 16 hours a day Monday thru Friday and 14 hours a day on the weekend. A multi-functional building, it is designed to the needs of students with multiple cafeterias, meeting rooms, and study areas. The auditorium can accommodate 200 people for meetings or dinner. The Pritzker Club, named after the University's major donor, offers upscale dining. There is a mail room, radio station, and bookstore in the building and students can unwind by playing ping-pong or billiards in the activity area.

However, the fact is that the lighting system in the building is inefficient. There is currently no ability to reduce wattage drawn during the day. The design of the building makes it cost prohibitive for a lighting fixture retrofit. There are over 30 different types of lighting fixtures in the building. The total number of lighting fixtures is 1228. The considerations made in the analysis of the building lighting system were:

- The current state of the lighting system
- The original design and the architect's interpretation of the lighting system for the building
- Potential improvements and which improvements would make the greatest impact
- The impact on the students and guests who use the building: after the retrofit and during
- The cost of the retrofit and return on investment

There is a major opportunity to increase lighting efficiency and reduce the wattage by 30 to 50%. The estimated cost including labor is $63,638 and the annual savings projected is $79,416 with a 10 month payback. The analysis also includes a cost of waiting. **It will cost the university $2000 every month that the building remains in its current condition.** There can be a lighting load reduction of 40 to 60% during the day. The building's exterior walls are floor to ceiling glass. The opportunity to take advantage of the ambient lighting is underutilized and there are no lighting controls in 90% of the building. The recommendations will enable the building to take advantage of these cost saving opportunities.

B.3.2 Recommendations

The recommendations are broken down into two categories:

1. **Lighting controls:** **Add controls to the areas that can take advantage of ambient light and reduce lighting when there are no occupants.**
2. **Lamp replacement:** **Implement a comprehensive lamp replacement program.**

The first recommendation is to control the lighting loads in the building. The installation of *occupancy and daylight sensors will create savings immediately.* Daylight sensors take advantage of ambient light. Occupancy sensors reduce wattage usage. The overall cost of a building control system is prohibitive. Because the building is finished, a building control system would be extremely labor intensive. This would require a significant portion of the building to be rewired. There is no advantage to a building control system. Individual controls on specific lighting loads would be cost effective and provide the greatest flexibility.

The second recommendation is a comprehensive lamp replacement program. In the sections of the building that are cost prohibitive for a lighting fixture retrofit, substantial savings were achieved by replacing inefficient lamps with low-cost LED lamps. This strategy will drastically reduce wattage and maintenance labor cost.

B.3.3 New System Design

Implementation Plan

1. Identify areas of the building where occupancy and daylight sensors will create the largest energy reduction.
2. Create a comprehensive lamp replacement strategy.
3. Generate an accurate takeoff of existing lamps.
4. Create scope of work to produce realistic labor cost.
5. Research devices and lamps for the most competitive cost.
6. Use benchmarks to determine energy savings and ROI.
7. Calculate the cost and benefits of the new system.
8. Reinvest savings to create new energy efficiencies.

Part one of the implementation plan focuses on the office areas and the meeting rooms. Occupancy and daylight sensors can reduce energy consumption in these areas by 50%. Figure B.3.1 and Table B.3.2 describe the **reflected ceiling plans of the existing and proposed designs** of the east entrance and the office area of the building. The symbol by the doorway in each office of the proposed design indicates the occupancy sensor. The line in the T8 fixture symbol designates a lamp replacement from 32W to 28W.

Reflected Ceiling Plans

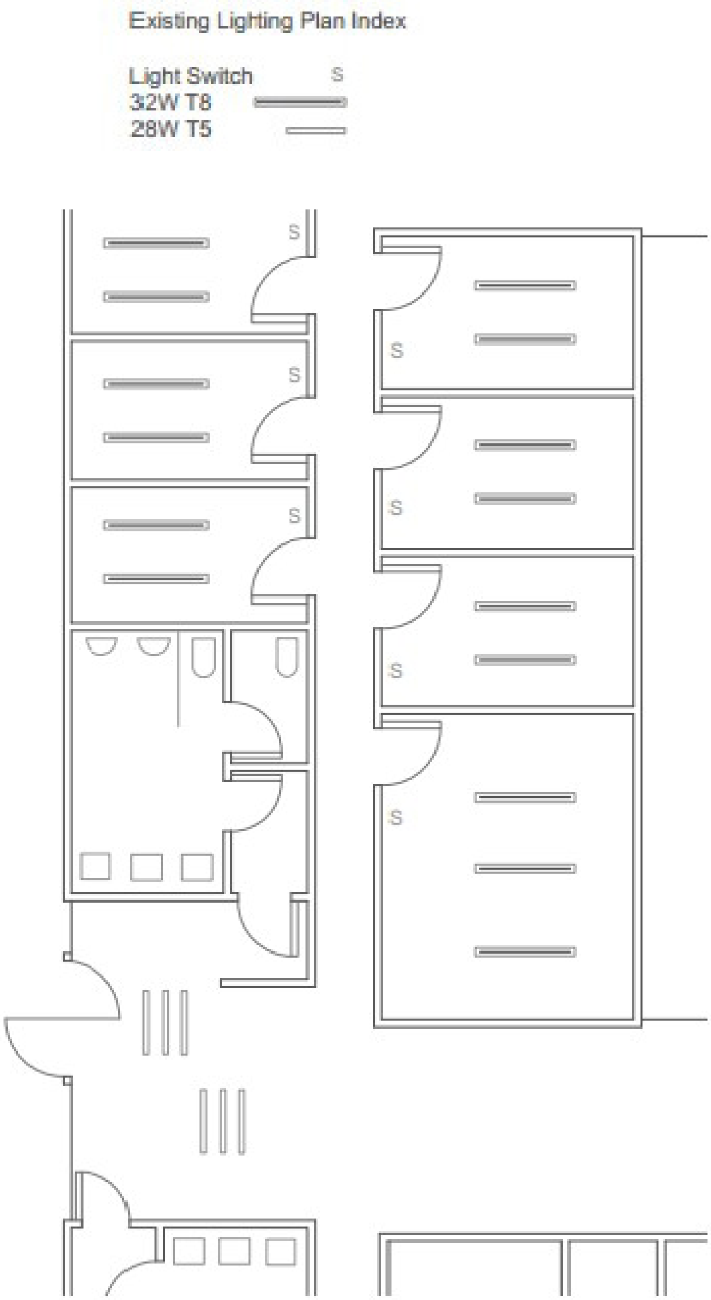


Figure B.3.1 Reflected ceiling plans

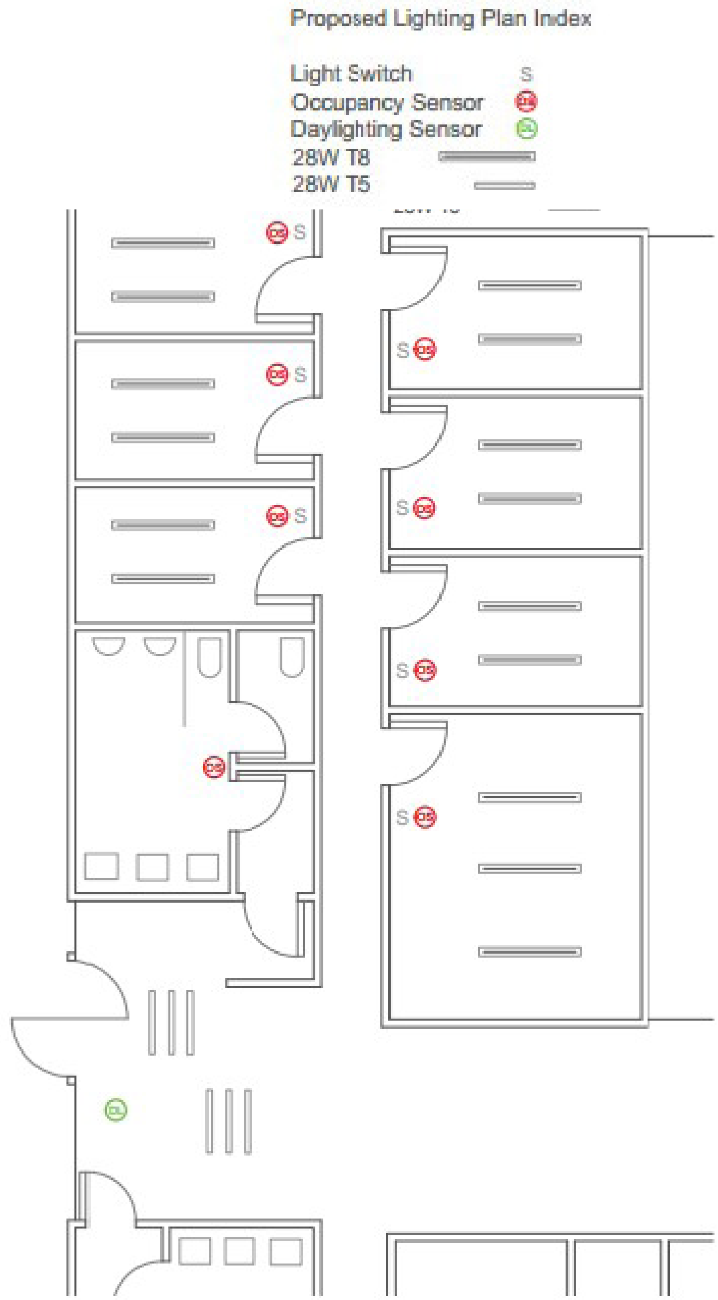


Figure B.3.2 Proposed reflected ceiling plans

Occupancy and Daylight Sensors

The installation cost of the occupancy and daylight sensors in the building is $2,408.(Appendix B.3.3) **The annual savings from the occupancy and daylight sensors are $22,478.** (Appendix B.3.1) The targeted areas of the building for the proposed occupancy and daylight sensors are in table B.3.1. The implementation of the daylight sensors takes full advantage of ambient lighting.

