Green Energy Challenge – From Green Building to Smart/DC Building

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Abstract

Environment impact and continuously increasing energy costs are driving the construction industry to pursue new design and technology alternatives. A thorough understanding of the science of building performances and effective design is required to achieve maximum energy efficiency and best cost-performance ratio. Therefore, a paradigm shift is needed in a university's curriculum by adding new materials and endeavors to train future workforce facing the challenges of green energy construction. Students enrolled in the construction management program at Wayne State University Engineering Technology Division are encouraged to participate in the annual ELECTRI International/NECA Student Chapter Competition on electrical construction managing projects. The main competition component is the challenge to propose an energy upgrade design and simulation for a facility providing community services to achieve a net zero facility by incorporating energy saving measures and distributed energy resources based on the unique needs of the buildings and climate. Students are expected to provide detailed technical solutions in the proposal by examining the past year utility expenses, planning the renovation design, estimating new system costs, and demonstrating energy efficiency improvements. In addition, students are required to seek funding sources, such as state grants and tax benefits.

In this paper, we present students' competition projects, discuss the last projects' assessments, and demonstrate new approaches and tools such as software introduced in the projects. The center is a non-profit human service agency that provides compassionate, expert comprehensive services to children and families impacted by abuse, developmental disabilities, and mental health challenges. The students have assessed existing conditions of the Center facilities and are making plans to save energy and costs for this year's (2019) competition. In addition, we introduce DC power grid and smart building components in this year's competition proposal for further improvement of energy efficiency. Competition results and student assessments are also discussed.

1 Introduction

Environmental impacts and continuously increasing energy costs are driving the construction industry to pursue new design and technology alternatives. There are generally two ways to improve power efficiency in a building, one is adopting alternative energy sources and integrating them to the current power grid, while the other is replacing electric devices by energy saving counterparts and improving the overhaul of the building's efficiency. Therefore, new materials and endeavors are needed for university construction management curriculum to train future workforce facing the challenges of green energy construction, including inputs from other engineering disciplines.

The best way for construction management students to apply the knowledge from the classroom, gain practical experiences, and build connections with suppliers is doing a project based on a real case. The annual ELECTRI International/NECA Student Chapter Competitions on electrical construction managing projects [1] provide such kind of opportunity for university students and faculty advisors with an engaging and fulfilling annual event that helps foster meaningful interaction between students, their community, and NECA member companies. The main competition component is the challenge to propose an energy upgrade design and simulation for a facility providing community services to achieve a net zero facility by incorporating energy saving measures and distributed energy resources. The proposed systems for upgrading facilities include lighting and integrated window treatments/controls, and the re-design of an energy efficiency program that responds to the unique needs of the building and climate. Students are expected to provide detailed technical solutions in the proposal by examining the past year utility expenses, planning the renovation design, estimating new system costs, and demonstrating energy efficiency improvements. In addition, students are required to seek funding sources, such as state grants and tax benefits.

The criteria of the competition include not only technical factors but also broader impacts to the community. Student teams participating the competition are required to create a volunteer plan of interaction with the client organization and demonstrate the activities and number of hours they volunteered towards the mission of the organization in the proposals. Teams will be expected to develop a relationship with the beneficiaries of their chosen community organization through volunteer efforts prior to submitting the Green Energy Challenge proposal. Students enrolled in the construction management program at Wayne State University Engineering Technology Division participated in the 2017, 2018, and also 2019 competitions collaborating with local charity organizations including Covenant House, Focus: HOPE, and Judson Center.

New technologies are continuously introduced in constructions, including smart building, or building automation, a technology that integrate sensors, network, and microcontrollers for life conveniences, home security, and energy saving by managing lighting, climate, entertainment systems, and appliances. More and more digital equipment including smart building devices, solar photovoltaic (PV), storage batteries, electric vehicles (EV), CAV infrastructures, and other end-use devices requiring DC power enter our world, reviving discussions on DC power grids across the nation. When a home goes green, for instance PV on the roof and an EV in the garage, the overall efficiency of the system is much higher if the power generated by PV is never converted to AC [2]. If there is an energy storage (battery) buffering the PV, then there is no reason to lose energy converting subsequently between AC and DC, an unnecessary, extra step costing energy. DC is an alternative that costs no energy in conversion and plays an important role in building grid systems, affecting the connected macro-grid. Therefore, the DC power framework is first introduced in the 2019 student proposal for the Green Energy Challenge competition.

