Northern Lights Solutions

In collaboration with Armour Heights Presbyterian Church





2019 Green Energy Challenge

CECA/NECA University of Toronto Chapter

April 9, 2019

Northern Lights Solutions

CECA/NECA University of Toronto Student Chapter

Table of Contents

Table of Contents 0

1 Project Summary 1

1.1 Executive Summary 1

1.2 NLS Mission Statement 1

1.3 Our Client - Armour Heights Presbyterian Church 2

1.4 Our Team 3

2 Technical Analysis 1: Energy Efficiency Analysis 9

2.1 Energy Audit Results 9

2.2 Energy Benchmark 13

2.3 DOE Building Assessment 14

2.4 Recommendations 14

2.5 Recommendations Regarding Net Zero 16

3 Technical Analysis 2: Lighting Retrofit 16

3.1 Existing Lighting System 16

3.2 Proposed Lighting Retrofits 18

3.3 Ceiling Plan 20

3.4 Photometric Analysis Drawing 21

3.5 Return on Investment Report 22

3.6 Contributions to Net Zero 23

4 Technical Analysis 3: Solar Energy System 24

4.1 Existing Conditions 24

4.2 Component Selection 24

4.3 Shading Studies 26

4.4 Schematic Drawing of PV System 27

4.5 Three-Line Diagram 28

4.6 Solar Energy Summary 29

5 Schematic Estimate, Schedule and Finance Plan 29

5.1 Cost Estimate 29

5.2 Scheduling 31

5.3 Safety 32
5.4 Cash Flow Plan 32
6 Outreach 34
6.1 Energy Awareness Campaign and Volunteering 35
6.2 Local NECA/CECA Chapter Interactions 37
6.3 Letter from Armour Heights Presbyterian Church 38
6.4 Campus and Local Media Engagement 39
7 Appendix A – Introduction and Technical Analysis 1: Energy Efficiency Analysis 41
8 Appendix B – Technical Analysis 2: Lighting Retrofit 41
9 Appendix C – Technical Analysis 3: Solar Energy System 43
10 Appendix D – Community and Contractor Engagement 44
11 References 46

1 Project Summary

1.1 Executive Summary

Northern Lights Solutions (NLS), represented by members of CECA University of Toronto Chapter, is proud to present 2019's Green Energy Challenge Proposal. This year, NLS worked with the Armour Heights Presbyterian Church (AHPC) located in Toronto, Canada to come up with a set of retrofits that reduces the building's energy usage and encourages onsite generation by photovoltaics. AHPC serves as a place of worship, as well as a community center for the general public. AHPC occupies standalone building that was constructed in the early 1900's, and has gone under several major renovations since. The last building retrofit took place in 2011 to replace the roof.

NLS recommends several measures to for AHPC to achieve net-zero in this proposal. A wall insulation retrofit, combined with an HVAC overhaul, will reduce the heating/cooling load and increase the efficiency of the mechanical systems. Smart lighting and replacement with LEDs will save the church 3,600 kWh of electricity annually. The proposed PV system, mounted on the east, west, and south facing roofs of the church, generates up to 72,000 kWh of electricity per year.

NLS also developed interactive and engaging Sunday School activities to teach energy conservation to youth. With the help of AHPC, the community engagement team was able to incorporate energy awareness campaign into Bible studies to better suit the church's curriculum.

Furthermore, NLS maintained connections with local CECA contractors throughout the competition period, many of whom contributed to the success of this project tremendously.

1.2 NLS Mission Statement

NLS empowers students to transform energy in the built environment through education and application, while assisting them with their professional development through industry engagement.

1.3 Our Client - Armour Heights Presbyterian Church

Established in 1951, AHPC is located just forty minutes north of downtown Toronto. AHPC hosts two services on Sunday, one for AHPC, and another for a Korean Presbyterian church that shares the building. AHPC offers a variety of services including outside of worship, including pastoral care, free senior exercise classes and secular activities to engage local children. In the past few decades, AHPC has opened their doors to people of different faiths and religions that reside in the area.