Section	Affected fixture type	Action	Affected fixture numbers	Sensor number
General Lighting	6 lamp 4’ 28W T5	Daylight Sensor	36	6
Pritzker Club Area	35 W Ceramic Metal Halide	Occupancy Sensor	15	3
	75W PAR30	Daylight Sensor	17	2
	28W F28 T5	Daylight Sensor	6	1
Post Office Area	32W T8	Daylight Sensor	13	1
The Commons Cafeteria	2-lamp 32W T8	Occupancy Sensor	51	3
	2-lamp 32W T8	Daylight Sensor	36	4
Conference Room Area	2-lamp 32W T8	Occupancy Sensor	29	7
Office Area	2-lamp 32W T8	Occupancy Sensor	40	34
	2-lamp 32W T8	Daylight Sensor	10	1

Table B.3.1. Proposed Occupancy and Daylight Sensors Schedule

The recommended brand of sensors is Lutron. Figure B.3.3 gives an example of the style of sensors. The specifications of these sensors are compatible for the needs of the building while delivering cost effectiveness. The daylight sensor is wireless. It will reduce the labor cost of the retrofit.

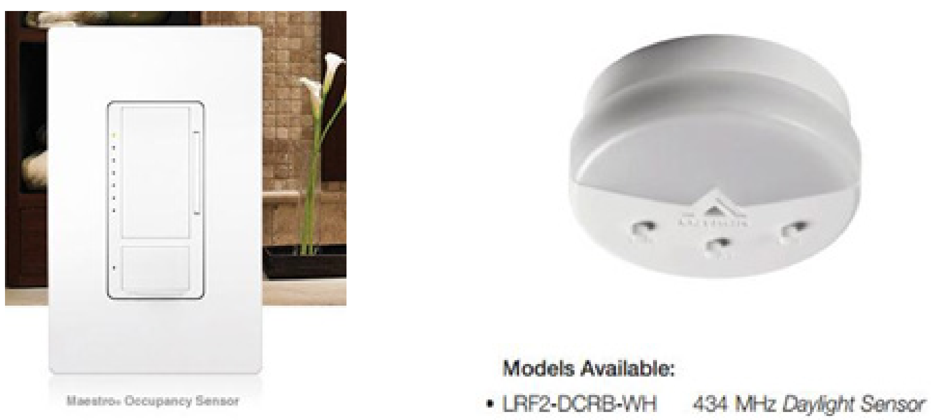


Figure B.3.3 Proposed Lighting Sensors

Comprehensive Lamp Replacement Strategy

The replacement of the inefficient lamps is the largest opportunity to increase savings and reduce wattage. A majority of the lighting fixtures in the building are on continuously. This will change as controls are built in. However, the largest numbers of fixtures in the building are HD type cans that will not be part of the control strategy. The savings for these fixtures will be in the lamp replacement. The replacement of the current lamps with cost effective LED lamps will provide higher lumens and lower wattage. The lamp replacement schedule is in Table B.3.2. This table shows the proposed replacement for the existing lamp and the number of fixtures affected.

Sections	Existing Lamps	Proposed Lamps	Numbers
General Lighting Upgrade	45W PAR20	8W PAR20 LED	350
Pritzker Club Area	75W PAR30	14W PAR30LN LED	71
	50W PAR20	8W PAR20 LED	15
Post Office Area	150W CDM150 T6	41W LED Flood	5
	50W PAR20	8W PAR20 LED	34
	90W PAR38	16W PAR38 LED	7
The Commons Cafeteria	75 W PAR30	14W PAR30LN LED	51
Conference Room Area	2-lamp 32W T8	28W T8 Lamp only	24
	2-lamp 32W T8	28W T8 Lamp only	5
	500W Halogen Flood	41W LED Flood	19
	90W PAR38	16W PAR38 LED	63
Coffee Kiosk Area	13W PL CFL lamp	5W LED PL lamp	50
Office Area	2-LAMP 32W T8	28W T8 Lamp only	40

Table B.3.2 Lamp Replacement Schedule

The annual energy usage reduction in table B.3.3 below shows the current usage compared to the energy usage after the comprehensive lamp replacement strategy. **The comprehensive lamp replacement strategy will reduce the energy output of these fixtures by 60.7% saving 305,343 kWh annually.**

Current Usage (kWh)	Projected Usage (kWh)	Reduction (kWh)	Reduction (%)
503,104.8	197,761.1	305,343.7	0.607

Table B.3.3 Annual Energy Usage Reduction

Lamp Replacement Samples

The lamp replacement recommendations are based on research for compatibility with existing lighting fixtures. The criteria used emphasized cost effectiveness and reduction in maintenance. Figure B.3.4 illustrates three lamp replacement samples that meet the criteria.

Philips Endura LED 426122

KolourOne LEDs S8947

Acuity Brands 213PE5

Figure B.3.4 Lamp Replacement Samples

Renderings

The office in Figure B.3.5 is unoccupied without lighting controls. The same office in figure B.3.6 is unoccupied with an occupancy sensor. The sensor is equipped with a timer that shuts off the lighting fixtures in the office after it is unoccupied for five minutes.

Figure B.3.5

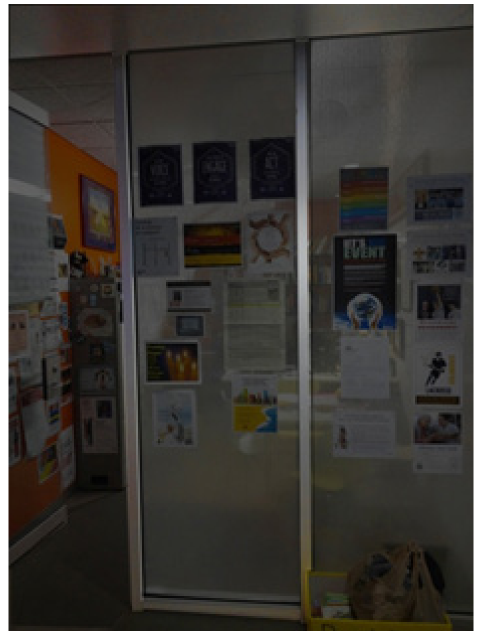


Figure B.3.6

B.3.4 Impacts on Day Lighting and Calculations of Cost and Benefits

Day Lighting Impact/Energy Use

The building has enormous ambient lighting. The exterior walls are floor to ceiling glass. There is an advantage of ambient light exposure throughout the building. With the addition of lighting controls and high efficiency replacement lamps, **the impact on day lighting is a reduction in wattage of 305,343 kWh.** In Figure B.3.7 the chart shows the current usage in kWh and the projected usage in kWh after the lighting system is installed. The reduction of wattage translates into longer life of the new replacement lamps.

Calculations of Cost and Benefit Use

There are many benefits to the new system design. The first is the annual electricity expenses saving results, which is estimated to be $33,615[1]. The second is the maintenance savings due to the comprehensive lamp replacement[2]. The savings annually will be $3,080 after the initial installation of the new lamps and sensors. The cost for the occupancy and daylight sensors is $2,408[3]. The cost for the lamp replacement is $29,445[4].

The cost of labor in Table B.3.4 is calculated by assuming a standard Chicago union labor rate consisting of: wages, benefits, health care costs, additional overhead costs to equal an average of $100/hr.

[1] Appendix B.3.1
[2] Appendix B.3.2
[3] Appendix B.3.3
[4] Appendix B.3.4

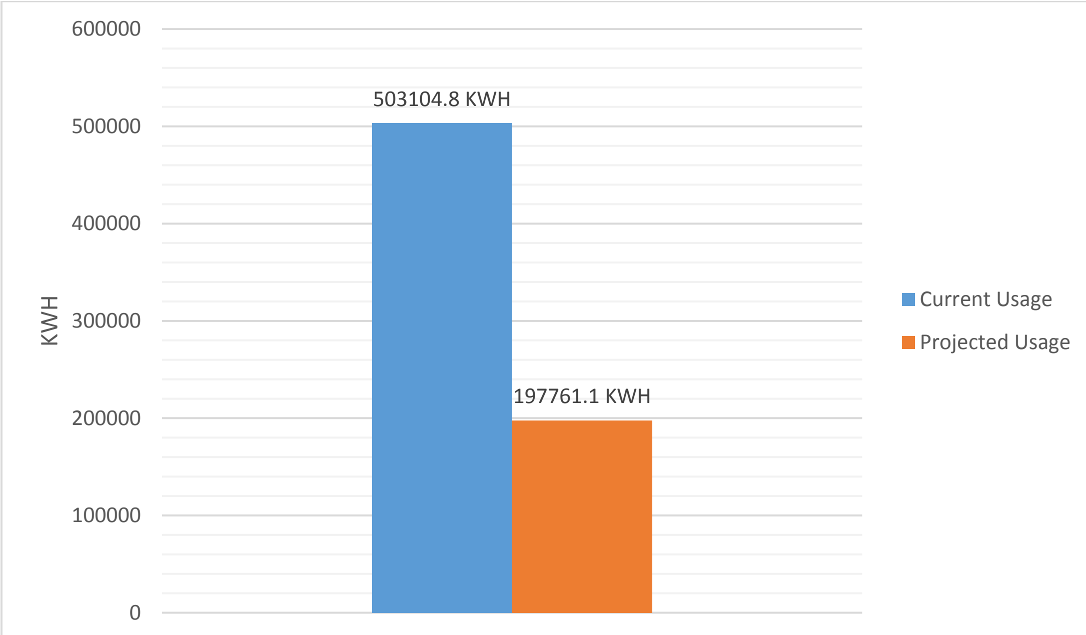


Figure B.3.7 Energy usage comparison between the existing condition and proposed plan

Description	Time Requirement hr.	Cost
Install occupancy sensor	160	$16,000
Install daylight sensor	48	$4,800
Replace Lamp	32	$3,200
Total labor work	**240**	**$24,000**

Table B.3.4: Estimated Labor Cost

Supplies	Cost
Conduit	$500
Hardware	$250
Miscellaneous	$250
Distribution Wire	$1,000
Total Cost	**$2,000**

Table B.3.5: Estimated Supplies

Description	Cost
Estimated material cost	$31,853
Estimated labor cost	$24,000
Estimated supplies cost	$2,000
10% Contractor Overhead	$5,875
Total estimated cost	$63,638
Annual lighting expense saving	$76,335
Annual maintenance saving	$3,080
Total yearly savings	$79,416
Payback	10 months

Table B.3.6: Lighting Retrofit Return on Investment

The annual total estimated saving is $79,416 shown in Table B.3.6. Note that a utility rate of $0.25/kWh is used in the above calculations. The total estimated project cost including material, labor and supplies, as well as a 10% contractor overhead is $63,638 shown in Tables B.3.5 and B.3.6. The payback period is 10 months. As shown in Figure B.3.8 below, after the initial investment on the new system in the first year, the total expense of the new lighting system bypasses the existing total expense. **The net savings for the lighting retrofit is $397,080 over 5 years.**