The paper is organized as what follows. In section 2 we briefly present the 2017 and 2018 student proposals submitted to the ELECTRI International/NECA Student Chapter Competitions on electrical construction managing projects. We also introduce the smart building and DC building technologies and demonstrate how they are integrated in the 2019 student competition proposal. Section 3 is dedicated to results and discussions, and we conclude in section 4.

2 Projects

2.1 2017 competition proposal

The 2017 project is collaborating with Covenant House Michigan (CHM), which is a youth homeless shelter located in the city of Detroit that offers a place to stay for young adults between the ages of 18 and 24. CHM aims to provide services that address, not only the issue of homelessness, but, also, issues that coincide with homelessness. The crisis care center consists of a 45-bed shelter providing a warm and welcoming space for youths. They are not only given food, a bed, and a safe place to stay, but also offered medical and mental health services as well as life guidance and supports. The Rights of Passage segment is a two-year independent living program where the residents have opportunities to continue their education and learn essential life skills to make it out in the real world and obtain careers that would change their lives. CHM sits on a 5.3-acre campus that consists of two residential programs, a dining and recreation center, and job development center.

Technical Analyses of the facility

Three CHM buildings were proposed to upgrade: Caritas Crisis Center, Rights of Passage, and the

Chapel. The Caritas Crisis Center, built in 1973 with an area approximately 6480 ft^2, serves as a 90-day shelter for youth coming directly off the streets. After the 90-day limit in the crisis center, residents have the option to leave or to continue to stay at CHM, in which case they would then transition to the Rights of Passage facility. Rights of Passage (ROP), built in 1965 with an area approximately 6480 ft^2, houses residents the two-year independent living program where they can continue their education, save money, and further their life skills. The Chapel serves mainly as an activity center, with an area approximately 5000 ft^2 built in 1973. The technical analyses focused on three aspects: energy efficiency analysis, lighting retrofit, and solar energy system.

Existing Lighting - Caritas			
Light Fixture Description	*Lamps per Fixture*	*No. Fixtures*	*Energy Consumption*
13 Watt Compact Fluorescent	1	21	2,158
T8 Fluorescent	4	56	1,792
T8 Fluorescent	2	28	896

Existing Lighting - ROP			
Light Fixture Description	*Lamps per Fixture*	*No. Fixtures*	*Energy Consumption*
32 Watt 12" Circline Fluorescent	1	21	672
26 Watt Compact Fluorescent	1	26	676
T8 Fluorescent	2	46	1472
T9 8" Circline	1	2	44
60 Watt Incandescent	1	12	720

Existing Lighting - Chapel			
Light Fixture Description	*Lamps per Fixture*	*No. Fixtures*	*Energy Consumption*
T12 Fluorescent	4	29	3712
65 Watt Incandescent	1	3	195
60 Watt Incandescent	1	3	180

Table 1 The list of lighting fixtures, controls, and energy consumptions of the three buildings

Technical Analysis 1: Energy Efficiency Analysis

- Assessment of Existing Conditions

  The lighting fixtures, controls, and energy consumptions of the three buildings are summarized in Table 1. For HVAC, Caritas has five furnace/condenser units that consist of a warm air furnace and freon infused coil condensers. The warm air furnaces run on natural gas, having an input of 80,000 BTU/H and an output 76,000 BTU/H, with a 94.3% efficiency rating. ROP has three furnace/condensing units like those in Caritas. The units have an input of 80,000 BTU/H and an output of 76,000 BTU/H running at an energy efficiency rating of 95.5% on natural gas. Chapel has two old furnace/condensing units installed in 1973 but never replaced, and they have relatively low energy efficiency. The ductwork of the three facilities is poorly sealed and poorly insulated. For building envelopes, all three have slab-on-grade foundation construction with no sub floor insulation. The exterior wall envelope for all buildings is masonry on brick construction with an overall R-15 wall assembly value. There are 26 - 3’-0” X 5’-0” double pane vinyl windows in both the Caritas and ROP dormitories with a U value of 0.3, Solar Heat Gain Coefficient of 0.22, and Window Visible Transmittance of 0.51. The roof on all buildings is shingle and shakes construction with 10” of fiberglass roll insulation and an overall R-15 roof assembly value.