Exhibit 1.1 - Scott Duncan Hall in AHPC

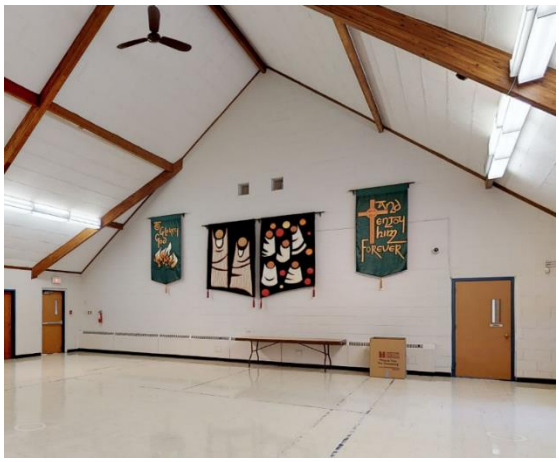


Exhibit 1.2 - AHPC Sanctuary

NLS had the pleasure to work with a graduate student from University of Toronto to produce a 3D walk through of the church (See Appendix A, page 41). The 3D model allows users to tour the facility virtually and see the inside from every angle. The 3D model not only helped our team visualize our suggestions to the church, it also served as a marketing tool for AHPC, as they accept booking requests for different venues throughout the year. The link of the model can be found in Section 6.4, where 3D modelling is explained more thoroughly.

AHPC has three floors in total. The ground floor and basement are used for the church's everyday activities, and the second floor, which is much smaller, holds an office for pastors and administrative staff. The church also owns the open area surrounding the building, including a front lawn and a 12-car parking lot, making it an ideal candidate for solar generation. Since AHPC is located in a relatively low population density area, it stands as the tallest building in its proximity, allowing full access to sunlight without obstruction.

AHPC has irregular operating hours that depend upon activities scheduled to take place. Nonetheless, the mechanical system runs 24/7 so that the indoor temperature is kept constant.

During the initial stage of collaboration, interviews with staff at AHPC helped us determine some of the occupant comfort issues that should be addressed. We identified temperature swings to be the most

crucial problem. In the proposal, we strive to increase the building's energy efficiency, while providing a comfortable and welcoming environment for the building's staff and regular users.

Rick King, the volunteer facility manager at AHPC, offered us a unique insight on the church's utilities. AHPC is set to have an overall inspection in late 2019 by a professional engineering firm to determine whether the current HVAC system needs replacing. As well, the church would like to buy out the current rental heaters and replace the roof. Our proposal offers a great way to finance the scheduled maintenance of the church. More importantly, the proposed solutions, especially the photovoltaic system, can be taken into consideration during the replacement of roof to ensure it structural integrity.

This year, NLS developed community programs for children that attend the church, including 3 Sunday school sessions, and one secular activity. With the assistance of Rebecca Jess, a minister at AHPC, we incorporated Bible studies into our sustainability campaign. Since most children are under the age of 10, we focused on simple concepts such as electricity conservation and Toronto's recycling program. At NLS, we strongly believe in learning by doing, therefore the curriculum we developed consists largely of hands-on activities, allowing kids to learn and have fun at the same time.

Overall the AHPC project can be used as a great example for other churches, who tend to occupy older buildings, and have the potential for large savings and improvements to indoor environmental quality from energy retrofits. Economically, this enables churches to allocate more funding towards developing activities and serving the community. Moreover, teaching energy conservation to church attendees, especially young children, can have a tremendous impact on their lifestyle choices, encouraging more people to choose a sustainable way of living.

1.4 **Our Team**

This year, NLS's executive team selected five talented and dedicated individuals to be team leaders in the Green Energy Challenge. Four out of the five team leaders are new to the challenge this year, all of them bringing new, exciting and innovative ideas to the table. Resumes of core team members are presented in the following five pages.