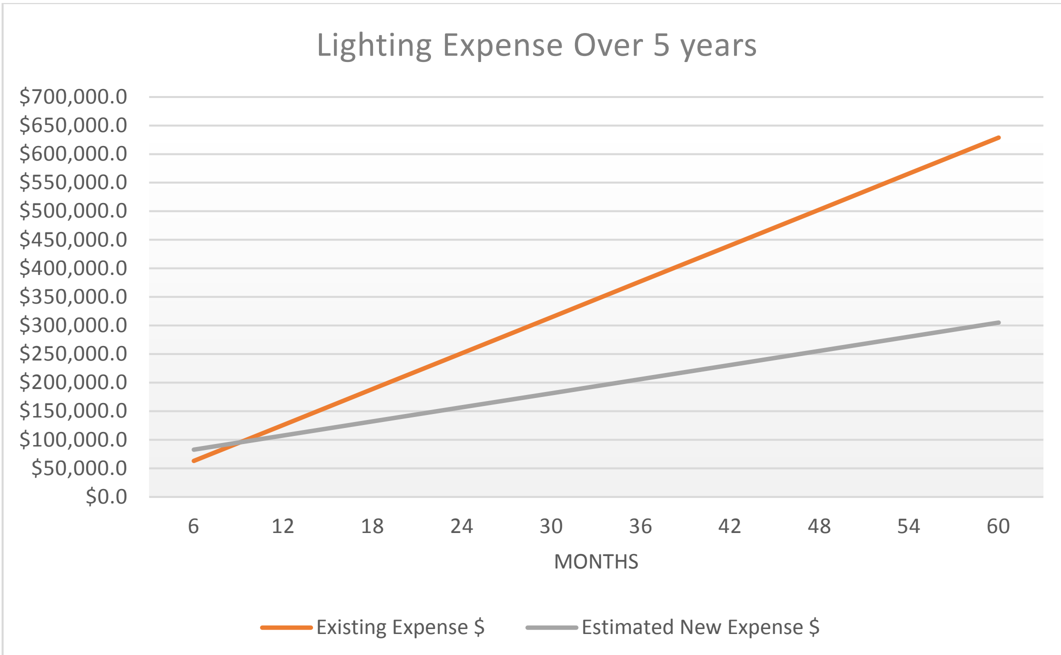


Figure B.3.8 5-year Expenses Comparison

Environmental Impact

The impact on the environment and the reduction of the buildings carbon footprint can also be improved with the designed retrofit. The reduction in the burning of coal, gas, and oil to generate the electricity needed to light the building will decrease air pollution by the following amounts: 226,327 pounds of carbon monoxide, 49,202 grams of sulfur dioxide, and 1,141,475 grams of nitrogen oxides.

The improvements of the lighting system in this report are a start. As the new system design begins to save money and energy, more initiatives towards reducing energy in the building are recommended.

B.4 TECHNICAL ANALYSIS 3: SOLAR RETROFIT

Overview: This section includes the on-site Photo-voltaic system, cost estimates, and the benefits to the image of the client

Result: $84,375 of savings in 5 years

Benefits: Promotes green energy, alternative source of energy production, and the university image of being environmentally proactive

B.4.1 Opportunity for Photo-voltaic System

The McCormick Tribune Campus Center (MTCC) building is part of the smart grid connecting the buildings on the campus of Illinois Institute of Technology, Chicago. As of 2014, there are two photo-voltaic (PV) panels in the university campus, with power ratings of 40kW and 60kW. These solar panels input energy into the existing smart grid. This progress of adopting renewable energy sources at different buildings on the university campus, specifically solar energy affirms that the potential for solar energy is significant.

The two existing PV panels are both located on buildings on the west side of the campus and the MTCC building is located on the east side of the campus. According to the facilities department of the university, a new PV system on the rooftop of the MTCC building would significantly reduce the load of the two PV panels while distributing the energy produced to the entire campus.

The rooftop of the MTCC building has a flat surface area of approximately 68,310 square feet. See figure B.4.1. The large area provides several options for the installation site of PV panels; the southeast section of the building is chosen. This section of the rooftop provides a larger area compared to the other sections so the panels can all be installed in one section.

Figure B.4.1Total area of the rooftop of the MTCC

The Proposed System

Solar Zentrum DE-60 Premium:
25 years performance guarantee, 10 years product warranty, 15.71% module efficiency
PLATINUM S Inverters:
10 years manufacturer's warranty, 95.3% efficiency

Figure B.4.2 Specification of selected Solar Panels

With a production of 9.0 watt/sq.ft., the 60kW system would require a solar panel area of 6,667 sq.ft., which is available at the southeast corner of the rooftop. See figure B.4.3. With available the solar energy 0.4kWh/sq.ft. per day in the Chicago area, the proposed photo-voltaic system would produce up to 67,500kWh/year.

The solar panels chosen are supplied by *Solar Zentrum NA Inc.* The DE-60 solar panels, specified in figure B.4.2 from Solar Zentrum incorporates manufacturing technology from Germany and the newly developed frame makes the panels suitable for high snow loads. The PLATINUM S Inverters are temperature resistant and works with high efficiency.

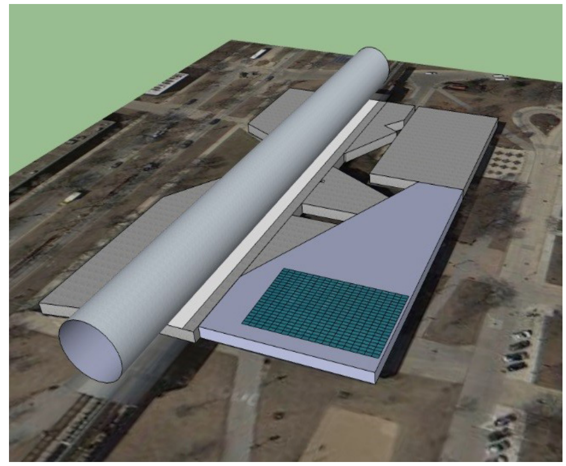


Figure B.4.3 Proposed solar panels on the southeast section

B.4.2 Cost Analysis for Photo-voltaic System

The total cost, which includes the cost for solar panel modules, mounts, wiring, inverter, and the installation, for the proposed 60kW photo-voltaic system is $240,000. A total of $92,250 would be available from grants and incentives. The investment required from the client is $147,750. See table B.4.1.

Total installation cost	$240,000
Grants and incentives	$92,250
Investment total	$147,750
Production per year	$16,875
Payback period	8.7 years

Table B.4.1 Cost analysis for the photo-voltaic sys-

The photo-voltaic system is expected to produce 67500 kWh of energy per year, which translates into $16,875 of energy production every year at a rate of $0.25/kwh. **This would result in a production of $84,375 in 5 years and a payback period of 8.7 years.**

System Components Price Quote

Solar Zentrum has provided a cost analysis for the system components. The price breakdown is listed in Table B.4.2. The different components add up to $4.0/watt and the proposed 60kW system would cost $240,000.

Components	Price per watt	Total price
Solar panel modules	$1.8/watt	$108,000
Mounts, wiring	$0.8/watt	$48,000
Inverter	$0.6/watt	$36,000
Installation	$0.8/watt	$48,000

Table B.4.2 System components price quote

Grants and Incentives

Rebate programs and grants are available for eligible photo-voltaic systems. Multiple programs can be applied for the same project and evaluation will be carried out before the funding is approved. Three on-going programs are listed as follows:

1. Small Business Improvement Fund (Illinois)
2. Renewable Energy and Energy Efficiency Project Financing (Illinois)
3. Solar Renewable Energy Credits (Illinois)

The Small Business Improvement Fund provides 25%, 50% and 75% of the total cost for a project, and for estimation purpose a 25% grant is used in calculation. This contributes $56,250 for the project, which is within the maximum amount of the program at $100,000.

The remaining two programs provide funds which varies from project to project, and an estimation of 8% of the total cost is used for these two funds in calculation. A total of $36,000 from these two programs is used as cost estimation. The total from grants and incentives would contribute a total of $92,250 for the project.

B.4.3 Image of the Client

Illinois Institute of Technology recognizes the critical importance of the university's mission "to advance knowledge through research and scholarship, to cultivate invention improving the human condition, and to educate students from throughout the world for a life of professional achievement, service to society, and individual fulfillment"– moving our world toward a more sustainable path.

Figure B.4.4 IIT Green Campus

The university reached a great milestone after receiving the Princeton Review's best "green" rating for universities in Illinois. As one of the country's most environmentally-responsible colleges, IIT has been selected for inclusion in a unique resource created for college applicants - "The Princeton Review's Guide to 286 Green Colleges."

MTCC is one of the architectural significant buildings on campus which attracts many visitors. When equipped with a green technology in the form of solar energy system, posters and tours around the building will allow the visitors to learn more about green energy systems.

B.5 Sub-Metering, Monitoring, and Feedback

Overview: This section includes a sub-metering plan, proposed technologies, and benefits of sub-metering, monitoring and feedback.
Result: $235,000 of savings over 5 years with continual commissioning.
Benefits: Increased building information and control leading to further energy savings

B.5.1 Plan to Increase Metering and Monitoring

The MTCC Facility manager can cut energy and maintenance costs without compromising the comfort or productivity of people by using smart meters and circuit-level monitoring. **Described below is a comprehensive plan to develop and execute metering and monitoring upgrades to the existing sub-metering and monitoring system.**

Current Status of Sub-Metering and Monitoring in MTCC:

The MTCC currently has metering only on a building level. The experimental Microgrid set up on campus as a research project by the Galvin Center monitors electrical consumption for all buildings on campus. It does this using Phasor Measurement Units (PMUs) installed in each building on campus. This gives real time information on the electrical usage for every building on campus, including MTCC, extremely valuable information.

However, right now the electrical usage can only be monitored for MTCC as a whole building. Electricity spent on the HVAC system is indistinguishable from electricity spent on lighting. In order to provide better knowledge and control over MTCC's power consumption, it is desirable to meter electrical usage at a smaller level of systems or even circuits.

Implementation Plan:

1. Identify, estimate, and select areas in the building where smart meters or circuit-level monitoring is most needed.
2. Select a vendor solution that will meet the requirements for both hardware and software.
3. Define the energy conservation measures (ECMs), such as changes to the building system's operations and scheduling, and estimate initial savings.
4. Engage in competitive bidding to select a qualified and reputable electrical contractor.
5. Verify proper installation, scheduling, and commissioning of new system.
6. Determine actual savings resulting from the implementation of the ECMs using the agreed Measurement and Verification (M&V) approach.
7. Re-evaluate at scheduled intervals, continuing to use the technology to identify new opportunities for energy savings.