- Facility Benchmarking

  Portfolio Manager [3] is a resource management tool used to track and assess energy and water uses across the entire portfolio of buildings. The Chapel received a score of 117.4 kBTU/ft^2, which is 68.1% worse than the median. ROP and Caritas shared the same score of 216.5 kBTU/ft^2, which is 88.4% worse than the median, as shown in Figure 1. The U.S. Department of Energy's Building Energy Asset Score is a national standardized tool for assessing the physical and structural energy efficiency of commercial and multifamily

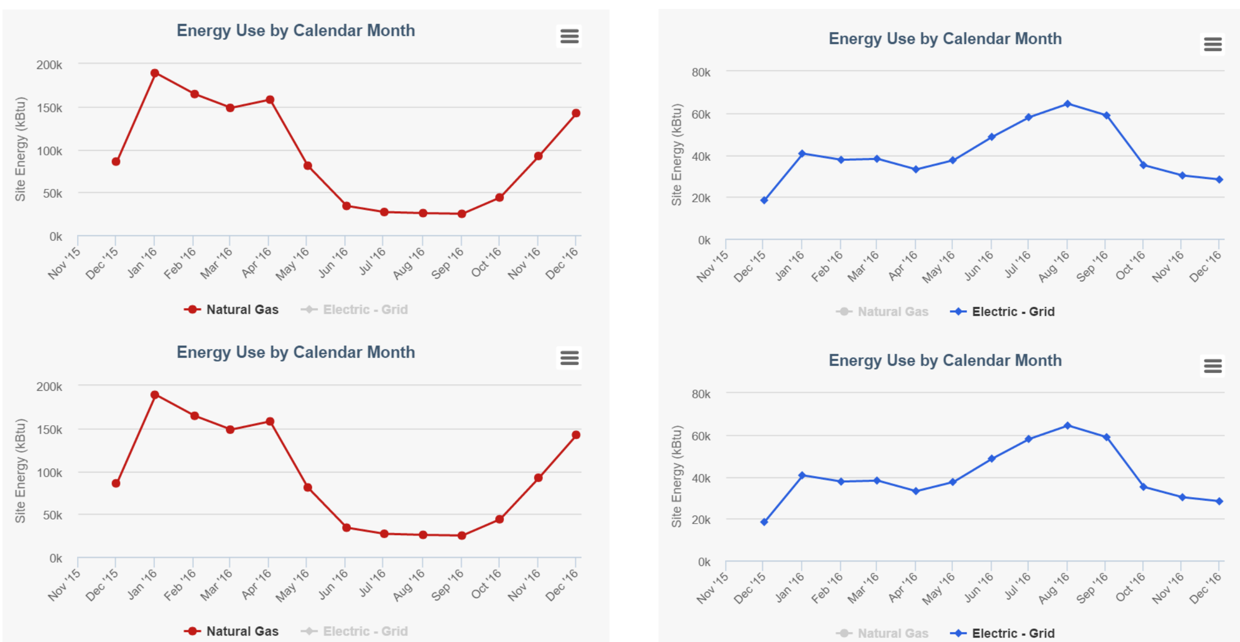

Figure 1 Upper: Dormitory natural gas and electricity usage. Lower: Chapel natural gas and electricity usage

  residential buildings. The Asset Score generates a simple energy efficiency rating that enables comparison among buildings and identifies opportunities to invest in energy efficiency upgrades. The ROP and Chapel both scored an 8.5 and Caritas scored a 9.0. Cost effective upgrade opportunities were found in the building envelope, interior lighting, and HVAC system.

- Recommendations

  The team concluded that there are multiple ways to upgrade the energy efficiency of the three buildings. Some short-term ideas are: light occupancy sensors, LED exit signs, new weather stripping for doors, replacing furnace filters, sink aerators, implementing a recycling program, and investing in energy star appliances. Thermal imaging photographs indicated the largest available savings were associated with heat loss and air leakage. Insulation improvements can be implemented in the following areas: slab-on-grade, roof, windows, and piping. The long-term ideas include rearranging thermal units in the three buildings. It was recommended that two of the five furnaces/condensing units can be retrofitted into the Chapel building to save about $12,000 for new ones. It was proposed to repair all the existing duct work in the three facilities with a unit cost $3.00 per square foot, and the pay back for the repairs was estimated five years.

Technical Analysis 2: Lighting Retrofit

The goal for the lighting upgrade is saving energy while producing more light. Two major points were proposed: LED lighting and a wireless control system. The use of LEDs boasts an annual savings of 62% in operating costs and wattage. All 223 fixtures were proposed to be replaced. The RAB Lighting's manufacturing numbers and the corresponding replacements are:

- DLED6R12Y @12W: 13W compact fluorescent and 26W compact fluorescent
- SK16XL20RY @20W: T8 Circline and T9 Circline
- GUS4-36YNW/D10 @36W: T8s
- SWISH2X4-39N/D10 @ 39W: T12s

The RAB Lighting's Lightcloud Controller is a light control system with a wireless based system that is accessed via the internet. It measures, tracks, and even estimates power usage. The controller is also integrated with the system with ceiling mounted sensors and dimmer switches. The control system adds an additional 50% savings to the proposed system without controls. The controlled system can save over 81% of current usage, while increasing the illuminance drastically and adding a sense of security and structure by its programmability.