Yuexin Liu

Building Performance Team lead

Yuexin Liu
yuexin.liu@mail.utoronto.ca

Roll in GEC

Building Energy Performance Team Lead

Experience

University of Toronto Concrete Canoe Team/Member
SEPTEMBER 2018 - PRESENT

- Contribute to the entire canoe building process leading up to the Canadian National Concrete Canoe Competition, including concrete testing, mold construction, and canoe casting
- Helped to seek sponsorship for the team

Peace by PEACE - University of Toronto/Mentor
OCTOBER 2018 - APRIL 2019

- Engaged a grade 4/5 class with the Peace by PEACE curriculum - a unique conflict resolution and community-building program for elementary school students
- Improved public speaking skills and learned to work with students of all personalities

First Year Campus Involvement Award (2018-2019)

Education

University of Toronto / Mathematics
Class of 2022

Niloufar Ghaffari

Lighting Team lead

Niloufar Ghaffari
niloufar.ghaffari@mail.utoronto.ca

Role in GEC

Team lead for lighting

Experience

York Region/ Transportation Department/ Engineering Assistant
SEPTEMBER 2018 - PRESENT

- Assist in capital road design projects for the Region by completing tender documents and other related road works
- Comment on environmental assessments and potential construction issues
- Design a complete pipe network in Civil 3D for the road widening and construction of Bathurst St.

University of Toronto/ Intramural Coed Volleyball/ Captain
JANUARY 2017 - PRESENT

- Recruited and currently manage a team of 12+ engineering students
- Schedule and run weekly practices to prepare for seasonal games

Education

University of Toronto / Civil Engineering
Class of 2019 + Professional Experience Year (PEY)

Fariha Oyshee

Solar Team lead

Fariha Oyshee
fariha.oyshee@mail.utoronto.ca

Roll in GEC

Team Lead for Solar PV Design

Experience

Engineering Strategies and Practices II / Communications Manager
JANUARY 2017- APRIL 2017

- Point of contact with the client, handled team meetings, and ensured deadlines were communicated appropriately
- Researched existing HVAC systems in the industry to propose cost-effective solutions that collect and reuses waste heat in a home through transportation or transformation.
- Performed product's lifetime energy consumption analysis, and cost analysis for implementation and construction.
- CAD for models of chosen top design.

Cecil Community Centre / Camp Counsellor
JUNE 2018-AUGUST 2018

- Planned, coordinated, and executed daily camp activities along with 3 other counselors.
- Supervised campers in order to maintain an order of safety, and communicated arising issues to guardians, and our supervisor.
- Created a total budget for the camp in order to keep track of spending.
- Effectively problem-solved under stressful and unpredictable situations.

Education

University of Toronto / Civil engineering
Expected Graduation Date: 2021

Jacqueline Lu

Finance Team lead

Jacqueline Lu
jac.lu@mail.utoronto.ca

Role in GEC

Team lead for estimation, scheduling, and financing

Experience

Walter P Moore / Diagnostics Intern
MAY 2017 - JUNE 2018,

- Performed enclosure consulting and commissioning services for new construction and rehabilitation projects
- Completed architectural drawing/submittal reviews, construction observations, and quality control testing
- Communicated with clients/contractors to coordinate project schedule, tasks, and events

Engineers in Action / Logistics Manager - Chillcani Footbridge
SEPTEMBER 2016 - MAY 2017

- Worked with local community in Bolivia for the construction of a 40m pedestrian footbridge
- Managed on-site finances, lodging, transportation, and food for a team of 20 in country
- Organized on campus events and workshops prior to travel

Education

University of Toronto / Civil Engineering
Expected 2019

Lauren Streitmatter

Community Engagement Team lead

Lauren Streitmatter

lauren.streitmatter@mail.utoronto.ca

Roll in GEC

Community Engagement Team Lead
Solar Team Member

Experience

Engineers Without Borders/ Policy and Advocacy Member
SEPTEMBER 2018 - PRESENT,

- Collected petition signatures supporting UN sustainable development goals; Co-ran member learning session
- Helped organize booth for International Women's Day
- Attended xChange Conference 2019 in Montreal

University of Toronto Chemical Vehicle Design Team/ Member
SEPTEMBER 2018 - MARCH 2019