In this document, steps 1 and 2 will be outlined, along with a beginning discussion of step 3. The following steps are in the implementation and will need to take place over a longer scale.

Identification of Key Panels :

In order to understand what areas of the building would benefit most from the implementation of sub-metering, apparent power of each electrical panel in the building is sorted and grouped by location (See Table B.5.1). As is obvious from the table, some panels consume much more electricity than others. These panels are the priorities to retrofit, since they have the greatest potential cost-savings from sub-metering. These 8 panels account for 48% of the building's apparent power, so they are the ones that would be most significant to replace.

Place	Total (KVA)	Panel 1	S (KVA)	Panel 2	S (KVA)	Panel 3	S (KVA)	Panel 4	S (KVA)	Panel 5	S (KVA)
Sports Bar	33	LLR1	33								
Electrical room	169	GR1	35	GR1A	26	GL1	85	GR1A	23		
Center Court	49	GR2	49								
Copy Center	1	GR3	1								
Auditorium	344	GR4	78	GR5	64	GR5A	30	GL2	158	CDM1	14
Open Court Area	39	GR4A	39								
Café	24	GR6	24								
Grocery Store	36	GR8	0	GL4	36						
Housing Office	100	MZR1	42	MZL1	58						
Elec. Closet	41	LL1	41								
Bookstore	51	GL3	51	GR7	0						
Emergency Lighting	39	EL1	39								
Emergency Receptacle	14	ER1	14								
A/V Confer-ence	4	GDM2	4								
Commons	217	CBEL1	15	KR1	39	KR2	33	KR3	38	KR4	37
		KR5	31	CBLL1	1	CBLR1	7	CBLR2	4	CBGL1	12

Table B.5.1 Estimated Apparent Power Consumption of MTCC Distribution Panels (red denotes the priority panels to retrofit)

Smart meters and circuit level monitoring are both effective technologies to increase the information about electrical usage. Both options are able to give more information to the facility manager about where, when, and how much electricity is being used in the building. However, circuit-level monitoring is capable of providing a more detailed overview of electrical usage in the building. **Thus, it is proposed to replace the 8 highlighted panels in Table B.5.1 with circuit-monitoring devices that will allow greater control for the building as a whole.**

B.5.2 Technological Solutions for Sub-Metering

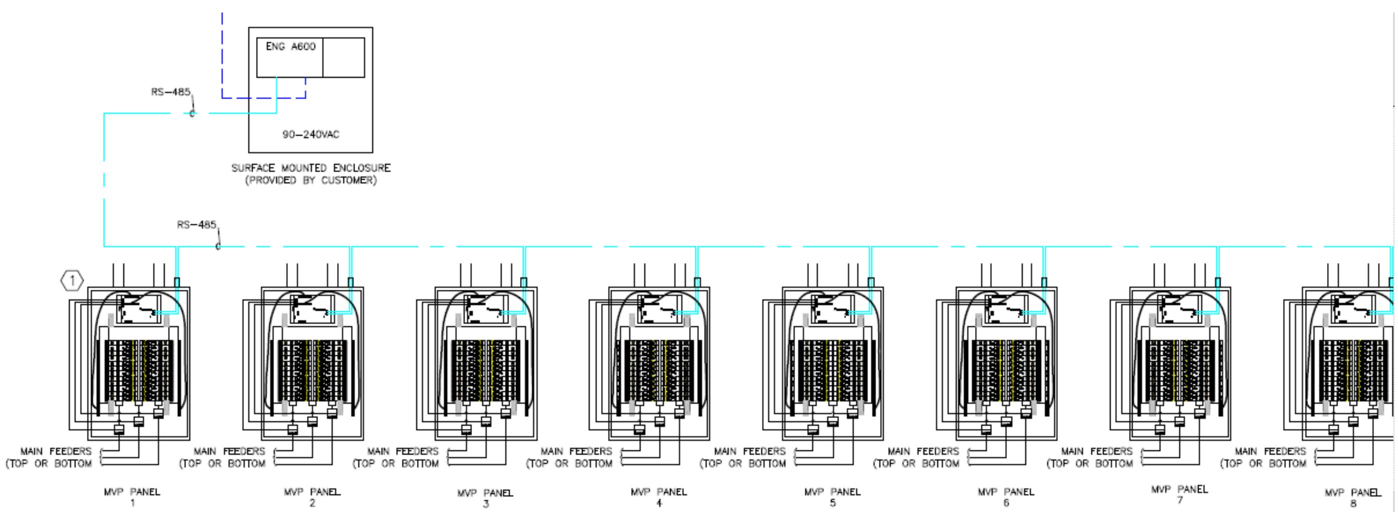
Having established the plan for increasing metering and monitoring in MTCC, the next step is to proceed to **propose the technology necessary to increase sub-metering in a way that advances the client's current practices**. Various companies currently market such technologies. Typically, the panel can be used to relay information to the system administrator who can then take appropriate action to reduce energy expenditure. Both hardware and software components are necessary for this to work effectively and both will be examined.

Hardware Solutions for Sub-Metering:

After an in-depth cost benefit analysis of the options that different vendors offer, Schneider Electric's Powerlink G3 Measurement and Verification Panelboards (MVP) are identified as an ideal solution to suit the hardware needs of the project. The MVP product provides insight into energy use, potential areas of energy waste, and the performance of energy conservation strategy down to the branch circuit level.

MVP Hardware Functions:

- Reliability and monitoring capability of measuring aggregated energy use from the panel level all the way down to the individual circuit level
- Branch circuit power meter supporting up to 84 branch circuit current transformers (CTs) for individual branch metering
- Flexibility and scalability in assuring a sustainable metering and verification program.
- Monitors current, voltage, energy consumption, demand, and power factor for complete energy profiling
- Reduces electrical energy consumption associated with lighting and other loads by automatically switching loads off during pre-programmed non-occupied periods.
- Ideal for reducing the peak demand by switching unnecessary lights off in response to an automated response signal or when high time-of-day energy costs occur.
- Accumulated energy metering data transmitted via network communications interface



Panel	GL2	GL1	GR4	MZL1	GL3	GR2	MZR1	LL1
Location	Auditori-um	Electrical Room	Auditori-um	Housing Office	Bookstore	Center Court	Housing Office	Elec. Closet

Figure B.5.1. Proposed Retrofit Diagram—Simplified System Architecture

Software Solutions for Sub-Metering:

The Energy Insight dashboard and the network of MVP Panelboards are the intelligent cores to our proposed energy management system. As a web-based program, it will provide a sophisticated yet operator-friendly software solution to accompany the MVP shown in Table B.5.2. This software has the ability to report and organize aggregate energy data to maximize the benefits and provide intelligence to the proposed system. The system can help users identify energy use trends and detect future opportunities for improved energy efficiency and sustainability.

The Energy Insight dashboard can be configured to be accessible over a local network or the internet. This allows the possibility for the facilities manager to review the energy consumption of the building across campus or even across the world.

Dashboard Software Functions:

- The panel data enters into the user configured dashboards and the Energy Insight application analyzes current (Amps), power (kW), and energy (kWh) on a circuit, zone, and panel basis
- Power Factor data is available on a circuit and panel per phase basis
- It allows multiple users to log in simultaneously from on site or remotely and monitor energy usage
- Monitors real-time voltage and current on a per phase basis
- Notifies upon adverse trends and load imbalances
- User configurable, easy to use interface compatible with any web browser
- Easily reconfigured at the touch of a button to align with a facility's changing environment
- Create user customizable dashboards
- View, benchmark, and generate reports for up to two years of data
- Easy to configure parameter settings for customized alarms and notifications
- Compare significant electrical load consumption to easily locate prime cost reduction areas
- Review historical patterns to build a curtailment plan to enable participation in utility programs
- Alert on demand levels, analyze trends to identify demand reduction, and load shifting opportunities

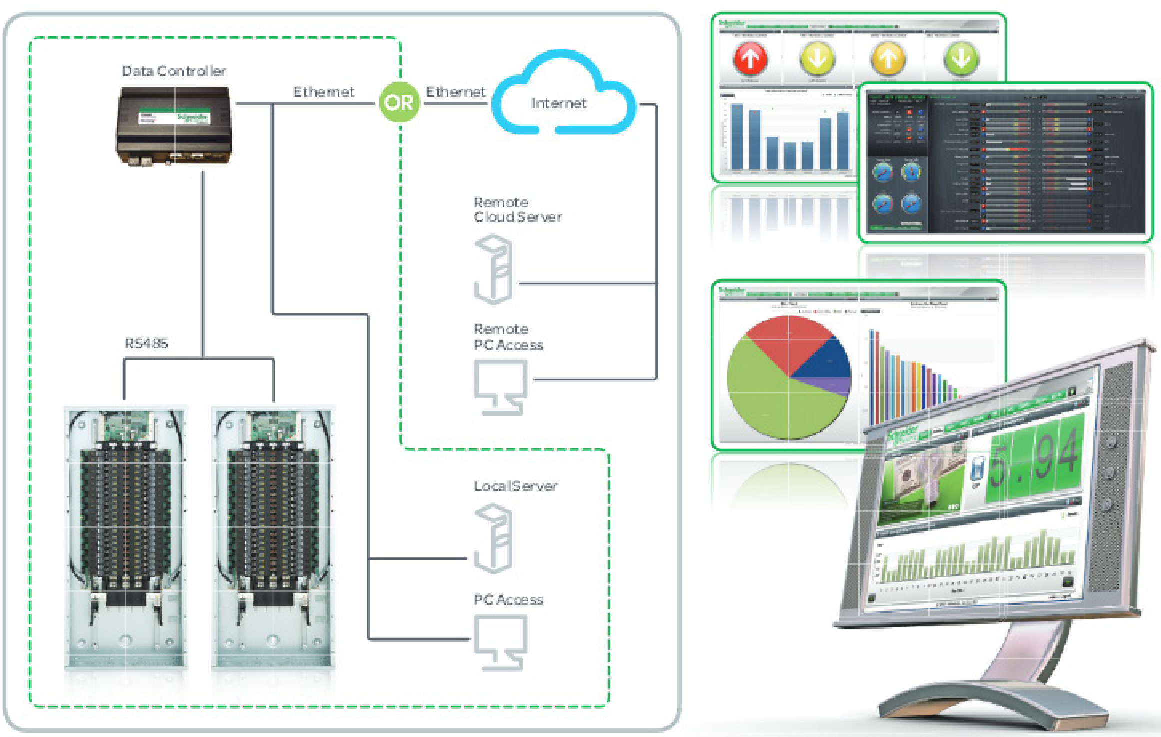


Table B.5.2 Software Integration to Servers[1]

Addressing Client's Current Energy Monitoring Needs:

The MVP solution by Schneider Electric addresses the specific needs of the client. The IIT Campus Resource Efficiency Manager has told our team that such a system would be a "great tool to managing overall peak control of the building"[2] and that the dashboard and scheduling aspects of the technology being proposed would be valuable. The automation of these systems will be a tremendous benefit to her and allow her to do her job more effectively.