Technical Analysis 3: Solar Energy System

Google Project Sunroof [4] is a new tool estimating solar energy a rooftop could potentially produce. The rooftops of Caritas Center, ROP, and Chapel were identified to be able to hold rooftop arrays for their nearly southern orientations with few obstacles blocking sunlight. The planned photovoltaic (PV) system was recommended to be connected in parallel with the local utility by so called "Net Metering" approach. The redundant power generated from PV will be sent to the grid with a credit in the utility bill each month. The category of 0 to 20 kW for Net

Metering has a 100% credit so that 20 kW was chosen as the planned PV system size.

To meet the 20kW threshold, 71-280 W SolarWorld Sunmodule Plus solar panels, for a total output of 19,880 W, were planned. All modules will be arranged on the ROP rooftop in four strings and mounted to the roof with Ironridge Flush Mount rack systems. SolaDeck wiring enclosure was selected as a weather proof combiner box and pass-through for the roof sheathing. The module power output will be interconnected with the existing infrastructure using two SolarEdge SE7600A single phase inverters to convert from DC power to AC. The inverters provide power to existing loads and send redundant power to the grid through net metering.

The preliminary cost of the photovoltaic system was quoted at $49,790 by Michigan Solar Solutions, including PV modules, inverters, the roof mounting, custom made PV cables, grounding clips and lugs, and the wiring enclosure, but excluding labor or materials. Assuming a 20-year life expectancy of the array for this project, the modules and the DC optimizers are covered by a 25-year limited warranty. However, the two inverters carry only a 12-year warranty, expecting a replacement prior to the full life expectancy of the array or an extension of the warranty with a small additional cost.

Schematic Estimate, Schedule, and Finance Plan

The cost estimate captures materials, labor, general conditions, overhead, and profit. The detailed cost was estimated by ConEst [5], where the breakdown for the project is shown in Table 2. Labor costs were calculated based on the 2016-17 local union rates from the Southeastern Michigan Chapter of NECA. An overhead of 12% is substantial based on typical contractor overhead percentages. In addition, an 8% profit was set as a good margin for a competitively bid project.

Detailed Estimate Breakdown	
Trade Activity	*Bid Total*
Solar	$49,790.00
Lighting	$12,000.00
Lighting Controls	$25,550.00
Labor Cost	$30,782.03
Material Cost	$6,180.35
General Conditions	$5,073.23
Overhead	$14,783.43
Profit	$11,532.72
Total	$155,691.76

Table 2 Detailed Cost Estimate Breakdown

Construction was planned to begin in late spring or early summer which allows the residents on campus to avoid the construction work. The project's schedule consists of thirty-five activities and will take twenty-five days to complete.

Many possible ways to fund this project had been reached out because the client did not have the liquid funds. One of the possible funding solutions is using NECA E-Cap. NECA E-Cap is a great financial option that we recommend to our client. However, this option can only be offered by NECA contractors. Another possible funding opportunity is CollectiveSun, an organization that is nationwide that exclusively helps nonprofit

Return on Investment	
Initial Cost	$155,691.76
Incentives	$2,176.79
Total Cost	$153,514.97
Total Annual Savings	$413,771.25
Payback Period	10.78 Years

Table 3 Return on Investment.

businesses fund solar projects with no upfront cost and low interest rates (0-10%). Grant opportunities were the Kresge Foundation ($100,000+ available), the DTE Foundation ($10,000+ available), and the Fred A. and Barbara M. Erb Foundation ($30,000 to $75,000 available). In addition, some companies offered donation of parts. The return on investment was calculated based on a 25 years life span, shown in Table 3.

2.2 2018 competition proposal

The 2017 project is collaborating with Focus: HOPE (FH), established by Father William T. Cunningham, Father Jerome Fraser, and Eleanor Josaitis, a nationally recognized civil and human rights organization whose mission recognizes the dignity and beauty of every person, pledges intelligent, and practical action to overcome racism, poverty, and injustice. With the objective of building a metropolitan community where all people may live in freedom, harmony, trust and affection by addressing the problems of hunger, economic disparity, inadequate education, and racial divisiveness through its three primary programs: Food, Career, and Community. In partnership with federal and state agencies, Focus: HOPE provides 41,000 low-income seniors with monthly food packages to help ensure basic needs are met. Since starting workforce development programs in 1981, Focus: HOPE has helped over 13,000 men and women establish successful careers. The Career Development Program curriculum has been developed in partnership with local employers to ensure students develop marketable skills.