- Studied sodium thiosulfate-hydrochloric acid reaction kinetics to implement in vehicle braking mechanism
- Weighed samples, prepared solutions, and disposed of waste using proper lab techniques

Education

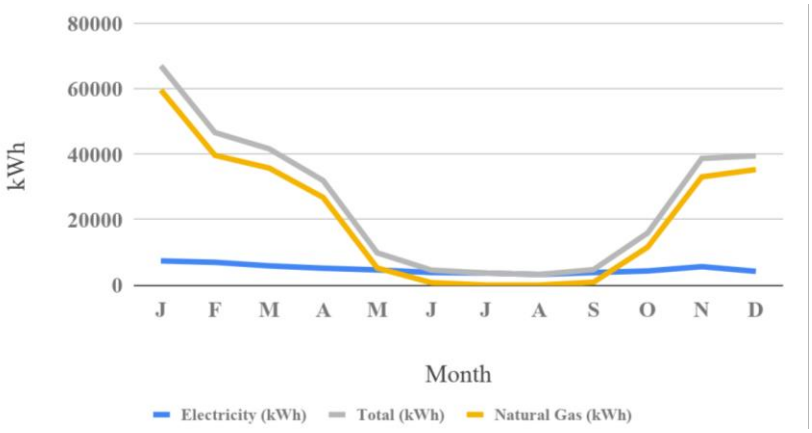
University of Toronto / Chemical engineering
Class of 2022

2 Technical Analysis 1: Energy Efficiency Analysis

2.1 Energy Audit Results

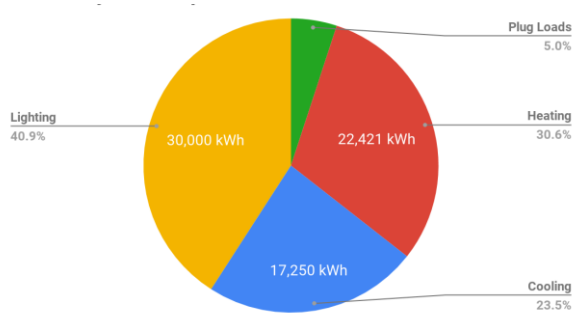
2.1.1 General Electrical System

Exhibit 2.1 - AHPC Energy Consumption in 2018



The team conducted a building energy audit at Armour Heights Presbyterian Church (AHPC) to learn about the energy use in the building. The total energy consumption of AHPC in 2018 was 322,090 kWh, which consists of 73,358 kWh of electricity use and 248,732 kWh of natural gas use, as presented by Exhibit 2.1. Electricity usage is consistent throughout the year, with an average of 6,113 kWh per month. Electricity is used for lighting, plug loads, and the HVAC system, with an exception for the boiler. A natural gas boiler is used to meet the building's heating demand. Since gas is only used for heating, it leads to a dramatic difference in natural gas consumption in the summer months and winter months, ranging from 0 kWh in July and August to 60,000 kWh in January. This means that making the building carbon neutral on-site may be as simple as replacing the natural gas boiler with an electric one.

Exhibit 2.2 - Total Electricity Breakdown



During the audit, the team inquired about the lighting and HVAC system of the building and took notes of all the electronic appliances in the building. The annual electricity consumption breakdown at Armour Heights Presbyterian Church is shown by Exhibit 2.2, determined based on audit results. The electricity consumption measured by the electricity meter is approximately 80% of the electricity consumption calculated by the team. The variance in estimation may be due to the church's inconsistent operating hours, irregular plug load usage, and the lack of specialized tools during the energy audit.

Lighting accounts for 41% of the building's electricity use. Approximately 31% of the total electricity is used to operate the HVAC system, pumping water supply to the natural gas boiler. Cooling and plug loads represent 23% and 5% of the total consumption, respectively. Lower plug load energy consumption is a direct result of normal use variations. Since most of the appliances are stored and only plugged in when they are needed, the parasitic load for AHPC is much lower than an average commercial building.