B.5.3 Benefits of Increased Metering and Monitoring

Despite the important role of sub-metering in improving the energy usage of a building, its benefits are often under appreciated because they tend to be indirect. Nevertheless, the importance of obtaining accurate information through detailed monitoring should not be under emphasized. **The benefits of the monitoring retrofit can be broken down into two major categories: Information and Control.**

Informational Benefits

The installation of more metering solutions will permit a greater component-level view into the building's energy consumption as opposed to the current system-level view. This provides the operator with more information of where exactly the majority of the energy is being consumed. This information better enables the control of the system by identifying potential components that may be switched off during certain periods of the day.

With this additional information, decisions can be made to retrofit other electrical components resulting in further savings. Occupants of the building (such as dining services and the bookstore) can be charged for their electrical usage, encouraging efficiency on their part. Electrical problems can be more easily diagnosed by examining the most recent usage data. These and further informational benefits are listed in Table B.5.3.

Action	Observed Savings
Installation of meters	0 to 2% (the "Hawthorne effect")
Bill Allocation Only	2-1/2 to 5% (improved awareness)
Building tune-up	5 to 15% (improved awareness and identification of simple O&M improvement)
Continuous Commis-sioning	15 to 45% (improved awareness, ID simple O&M im-provements, project accomplishment, and continuing management attention)

Table B.5.2 Metering Savings Ranges[3]

[1]Images courtesy of Schneider Electric

[2]Personal Email, Maram Falk, 10 Apr. 2014.

[3] "Guidance for Electric Metering in Federal Buildings." U.S. Department of Energy Efficiency and Renewable Energy. 3 Feb. 2006. Web. <http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf>

Benefits of Proposed Sub-Metering
Assist in identifying effective maintenance and retrofits
Verify savings from energy improvement projects
Facilitate charge-backs to occupants (such as dining services and bookstore) to encourage energy efficiency
Provide information for better building management decisions
Quickening response time to failed system components
Allowing control of electricity at the circuit-level
Help decrease peak demand charges

Table B.5.3 Informational and Control Sub-Metering Benefits[4]

Control Benefits:

Not only do the proposed Schneider Electric MVPs allow monitoring of electrical consumption; they also allow precise control of it. The panels are capable of being programmed to turn an individual circuit on or off on a schedule or even on demand.

This feature provides many other great opportunities for energy savings, such as programming the lights to turn off every evening after the building is closed and then turn on again before it is opened. It could also be an effective way to combat the peaks in electrical usage that occur every afternoon and evening during the lunch and dinner hours by turning off non-essential circuits in the building during that time.

Savings and Return on Investment:

As Table B.5.2 shows, the amount of electrical savings depends hugely on an ongoing, continuous monitoring of the building. The energy savings greatly depend and may fluctuate. However, based on Table B.5.2, building energy savings of 25% are quite possible with continued steps to improve energy efficiency. Using this information, a payback period is calculated of 4.1 years, as shown in Table B.5.7.

The estimated yearly savings in Table B.5.7 are calculated assuming a 25% savings on 48% (the portion of the building's electricity consumed by the selected 8 panels) of the building's yearly electrical usage of 1,553,000 kWh at a standard electrical rate of $0.25/kWh. **This equates to $47,000 in savings per year.**

The cost of labor is calculated by assuming a standard Chicago union labor rate consisting of: wages, benefits, health care costs, additional overhead costs to equal an average of $100/hr shown in Table B.5.5.

Equipment	Price
Panel Controller	$3,968
Control Bus	$1,065
Smart Breaker	$237
Power Supply	$3,045
Control Software	$1,523
Total Price	**$13,867**

Table B.5.4 Estimated Equipment Cost

[4]Adapted from Submetering of Building Energy and Water Usage: Analysis and Recommendations of the Subcommittee on Buildings Technology Research and Development. National Science and Technology Council Committee on Technology. Oct. 2011. Web.

Description	Time Requirement	Cost
Remove Existing Panel	8hr	$800
Installation MVP	8hr	$800
Interconnect MVP	8hr	$800
Testing/Supervision	8hr	$800
Total labor work	32hr	$3,200

Table B.5.5 Estimated Labor

Supplies	Cost
Conduit	$2,500
Hardware	$1,000
Miscellaneous	$1,000
Network Cable	$500
Total Cost	$5,000

Table B.5.6 Estimated Supplies

Description	Cost
Installation Cost per Panel	$22,067
Installation Cost of 8 Panel	$176,536
10% Contractor Overhead	$17,653
Total Estimated Cost	$194,189
Estimated Yearly Savings	**$47,000**
Payback Time	**4.1 years**

Table B.5.7 Sub-Metering Return on Investment

From these numbers, expected savings are calculated over a 5 year period. **The total estimated savings over 5 years amounts to $235,000.** The invested cost per panel is $22,067 after adding labor, equipment, and supplies shown in Tables B.5.4, B.5.5, and B.5.6. Our proposed system uses 8 total panels which would result in a total investment cost of $194,189 with a 10% contractor overhead. After subtracting the total invested cost with our savings, the project comes to a net profit of $40,811 over 5 years.

Sub-meters are a tremendous tool toward reducing electrical consumption, but in order for energy savings to be realized the feedback from the meters must be used to support further energy improvements. The importance of laying out an effective monitoring plan cannot be overstated.

B.6 Schematic Estimate, Schedule, and Finance Plan

Overview: This section includes a sub-metering plan, proposed technologies, and benefits of sub-metering, monitoring and feedback.

Result: $739,019 savings over 5 years.

Benefits: Continue as a nationwide leader in sustainable universities as well as minimize the utility costs of energy and carbon footprint.

B.6.1 Cost Estimate

Lighting Retrofit Cost Estimate

Proposed Fixture	Manufacturer	Unit Price	Number	Cost
8W PAR20 LED	Philips EnduraLED 426122	$23	549	$12,627
14W PAR30LN LED	KolourOne LEDs S8947	$40	71	$2,840
41W LED Flood	ACUITY BRANDS 213PE5	$442	24	$10,608
16W PAR38 LED	LG P3816FC1CC1	$30	70	$2,100
28W T8 Lamp only	Philips Lighting F32T8/ ADV850/EW/ALTO	$6	120	$720
5W LED PL lamp	LEDS MALL 5W E27 LED	$11	50	$550
Total				$29,445

Table B.6.1: Proposed Lamp Cost

Supplies	Cost
Conduit	$500
Hardware	$250
Miscellaneous	$250
Distribution Wire	$1,000
Total Cost	**$2,000**

Table B.6.2: Lighting Material Cost

Description	Time Requirement hr.	Cost
Install occupancy sensor	160	$16,000
Install daylight sensor	48	$4,800
Replace Lamp	32	$3,200
Total labor work	**240**	**$24,000**

Table B.6.3: Estimated Labor Cost

Adding up labor and material costs in Tables B.6.1, B.6.2, B.6.3, **the total investment for the lighting retrofit will be $63,638 with a 10% contractor overhead.**

Solar Retrofit Cost Estimate

The cost for the solar retrofit was estimated with the collaboration of the vendor Solar Zentrum Inc. The cost includes all material and labor show in Table B.6.4. **The total cost of investment for the solar retrofit is $240,000 for a 60 kilowatt photo-voltaic system.** Because price quotes were taken directly from a vendor, contractor overhead was assumed to already be taken into account.

Components	Price per watt	Total price
Solar panel modules	$1.8/watt	$108,000
Mounts, wiring	$0.8/watt	$48,000
Inverter	$0.6/watt	$36,000
Installation	$0.8/watt	$48,000

Table B.6.4: Solar Cost Breakdown

Submetering Retrofit Cost Estimate

The cost for installation and materials for one of the proposed MVP panel boards are detailed in Tables B.6.5, B.6.6, and B.6.7. The planned retrofit will utilize eight panels resulting in **a total investment cost of $194,189 with 10% contractor overhead included.**

Equipment	Price
Panel Controller	$3,968
Control Bus	$1,065
Smart Breaker	$237
Power Supply	$3,045
Control Software	$1,523
Total Price	**$13,867**

Table B.6.5: Submetering Panel Cost

Supplies	Cost
Conduit	$2,500
Hardware	$1,000
Miscellaneous	$1,000
Network Cable	$500
Total Cost	$5,000

Table B.6.6: Submetering Material Cost

Description	Time Requirement	Cost
Remove Existing Panel	8hr	$800
Installation MVP	8hr	$800
Interconnect MVP	8hr	$800
Testing/Supervision	8hr	$800
Total labor work	32hr	$3,200

Table B.6.7: Estimated Labor Cost

All three proposed retrofits will have a total invested cost of $498,000.

B.6.2 Retrofit Schedule

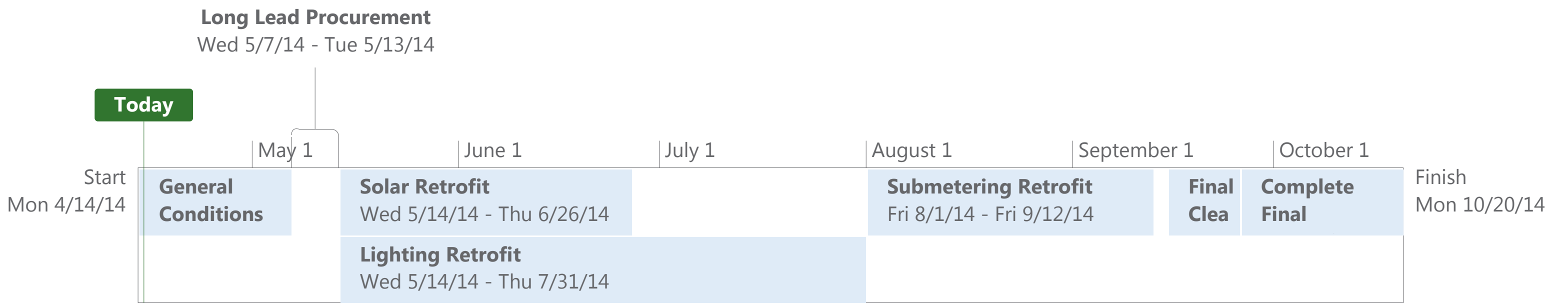


Figure B.6.1: Project Calendar

The MTCC retrofit will have **a full project duration of 6 months,** starting on April 14, 2014 with completion on October 10, 2014. Figure B.6.1 shows the total project calendar. This is based on a 5-day work week, with resources working at 8 hours per day. All aspects of the project are considered including the procurement phase, handling any necessary procedures to begin the retrofit.