Technical Analyses

Focus: HOPE has several buildings in the facility, and the Net Zero Plan was focused on Buildings A and B. Building A, built in 1928, was established as an educational intuition for skilled trades. Building B, built in 1935, was established as a storage facility and is currently in use. Building A is 85,999 Sqft and is broken down in to three sections: a main section including office spaces, classrooms, and a workshop with machinery for educational use. Building B is 414,546 sqft and mainly serves as a warehouse for donated food storage with a 3,000 sqft walk-in cooler for perishables. This building also has loading docks and office space.

Technical Analysis 1: Energy Efficiency Analysis

- Existing Condition Assessment

  Building A is centered by the machine workshop with offices and the classrooms surrounded. Both floors are open to the workshop with the second floor utilizing a track that wraps around the building. This building has had basic renovations completed in 2002 including LED fixtures (only in the workshop), cosmetic remodeling of the offices and classrooms, and new windows installed in the office areas. The exterior doors contain zero insulation and have visible gaps that allow excessive heat loss. The roof structure currently consists of a flat asphalt material and multiple window lenses that have been updated to Kal-Walls (insulated window panels). Focus:HOPE utilized an old inefficient steam boiler that comes from several hundred yards away. Multiple thermostats are used to control the temperature manually and the temperature cannot be maintained consistently.

Building B consists of no A/C and is also heated by the old steam system that cannot maintain the temperature. The office spaces consist of drop ceilings, fluorescent lighting, and have poor insulation. The 3,000 sqft cooler does not meet the OSHA safety standard of 38 degrees for perishables and the cooler door is not airtight. This leads to high energy bills and inefficiency with possible food contamination. The roof structure of the warehouse has multiple window walls that are single pane. The roof has been renovated within the past 5 years but many roof windows have been either damaged or broken.

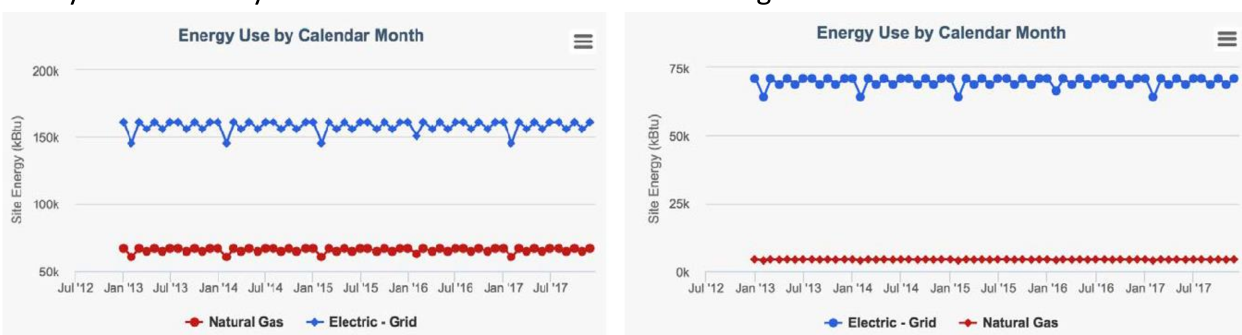

Figure 2 Natural gas and electricity use of Building A (left) and Building B (right) by calendar month.

- Facility Benchmarking

  Building A Portfolio Manager Property ID number is 6290473 and Building B Portfolio Manager Property ID number is 6290470. Figure 2 shows the natural gas and electricity use of Building A (left) and Building B (right) by calendar month.

- Recommendations

Short-term recommendations of renovations for both Building A and B are: replacing all lighting and fixtures with LED alternatives, installing light occupancy sensors and Cat Walk systems, reducing window sizes by 50% and converting to Kal-wall windows, replacing exterior doors, putting Sip Panels along interior walls, and introducing air pumps to use convection to naturally cool the building during summer evening hours.

Most of the long-term recommendations are incorporated in building B: (1) a solar array system on the roof, (2) a parabolic system that will lead into the exiting HVAC system, (3) a partial green roof with runoff water from a new gray water system in the area above the cooler and offices which will allow maximum insulation for the employees' working space, (4) wind turbines mainly for the windy winter months, (5) a geo-thermal system in the parking lot behind building C to assist the parabolic system in the winter months. In addition, a new walk-in cooler that will use less energy and provide a healthy temperature for all the perishables.

KwH Rate	0.20
Focus: HOPE	

ENERGY ESTIMATOR

Type	Existing	Qty	Watts	Hours	Operating Cost	Proposed	Qty	Watts	Hours	Operating Cost
A	3LT8 2'	21	92	3000	$ 1,159.20	LED HIGH BAY	63	112.72	3000	$ 4,260.82
B	2LT8 4'	21	58	3000	$ 730.80	LED HIGH BAY	126	95.25	3000	$ 7,200.90
C	3LT8 4'	257	85	3000	$ 13,107.00	LED HIGH BAY	48	150.15	3000	$ 4,324.32
D	4LT8 4'	144	112	3000	$ 9,676.80	LED TROFFER 4'	520	34.15	3000	$ 10,654.80
E	2LT8 8'	60	112	3000	$ 4,032.00	LED STRIP 8'	47	66.47	3000	$ 1,874.45
F	CFL	55	26	3000	$ 858.00	LED CANOPY	25	16.6	3000	$ 249.00
G	MH	56	250	3000	$ 8,400.00	LED DL	83	12.6	3000	$ 627.48
H	INC	60	100	3000	$ 3,600.00	LED STRIP 8'	14	34.8	3000	$ 292.32
I	2LT8 4'	16	58	3000	$ 556.80	LED STRIP 4'	24	66.47	3000	$ 957.17
J	4LT12 4'	116	72	3000	$ 5,011.20	LED TROFFER 2'	21	19.57	3000	$ 246.58
K	2LT12 8'	18	123	3000	$ 1,328.40					
L	CFL	454	105	3000	$ 28,602.00					
M	MH	27	400	3000	$ 6,480.00					
N	INC	8	100	3000	$ 480.00					
O	MH 4X4	4	100	3000	$ 240.00					
P										
			46812.33		$ 84,262.20			17048.8		$ 30,687.84

Energy Savings	29,763.53	Annual
Energy Cost Savings	$ 53,574.36	Annual

Gasser Bush Associates doesn't guarantee savings based on this energy estimator

Table 4 Energy Savings Estimator of light retrofit.

Technical Analysis 2: Lighting Retrofit

Both of building A and B have already excellent access and potential to natural daylight from Kal-wall and skylights on the roof. The proposal consists of four major points: upgrading to LED lighting, using daylight sensing and motion sensing fixtures, and maximizing natural daylight harvesting. The lighting retrofit centers around the fixtures and the lamps. Assisted by Gasser Bush Associates, the estimated savings of changing all light fixtures to LED are significant. Focus: HOPE can save $53,574.36 each year just by upgrading their lighting, as shown in Table 4. The selected daylight sensing and motion sensing fixture was Philips SpaceWise system.

Technical Analysis 3: Solar Analysis

This project partnered with two contractors, Michigan Solar Solutions and Energy Sciences, to design a photovoltaic system and connect to the local utility in the "Net Metering" system. Using Google Project Solar, Building B was chosen to install solar panels for its smaller roof elevation changes. The designed solar array was limited to 480 panels and 175.2 KW for the reason of the net metering credit. The solar panels are Sunmodule Plus SW 285-300 MONO panels designed to withstand heavy snow and ice loads with a 25-year warranty. They will be mounted and ballasted using the RapidRac Flat Room Mounting RM10. Each panel will also include the SolarEdge Power Optimizer allowing communication to a monitoring platform for any maintenance issues via a web-based app. The power invertor boasts a 98.5% efficiency rating. Energy storage systems such as batteries were not considered.

The initial cost of the proposed array was $355,305 after taxes, including all the solar panels, the ballast system, the power optimizers, and the power invertors, without labor involved for installation. The payback period for this array is estimated 8.5 years and over the 20-year lifetime, which implies a 135% return on investment or totally $480,000.

Technical Analysis 4: Geothermal Retrofit

A geothermal retrofit was explored to replace the existing boiler and air conditioning system. The proposed geothermal system will separate building A and building B from the existing system, and heat and cool the necessary regions of both buildings on their own loop and heat pumps. Soils in the region of Detroit surrounding Focus:Hope are generally made up of clay and other saturated material, with a thermal conductivity ranging from 0.64 to 0.96 Btu/ft hr F. The constant ground temperature below the frost line in Michigan ranges from 47-50 degrees F., providing suitable conditions for the large vertical ground loop.

A vertical closed loop system costs an average of $19 per linear foot of bore, for labor and material. The proposed 31,667 feet of bore would bring the cost to install the system to roughly $602,000. The projected annual savings of switching to a geothermal system was estimated $38,000 and would be paid for in 16 years.