Solar Retrofit

The majority of the work done for the solar retrofit will occur on the roof of the MTCC. This would not pose any problems to disrupting operations of the MTCC, but it will have implications on the service of the Green Line. Because the MTCC is placed just beneath the elevated track of the Green Line, train operators would have to proceed cautiously when construction is being conducted with the roof. The time frame for the solar retrofit is set for about 1 and a half months, and this has included any constraints that exist with working with the service of the Green Line. Table B.6.8 provides all the tasks involved in the solar retrofit including durations.

Task Name	Duration	Start	Finish	Resource Names
Solar Retrofit	**32 days**	**Wed 5/14/14**	**Thu 6/26/14**	
Prepare site - lay down yard and temporary fencing	2 days	Wed 5/14/14	Thu 5/15/14	Site Grading Contractor,G.C. Labor Crew[10%]
Install flashing at parapet walls	4 days	Wed 5/14/14	Mon 5/19/14	Roofing Contractor
Pour lightweight concrete roof fill	2 days	Tue 5/20/14	Wed 5/21/14	Roofing Contractor
Install seamless roofing material	5 days	Thu 5/29/14	Wed 6/4/14	Roofing Contractor
Spread stone ballast on seamless roof	5 days	Thu 6/5/14	Wed 6/11/14	Roofing Contractor
Set solar rooftop equipment	2 wks	Thu 6/12/14	Wed 6/25/14	Solar Contractor
Connect Solar to Site Electric	7 days	Wed 6/18/14	Thu 6/26/14	Solar Contractor[50%],Electric Contractor[50%]

Table B.6.8: Solar Retrofit Task Chart

Lighting Retrofit

Unlike the solar retrofit, the lighting retrofit will have direct implications on the operations of the MTCC. Because of the nature of retrofitting the lighting systems, which include replacing necessary electrical wiring and removing and installing new fixtures, the lighting retrofit will take twice as long as the solar retrofit. In order to prevent all operations of the MTCC from being disrupted, the retrofit will take place in three phases, the first phase will be to retrofit the Commons dining area, the second will be retrofitting Center Court, and finally the rest of the MTCC will be retrofitted. The Commons and Center Court are the primary business operations of the MTCC, both serving as dining areas. This procedure would allow the client to shut down one dining area, and keep the other open. Another advantage to the project plan is the lighting retrofit will occur right after the spring semester has ended and right before the fall semester starts. There are still students in the summer sessions, but the volume of business in the dining areas will be a quarter of what they would be in the fall or spring semesters. Table B.6.9 provides all the tasks involved in the lighting retrofit including durations.

Task Name	Duration	Start	Finish	Resource Names
Lighting Retrofit	**57 days**	**Wed 5/14/14**	**Thu 7/31/14**	
Lighting Retrofit- The Commons	**25 days**	**Wed 5/14/14**	**Tue 6/17/14**	
Restrict Access to Commons	5 wks	Wed 5/14/14	Tue 6/17/14	Facilities Director
Replace New Electrical Wiring in the Commons Area	2 wks	Wed 5/14/14	Tue 5/27/14	Electric Contrac-tor,Electric Contractor Management
Place New Light Fixtures - The Commons	3 wks	Wed 5/28/14	Tue 6/17/14	Lighting Contractor
Install Daylight Sensors - The Commons	1 wk	Wed 5/28/14	Tue 6/3/14	Lighting Contractor
Reopen the Commons for student dining	0 days	Tue 6/17/14	Tue 6/17/14	Facilities Director
Lighting Retrofit- Center Court	**10 days**	**Wed 6/18/14**	**Tue 7/1/14**	
Restrict Access to Center Court	5 days	Wed 6/18/14	Tue 6/24/14	Facilities Director
Replace New Electrical Wiring- Center Court	5 days	Wed 6/18/14	Tue 6/24/14	Electric Contractor
Place New Light Fixtures - Center Court	5 days	Wed 6/25/14	Tue 7/1/14	Lighting Contractor
Install Daylight Sensors - Center Court	2 days	Wed 6/18/14	Thu 6/19/14	Lighting Contractor
Reopen the Center Court for student dining	0 days	Thu 6/19/14	Thu 6/19/14	Facilities Director
Lighting Retrofit- MTCC	**30 days**	**Fri 6/20/14**	**Thu 7/31/14**	
Replace New Electrical Wiring- MTCC	4 wks	Fri 6/20/14	Thu 7/17/14	Electric Contractor
Place New Light Fixtures - Center Court	2 wks	Fri 7/18/14	Thu 7/31/14	Lighting Contractor
Install Occupancy Sensors- Office Area	2 days	Fri 7/18/14	Mon 7/21/14	Lighting Contractor
Install Occupancy Sensors- Bathrooms	2 days	Fri 7/18/14	Mon 7/21/14	Lighting Contractor
Install Daylight Sensors - Center Court	5 days	Fri 7/18/14	Thu 7/24/14	Lighting Contractor

Table B.6.9: Lighting Task Chart

Submetering Retrofit

The submetering retrofit will occur last. The advantage of scheduling it this way is that all the necessary hardwiring and equipment replacements will be done in parallel with the solar and lighting retrofits. The majority of the system architecture will be implemented and the next step would be wiring the systems to the MVP Panel Board. The majority of the work will then be to test the submetering system and make sure that the results of the system are in line with actual energy consumption.

B.6.3 Finance and Cash Flow Plan

Annual savings incurred from the lighting retrofit will be $79,416. The solar panels will produce 67,500 kwh annually resulting in a savings of $16,875. Finally, the submetering retrofit will have an estimated savings of $47,000 per year. All savings are based on an energy cost of $0.25/kwh.

In addition to yearly energy savings, grants and incentives have been pursued in order to help subsidize large initial investment costs. Three separate state funded grants for renewable and energy efficient programs have been found:

1. Small Business Improvement Fund (Illinois)
2. Renewable Energy and Energy Efficiency Project Financing (Illinois)
3. Solar Renewable Energy Credits (Illinois)

These three grants will result in a funded cost of $92,250. This would result in a total project budget of $406,000. With an annual savings of $144,000, the 5 year cash-flow plan is shown in Figure B.6.2.

5-Year Cumulative Cash Flow

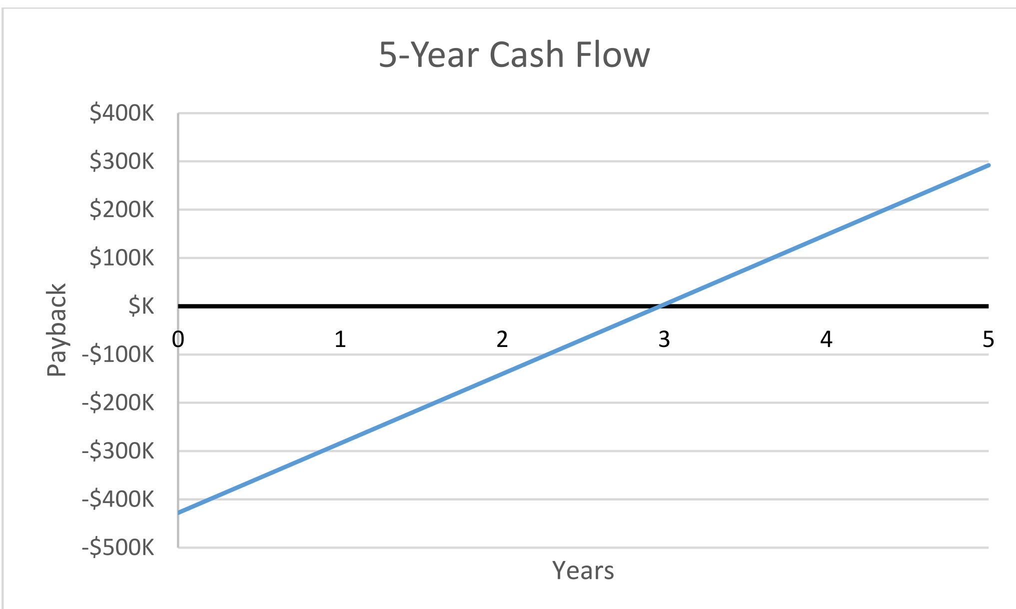


Figure B.6.2 : 5-Year Cash Flow

Overall the entire retrofit will result in a 3 year payback with a return on investment of 64%. Once the investment is completely paid back, savings will result in large energy savings. These savings will benefit the university in multiple ways, most of all lowering the utility bills, and the reputation of having a campus leading in sustainability.

C.1 Energy Awareness and Business Development

Integration with Existing Programs

Illinois Institute of Technology prides itself on its leadership in sustainability. This project was conducted for the NECA Green Energy challenge, but the bigger picture lies within its integration to the movements of sustainability within the campus. Every year the office of sustainability creates a plan for the upcoming year in how to improve the institution as a whole. This year, we are making strong efforts to have the voices of the students heard along with our technical analysis to show that it is both wanted by the student body and economically feasible to improve the energy performance of the MTCC.

Innovation in Program Design

The proposed retrofit solutions provided by the lighting, solar, and submetering data utilizes forward and modern technology. The use of this new technology will significantly improve the performance of the MTCC as well providing large economic savings for the client, Illinois Institute of Technology.

Feedback

After conducting a survey with 19 randomly selected universities students, 42% said they agreed on the importance of energy efficiency, will 37% said they strongly agreed, and 21% had a neutral opinion (Appendix C.1.1). Students at IIT are one of the largest stakeholders of the institution. The voice and opinion of students are in many ways the loudest, and if demands for increased sustainability and energy efficient systems are requested, then IIT will listen and find solutions to improve.

Future Plans of Implementation

We are happy to report that our innovative ideas and proposal for improving the IIT MTCC building are being included into the university utilities and energy improvement plans. Meetings have taken place with the Director of Campus Utilities and Energy, Jeff Barrie, and also the Manager of Resource Efficiency at the Illinois Institute of Technology, Maram Kittaneh. They have enthusiastically embraced our findings and ideas.

In addition, our report has been given to the Dean of the School of Applied Technology and distributed the Vice President for implementation. Here are sample statements by the IIT Resource Efficiency Manager, about our ideas and report: "*the energy audit has provided valuable insights…..the performance of the team has been outstanding. The results are very valuable for us as we continue to advance our university with green and energy efficiency.*" Likewise, Dean Carlson's states "*I commend the student members of the NECA Chapter…..valuable ideas and contributions for energy efficiency…it is an honor to support them.*"

Additional meetings are being scheduled in May 2014 with the IIT university utilities energy, and resource efficiency departments for discussion of actual action plans for implementation of ideas and proposals and capital budgets, time projections, and resource management. We are fortunate that our university administration has taken our ideas and proposal so seriously and that they have received such wide dissemination. We appreciate the opportunity to have been involved in this NECA Green Energy Challenge and helping our University, as well.

C.2 Feedback Letter from Client

ILLINOIS INSTITUTE OF TECHNOLOGY

Date: 4-23-14

To: NECA, Wanessa Alves

RE: NECA Green Energy Challenge Competition: Client Feedback Letter

Dear NECA:

I am pleased to support the Illinois Institute of Technology (IIT) NECA student chapter's work on the NECA Green Energy Audit of our MTCC building. The members have worked very hard to conduct an energy audit and provide us with valuable insights and recommendations for energy efficiency. The performance of the team has been outstanding. The results are very valuable for us as we continue to advance our university with green and energy efficiency. I would like to also commend the student members of the NECA chapter. They are always enthusiastic and hard-working. If you have any questions, please contact me.

Sincerely,

Maram Kittaneh

Maram Kittaneh
Resource Efficiency Manager
Energy Efficiency
Office of Campus Energy and Sustainability (OCES)
Illinois Institute of Technology
100 W. 33rd St. Suite 200
Chicago, IL 60618

C.3 Article in Department Newspaper

IPRO 338 participates in NECA Challenge

By: Charles Rivas
Date: Saturday, April 19th, 2014

TechNews
Student newspaper of Illinois Institute of Technology since 1928

Dr. Tomal's IPRO 338 will be competing in ELECTRI International and the National Electrical Contracting Association's (NECA) 5th annual Green Energy Challenge! The challenge entails us, as NECA chapter members, to design a retrofit to improve energy efficiency for a Student Union Building. Our building of choice was the famous McCormick Tribune Campus Center located directly under the steel tube.

Constructed in 2003, the MTCC was built in order to accommodate student activities for the Illinois Institute of Technology and Shimer College. The building was designed by famous Dutch architect Rem Koolhaas, who was chosen through a competition held in 1997 through 1998. The Center carries important architectural significance due to its relationship with Mies Van Der Rohe's vision, as it is the first planned addition to Mies' grand design of the campus. The Campus Center itself directly connects to one of Mies' buildings called The Commons. Much of Rem Koolhaas' design was influenced by satellite images of the site. Koolhaas noticed paths in the grass that had been made by students, which ended up defining the circulation inside and outside the building. Today, the MTCC has become central for student activities and as a representation of the university itself.

The next part of our challenge was to conduct an energy audit of the power and lighting systems within the building. The results from the audit were very surprising. We found that the MTCC is anything but energy efficient. Although it is a newer building, it needs some updating. After our audit we were able to find the major flaws within the MTCC. To fix these flaws we designed an energy retrofit for power and lighting systems. Along with those retrofits, we plan to add in a more efficient sub-metering system and even have plans to use solar energy. With our proposed plan we can save $75,000 annually in just lighting retrofits alone.

To get a more in-depth look at our IPRO's work, come by our booth during IPRO day - Friday, April, 25 2014! Look for IPRO 497-338 - Developing Insights for Energy Efficiency Improvement. This IPRO is led by Professor Daniel Tomal and Team Leader Ivan Jose, the Power Team consists of Yoon Chye Lee, Ye Tian, Xuehai Shao, Yuanbin Wang and Yanyan Jiang. The HVAC Team consists of Briana Villagrana, Abbas Palgharwala, Soonen Ahua and Abhiroop Chattapadhyay. The Lighting Team consists of Sima Mustaklem, Yiyun Fan, Fengrui Yang and Ming Chen.

C.4 Local NECA Interaction

ECA

Electrical Contractors' Association
of City of Chicago, Inc.

April 28, 2014 (Updated listing)

Ms. Wanessa Alves
NECA Director, Member Relations
3 Bethesda Metro Center, Suite 1100
Bethesda. MD 20814

Dear Wanessa:

I am writing in regard to a prerequisite for the 2014 NECA Green Energy Challenge; specifically, Section C: Outreach, Item #4: Local NECA Chapter Interaction. On behalf of the Chicago & Cook County Chapter, NECA, we are pleased to support the IIT NECA student Chapter for the *Green Energy Challenge* competition by providing examples of interaction with the Chapter. As the sponsor of the IIT chapter, our Student Committee and overall membership continues to be regularly involved with the students in a variety of activities.

Listed below are a number of those activities:

- NECA presentation, T. Taylor, 9-19-13
- Electrical Grid System, Mehdi Ganji, 11-14-13
- NECA Overview, T.Taylor, 1-28-14
- Conducting an Energy Audit, Brian Earl, Connexion, Inc. 3-11-14
- ChicaGo Green Energy Workshop, 1-16-14
- Presentation & meeting at Chicago Chpt., NECA office on energy audit project, 11-11-13
- Presentation at Chicago Chpt., NECA office on energy project and chapter, 2-20-14
- Meeting at Chicago Chpt., NECA office on energy project and progress, 3-6-14
- Meeting on energy progress at IIT with Gurtz Electric Company, 3-31-14
- Student Internships with various NECA member companies in Fall and Spring
- Meeting/presentation at Chicago Chpt., NECA on Energy Challenge project, 4-21-14
- Student Chapter working with IIT IPRO wins track in IPRO Competition, 4-25-14

In addition to the above listed activities, our office has had many telephone and e-mail conversations with the student chapter members, students have contacted several of our member contractor companies regarding topics for meetings, as well. We are pleased to sponsor and work with this NECA Student Chapter.

Sincerely,

Timothy A. Taylor

Tim Taylor
Assistant Manager

Appendix B.3.1: Energy Saving Analysis

Sections	Action	Days / Week	Hours / Day	Control Savings(%)	Old Watts	New Watts	Affected Fixtures	Total kW	Annual kWh	Annual Savings
General Lighting Upgrade	Replace - 45W PAR20 w/ 8W PAR20 LED	7	24		45	8	350	13	113,566.3	$28,391.58
	Add Daylight Sensor - Existing 6 lamp 4’ 28W T5	7	24	0.6	168		36		31,923.1	$7,980.78
Pritzker Club Area	Replace - 75W PAR30 w/ 14W PAR30LN LED	7	12		75	14	71	4.33	18,986.2	$4,746.55
	Replace - 50W PAR20 w/ 8W PAR20 LED	5	12		35	8	15	0.63	1,973.2	$493.30
	Add Occupancy Sensor - 35 W Ceramic Metal Halide	5	12	0.6	35		15		986.6	$246.65
	Add Daylight Sensor - Existing 75W PAR30	7	24	0.6	75		17		6,708.7	$1,677.18
	Add Daylight Sensor - Existing 28W F28 T5	7	24	0.6	28		6		884.0	$221.00
Post Office Area	Replace - 150W CDM150 T6 w/ 41W LED Flood	7	24		150	41	5	0.55	4,823.3	$1,205.83
	Replace - 50W PAR20 w/ 8W PAR20 LED	7	24		50	8	34	1.43	12,540.5	$3,135.13
	Replace - 90W PAR38 w/ 16W PAR38 LED	7	24		90	16	7	0.52	4,560.2	$1,140.05
	Add Daylight Sensor - Existing 32W T8	7	24	0.6	32		13		2,188.9	$547.23
The Commons Cafeteria	Relamp - 2-lamp 32W T8 w/ 28W T8 Lamp only	7	24		64	28	51	1.84	16,136.1	$4,034.03
	Add Occupancy Sensor - Existing 2-lamp 32W T8	7	24	0.6	64		51		17,174.4	$4,293.60
	Add Daylight Sensor - Existing 2-lamp 32W T8	7	24	0.6	64		36		12,123.1	$3,030.78
Conference Room Area	Relamp - 2-lamp 32W T8 w/ 28W T8 Lamp only	7	24		64	28	29	1.05	9,208.1	$2,302.03
	Replace - 500W Halogen Flood w/ 41W LED Flood	5	8		500	41	19	8.72	18,207.4	$4,551.85
	Replace - 90W PAR38 w/ 16W PAR38 LED	5	8		90	16	63	4.66	9,730.1	$2,432.53
	Add Occupancy Sensor - Existing 2-lamp 32W T8	7	24	0.6	64		29		9,765.8	$2,441.45
Coffee Kiosk Area	Replace - 13W PL CFL lamp w/ 5W LED PL lamp	7	8		13	5	50	0.4	1,169.3	$292.33
Office Area	Relamp - 2-LAMP 32W T8 w/ 28W T8 Lamp only	5	12		64	28	40	1.44	4,510.1	$1,127.53
	Add Occupancy Sensor - Existing 2-lamp 32W T8	5	12	0.6	64		40		4,810.8	$1,202.70
	Add Daylight Sensor - Existing 2-lamp 32W T8	7	24	0.6	64		10		3,367.5	$841.88
Total								38.5	305,343.7	$76,335.93