Detailed Estimate Breakdown	Option1	Option 2
Trade Activity	Bid Total	Bid Total
Solar w/Labor	$369,684.68	$369,684.68
Lighting w/Labor	$865,000.00	$865,000.00
Geothermal System		$1,200,000.00
General Conditions	$10,146.46	$10,146.46
Overhead	$87,138.15	$171,138.18
Profit	$62,241.53	$122,241.56
Total	$1,394,210.82	$2,738,210.88

Table 5 Estimated cost breakdown.

Schematic Estimate, Schedule, and Finance Plan

The cost estimate captures materials, labor, general conditions, overhead, and profit. The estimate includes two options with/without the geothermal system, as show in Table 5. An overhead of 7% was set based on various articles in Electrical Magazines, and a profit of 5% was considered as a good margin for a competitively big project based on rates of local electrical contractors. Construction will begin in late spring to early summer to coincide with Michigan weather. The project's schedule consists of thirty-five activities and will take forty-two days to complete. All activities are scheduled to take place during the normal business time.

The client does not have the means to finance this project. One of the possible funding solutions is using NECA E-Cap because it will work with a variety of lenders to find a competitive rate after being properly. Another possible funding opportunity is contacting CollectiveSun, an organization that is nationwide that exclusively helps nonprofit businesses fund solar projects. The organization can provide financial opportunities to fund new installed solar systems. In addition, table 6 explains the payback period and return on the investment.

Return on Investment	Option 1	Option 2
Initial Cost	$1,096,193.00	$2,440,193.30
Total Cost	$1,096,193.00	$2,440,193.30
Total Annual Savings	$95,370.74	$133,370.74
Payback Period	11.5 Years	18.3 Years
Return on Investment	174%	109%

Table 6 Return on investment

2.3 2019 Project

The proposal for the 2019 competition is due on April 29 and the project is currently under preparation. The 2019 project partner is Judson Center, a non-profit human service agency that provides compassionate, expert comprehensive services to children and families impacted by abuse and neglect, autism, developmental disabilities, and mental health challenges so they are successful in their communities.

The student team has assessed the facilities existing conditions to establish baseline energy scores using both the Department of Energy Building Asset Assessment [6] and the EPA Energy Star Portfolio Management tools. The team conducted a thorough assessment of the existing lighting and HVAC systems in the four wings of the main headquarters building. The existing power consumption of the lighting and the implement lighting retrofit had been studied. Alternative energy systems had been considered in the project, including a PV system evaluated with local solar consultants and other entities.

A new concept of smart and DC building is introduced in this project. More and more digital equipment, solar photovoltaic, storage batteries, electric vehicles (EV), CAV infrastructures, and other end-use devices requiring DC power enter our world, reviving discussions on DC power grids across the nation. When a home goes green, for instance PV on the roof and an EV in the garage, the overall efficiency of the system is much higher if the power generated by PV is never converted to AC [2]. If there is an energy storage (battery) buffering the PV, then there is no reason to lose energy converting subsequently between AC and DC, an unnecessary, extra step costing energy. DC is an alternative that costs no energy in conversion and plays an important role in building grid systems, affecting the connected macro-grid.

Recognizing this industry shift, and anticipating future changes, many projects exploring DC power and its implementation are launching across the USA. Emerge [7], an industry alliance, developed DC standards and certified more than 400 products using DC power for commercial and industrial buildings. Smart home, a recent hot topic, is using home automation and network capability to control lighting, climate, entertainment systems, and appliances that increase living convenience and save energy. DC power systems will further reduce the energy usage of appliances in smart home design by reducing the energy lost from converting between AC and DC. Currently Next Energy [8] in Detroit has a DC home that is up and running as a test lab. The home has PV on the roof, batteries, EV chargers, LED lighting, and an all DC kitchen and entertainment system. In addition, Department of Energy's Office of Energy Efficiency and Renewable Energy has a pilot program on DC Buildings and Smart Grid [9]. These pilot projects demonstrate energy solutions that may be implemented on a broad scale in near future. The students in this competition project will be arranged to visit the Next Energy DC home facility to learn the concepts and techniques that can be applied to the proposal.