Appendix B.3.2: Maintenance Saving Analysis

Existing				New				
Sections	Fixture Type	Lamp Life (hour)	Lamp(s) Cost / Fixture $	Fixture New	Lamp Life (hour)	Lamp(s) Cost /Fixture $	Fixture Numbers	Annual Main-tenance Savings
General Lighting Upgrade	45W PAR20	20000	15	8W PAR20 LED	45000	23	350	733.2
Pritzker Club Area	75W PAR30	2000	7	14W PAR30LN LED	25000	40	71	1183
	50W PAR20	2000	5	8W PAR20 LED	45000	23	15	261.6
Post Office Area	150W CDM150 T6	12000	27	41W LED Flood	100000	442	5	-95.2
	50W PAR20	2000	5	8W PAR20 LED	45000	23	34	593
	90W PAR38	2000	5	16W PAR38 LED	25000	30	7	79.8
The Commons Cafeteria	2-lamp 32W T8	20000	8	28W T8 Lamp only	30000	6	51	89.4
	500W Halogen Flood	2000	3	41W LED Flood	100000	442	19	-486.5
	90W PAR38	2000	5	16W PAR38 LED	25000	30	63	718.2
Conference Room Area	2-lamp 32W T8	20000	8	28W T8 Lamp only	30000	6	29	50.9
Coffee Kiosk Area	13W PL CFL lamp	10000	3	5W LED PL lamp	30000	11	50	-29.2
Office Area	2-lamp 32W T8	20000	3	28W T8 Lamp only	30000	6	40	-17.5
Total								3080.7

Appendix B.3.3: Sensor Cost

Sensor Type	Manufacturer	Unit Price $	Number	Cost
Occupancy Sensor	Lutron MS-OPS2	29	52	$1,508
Daylight Sensor	Lutron LRF2DCRB	90	10	$900
total				$2,408

Appendix B.3.4: Lamp Costs-

Proposed Fixture	Manufacturer	Unit Price $	Number	Cost $
8W PAR20 LED	Philips EnduraLED 426122	23	549	12,627
14W PAR30LN LED	KolourOne LEDs S8947	40	71	2,840
41W LED Flood	ACUITY BRANDS 213PE5	442	24	10,608
16W PAR38 LED	LG P3816FC1CC1	30	70	2,100
28W T8 Lamp only	Philips Lighting F32T8/ ADV850/EW/ALTO	6	120	720
5W LED PL lamp	LEDS MALL 5W E27 LED	11	50	550
total				29,445

DE-60 PREMIUM

Solar Zentrum North America
innovational solutions

General				
Cells	60 (10 x 6) monocrystalline BOSCH cells	Cellsize	156 x 156 mm	6.14 in x 6.14 in
Frame	Anodized aluminium	Front glass	3.2 mm (0.13 in) Solarglass	
Connection	Junction box with 3 bypass-diodes	Wire length	4 mm² Solar cable, 1000 mm /.157 in² 39.37 in	
Connector	MC4 compatible	Power tolerance	Positive-only tolerance 0 to +4.99Wp	

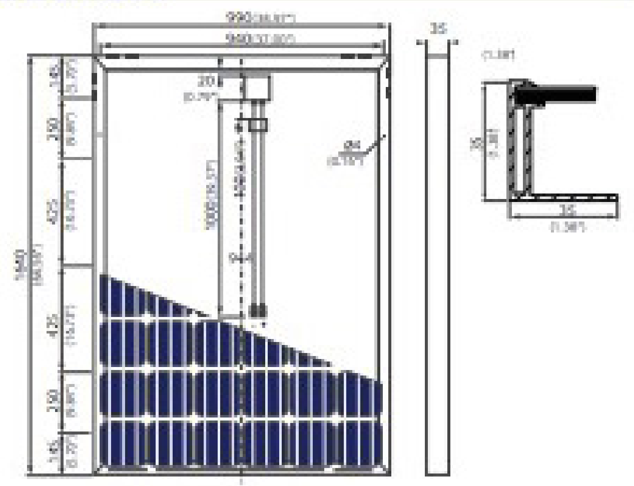
Electrical Data (STC)						
Moduletype			DE-C245M-P	DE-C250M-P	DE-C255M-P	DE-C260M-P
Nominal power	P_{MPP}	Wp	245	250	255	260
Max. power voltage	U_{MPP}	V	30.11	30.31	30.51	30.71
Max. power current	I_{MPP}	A	8.14	8.25	8.36	8.47
Open-circuit voltage	U_{OC}	V	37.80	37.90	38.00	38.10
Short-circuit current	I_{SC}	A	8.72	8.82	8.92	9.02
Module efficiency	η %		14.78	15.09	15.40	15.71
Electrical Data (NOCT)						
Nominal power	P_{MPP}	Wp	178	182	185	189
Max. power voltage	U_{MPP}	V	27.19	27.36	27.54	27.70
Open-circuit voltage	U_{OC}	V	34.73	34.82	34.92	35.01
Short-circuit current	I_{SC}	A	7.03	7.11	7.19	7.27

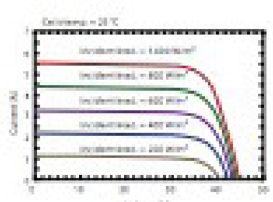
At a low irradiation intensity of 200 W/m² (AM 1.5, cell temperature 25 °C) 96 % of the STC module efficiency will be archived.

STC = Standard Test Conditions (1000 W/m², AM 1.5, cell temperature 25 °C)
NOCT = Normal Operating Cell Temperature (800 W/m², AM 1.5, windspeed 1 m/s, ambient temperature 20 °C)

Temperature coefficients		
Temperature coefficients I_{SC}	+0.031 % / K	
Temperature coefficients U_{OC}	-0.31 % / K	
Temperature coefficients P_{MPP}	-0.44 % / K	
NOCT	48 °C ± 2 °C	118.4°F ± 35.6°F
Limits		
Maximum system voltage	600V / 1000 V	
Maximum reverse current	25 A	
Operating temperature	-40 °C - 80 °C	-40°F - 194 °F
Maximum load	5400 Pa/m² = 550 kg/m² (75 lbs/ft²)	
Safety class	II	
Certifications and warranty		
TÜV	IEC 61215 / IEC 61730 / 1703 LV.	
Product warranty	10 years	
Performance guarantee	linear 25 years	
Mechanic Data		
Dimensions (± 1 mm / 0.03 inch)	1.640 x 990 x 35 (64.56" x 38.97" x 1.38"/1.97")	
Weight	18 kg | 39.68 lbs	
Packing configuration	**RH35**	
Modules/Cardboard	30	
Cardboard/Container	28	
Modules/Container	840	

Technical drawing





PV CYCLE · IEC · CE

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Osgood, Indiana 47037	
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	www.szna-usa.com

Your Solarzentrum North America Dealer:

All figures are according to DIN EN 50380.
Tolerance at rated power 0 to +4.99 Wp. All other specifications ± 3%.

Appendix B.4.1: Solar Zentrum PV Module Data Sheet

Specifications

R3 inverter	2100 S	2800 S	3100 S	3800 S
DC Input				
Max. PV power	2,300 Wp	3,200 Wp	3,450 Wp	4,200 Wp
Max. DC power (@ cos phi = 1)	2,100 W	2,800 W	3,100 W	3,800 W
MPPT voltage range	206 ... 380 V	313 ... 630 V	314 ... 630 V	315 ... 630 V
Max. input voltage	480 V	780 V		
Max. MPPT inout current	9 A			12 A
Number of string inputs	1			2
Number of MPP trackers	1			
DC disconnector	o			
DC short circuit current	13 A			17 A
Reverse polarity protection / Ground fault monitoring (isolation check)	• / •			
AC Output				
Rated power (@ cos phi = 1)	1,750 W	2,400 W	2,650 W	3,300 W
Rated current	7.6 A	10.4 A	11.1 A	14.3 A
Max. apparent power	1,900 VA	2,600 VA	2,800 VA	3,600 VA
Max. AC current	8.3 A	11.3 A	12.2 A	15.7 A
Power feed starts at	13 W	14 W		18 W
Mains output voltage	230 V (+/-20 %)			
Feed in phases / connection phases	1 / 1 or 3			
Max. permitted grid impedance (Zmax) (EN 61000-3-11)	–			
Standby consumption	2.5 W			
Mains frequency	50 Hz (+/-5 %)			
Power factor (cos phi) (ind ... kap)	1			
Short circuit resistance / Ground fault monitoring (RCD)	• / –			
Interfaces				
DC connection	MC4			
AC connection	Wieland RST 3i / 5i			
RS 485 (Clamps / RJ45)	• / •			
Ethernet / CAN	– / –			
Integrated web server	–			
Alarm relay	24 V_{AC} / 2 A			
Appliance data				
Max. efficiency	94.7 %	95.3 %		95.6 %
European efficiency	93.7 %	94.4 %		94.6 %
Weight	30 kg	35 kg		42 kg
Dimensions (H x W x D in mm)	720 x 320 x 250			
Operating temperature	-20 ... +60 °C			
Storage temperature	-25 ... +80 °C			
Relative humidity	0 ... 95 %			
Altitude at rated power	2,000 m / 6,560 ft			
Protection degree (except digital interface)	IP 54			
Protection class / overvoltage category	I / Type 3			
Full graphic display (color / monochrome)	– / •			
Storage capacity data logger	30 years			
System topology	LF transformer			
Cooling	Convection	Fan		
Standards / grid codes	VDE 0126-1-1, G83/1, G59/2, EN 50438, EN 50178, ÖNORM E8001-4-712, UTE C15-712-1			
Warranty	10 years			
Type designation	**2100 S**	**2800 S**	**3100 S**	**3800 S**

Subject to alterations. Valid as of 04/2013. More than 45 countries are currently supported. The current list is available from the download area of our homepage www.platinum-nes.com
In order to comply with legal requirements, this model is no longer approved for the German market.

• Standard   o Optional   – Not available

Appendix B.4.2: Solar Zentrum Platinum S Inverter Spec Sheet

Appendix C.1.1: MTCC Energy Survey and Results

MTCC Energy Survey

1. The MTCC is a leading example of an energy efficient building.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

2. I find the indoor air temperature of the MTCC to be comfortable.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

3. It is important to me that the MTCC and our campus to be energy efficient.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

4. The lighting in the MTCC is sufficient for me to do my work or comfortably enjoy my meal.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

5. The MTCC optimizes its use of daylighting.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

6. In the summer, the orange hallway past the IIT radio station is warmer than other areas.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

7. The Mies van der Rohe figure on the main entrance is significant to the design of the MTCC.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

8. I enjoy spending time at the MTCC.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

9. I enjoy eating at the Commons and/or Center Court.
strongly disagree ○ disagree ○ neutral ○ agree ○ strongly agree ○

MTCC Energy Survey									
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Strongly Disagree	2	2	0	1	1	0	0	0	3
Disagree	2	3	0	2	7	0	2	1	3
Neutral	12	4	4	1	4	5	8	6	8
Agree	2	8	8	10	4	5	7	7	4
Strongly Agree	1	2	7	5	3	9	2	5	1