Since lighting retrofit is a major part of facility upgrades using LED and sensor fixtures, DC power schematics will be evaluated as an option in this year’s project. In this option Net Metering will not be considered because inverting DC to AC consumes energy. The power generated by solar panels or other DC green energy sources will be well planned and managed by the energy storage systems and power controllers so that it will be consumed completely in the proposed building. The needed power exceeding the capacity of green energy sources will still come from the local power grid. The following elements will be considered and included in this pure DC setup:

- Energy storage system, including batteries, super capacitor, and flying wheels
- Mini DC power grid controller and sensors
- Inverter (AC to DC) to supply the loads from the local utility if green energy is not enough
- DC power outlets (by USB and other ports)

Overall, this proposal serves as the first steps to provide Judson Center with a more sustainable future through lighting, solar energy, smart/DC setup, and energy efficiency. The student team provides unique solutions in hopes of a better quality of life for the community.

3 Results and Discussion

The 2017 student team won the third Place of the 2017 Green Energy Challenge Poster Competition However, the 2018 team was not ranked in the top three of the 2018 Green Energy Challenge. The reason could be time arrangement because the 2018 competition announcement was later than usual. Feedbacks from both Covenant House Michigan and Focus:Hope about communications with and services of the students were excellent and they did appreciate students' efforts on both planning building upgrades and community services. Many experiences were learned and can be applied to the 2019 or future proposal for students to success in the competition.

The Green Energy Challenge competition project is part of the course CMT 4200 Senior Project of the Construction Management program. The course objectives of CMT 4200 are for students to perform the following activities and complete the following deliverables:

1. Prepare a complete quantity takes offs and cost estimates.
2. Prepare invitation to bid, that will be sent to subcontractors, and develop a Bid Summary
3. Schedule all activities related to the completion of the course projects.
4. Develop a comprehensive material handling policy
5. Develop a cash flow schedule and financial plan.
6. Prepare letters of recommended solutions for cost, schedule, change management, document submittal, and/or related issues.
7. Develop a comprehensive safety program.
8. Develop mechanical / electrical scopes of work.
9. Participate effectively in a change order process.
10. Assemble all project work into a single organized portfolio.
11. Take AIC AC exam

Students' performances and grades were assessed by the following factors:

- Attendance and Leadership (25%): Students are required to attend all the activities in person, including both technical development and volunteer services for the facilities to fill up the 200 hours course requirement. Students are divided into six groups, where each group has a project manager served by group members in turn leading the group for a certain period. The leadership of the managers will be monitored by the course instructor and the serving time may be shortened due to poor performances.
- Group report writing (25%): The are several sections in the competition proposal including introduction, energy efficiency analysis, lighting retrofit, solar analysis, and schematic

estimate, schedule, and finance plan. Usually each group is responsible of one section and there will be one group integrating and editing for the entire proposal writing. In addition, the written sections will be evaluated mutually among the groups.

- Technical performances and feedbacks from collaborating contractors (25%): Students are expected to consult the contractors to plan technical upgrading for the facilities. The designs will be reviewed and evaluated by the contractors as a part of students' performances.
- Clients' feedbacks and competition results (25%): Although the proposed upgrading plans are only for simulations, students are required to interact with the clients as dealing with a real case. Clients' feedbacks including satisfaction as well as the communication effectiveness and attitudes will be counted in the students' grades. Finally, the competition results are taken decisive. For projects ranked top three in the competition will be considered grade A.

4 Conclusion

In this paper we presented the 2017 and 2018 proposals submitted to the Annual ELECTRI International/NECA Student Chapter Competition on electrical construction managing projects. The main competition component is the challenge to propose an energy upgrade design and simulation for a facility providing community services to achieve a net zero facility. In the proposals, students formed a team to perform technical analysis, schematic estimate, schedule, and finance plan for the chosen facilities to achieve the net zero goal. The 2017 student team won the third place in the Green Energy Challenge Poster Competition. Collaborating with Judson Center, a non-profit human service agency, a student team is working on a proposal for the 2019 competition. The concept of smart building and DC building was introduced in the 2019 project because smart building uses sensors to monitor the energy usage while DC power systems can further reduce energy lost from converting between AC and DC.

Participating the competitions was part of the CMT 4200 Senior Project course activities that enriched students learning experiences in a way that no traditional lectures could achieve. Team based projects encourage students to work both as individuals and as part of a team, that inspire their critical thinking and improve their communication skills. They also encourage students to find alternative answers, imaginative options, and practical solutions to a real-life problem. Although traditional lecture mode is still the primary method of teaching, we believe that supplementing with real life practices such as the "Green Energy Challenge" competition can fill the gap between knowledge in books and real-life problems.

5 Acknowledgements

We appreciate Covenant House Michigan, Focus:HOPE, and Judson Center for providing the opportunities for students to access their facilities. We also appreciate the contractors, Michigan Solar Solutions and Energy Sciences, to assist students on the technical problems.

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