2.1.2 Lighting Fixtures and Lighting Controls

Data on the building's lighting system was collected during the energy audit. A large variety of lighting fixtures and bulbs were found throughout the building. Incandescent, T12 and T8 fluorescent, and CFL bulbs were the most common fixture types. Daily operating hours of each room was estimated by the building manager. The monthly calendar on AHPC's website was also used to estimate the operating hours of certain rooms, such as the Sanctuary and Scott Duncan Hall. Overall, the Sanctuary has the most light bulbs. Assuming the lights are on for five hours per week, the daily average usage was calculated to be 0.7 hours for the Sanctuary. Three hours of light usage was assumed for offices because they receive a large amount of natural light during the day. In terms of lighting controls, almost all rooms have manual light switches, except for three rooms that have slide dimmer switches, and one room with a dial dimmer switch.

The building's lighting system is summarized in Exhibit 2.3. The table lists the weekly energy use of each room type and bulb in kWh. This was calculated by multiplying the total wattage and weekly operating hours of all the bulbs inspected in the audit. The annual energy consumption for building lighting was determined to be approximately 25,675 kWh over an estimated area of 1,650 m^2 which equates to a lighting power density of 15.6 kWh/m^2.

Exhibit 2.3: Summary of Existing Lights

Location	Light type	Total Wattage (W)	Daily Operating Hours	Total Weekly Operating Hours	Weekly Energy Use (kWh)
Sanctuary Washrooms	Halogen	4230.0	0.7	5.0	21.0
	CFL	39.0	0.7	5.0	0.2
	Incandescent	756.0	0.7	5.0	3.8
	Halogen T4	2550.0	0.7	5.0	12.7
	T8 F	320.0	4.0	28.0	9.0
	Incandescent	180.0	4.0	28.0	5.0
	T12 F	160.0	4.0	28.0	4.5
General Rooms	T12 F	7320.0	4.0	28.0	205.0
	T12 F	80.0	2.0	14.0	1.1
	T12 F	364.0	0.5	3.5	1.3
	Halogen	1125.0	3.0	21.0	23.6

	LED	172.0	4.0	28.0	4.8
	CFL	78.0	4.0	28.0	2.2
	Incandescent	180.0	4.0	28.0	5.0
	Incandescent	120.0	0.5	3.5	0.4
Stairwells and Hallways	Halogen (bi-pin)	40.0	2.0	14.0	0.6
	Incandescent	300.0	5.0	35.0	10.5
	Halogen (T3)	100.0	5.0	35.0	3.5
	CFL	78.0	8.0	56.0	4.4
	T12 F	160.0	5.0	35.0	5.6
	Halogen (2-4 inch tube)	200.0	5.0	35.0	7.0
	T12 F	960.0	8.0	56.0	53.8
Emergency Exits	LED	1.3	24.0	168.0	0.2
	Fluorescent	91.0	24.0	168.0	15.3
Kitchen	T12 F	560.0	6.0	42.0	23.5
	T12 F	120.0	4.0	28.0	3.4
	T8 F	192.0	4.0	28.0	5.4
	U shaped fluorescent	128.0	6.0	42.0	5.4
Office	T8 F	768.0	3.0	21.0	16.1
	T12 F	640.0	3.0	21.0	13.4
Exterior	CFL	104.0	8.0	56.0	5.8
	Halogen 150	2100.0	0.2	1.4	2.9
	Halogen 90	180.0	8.0	56.0	10.1

	CFL with floodlight	39.0	24.0	168.0	6.6
	standard floodlight	560.0	0.2	1.4	0.8
	Weekly Energy Usage (kWh)				493.7
	ANNUAL ENERGY USAGE (kWh)				25674.5

2.1.3 HVAC and HVAC Motor Controls

Date used for HVAC system analysis was obtained during the energy audit with the assistance of Rick King, the building manager. When equipment specifications were not accessible, consumption was estimated based on assumed performance and usage characteristics.

For heating, the building relies on burning natural gas inside a hydronic boiler with heating capacity of 1.1 MMBtu/hr. The boiler consists of a main system supply pump with ¾ HP, and two inline circulation pumps (each ¼ HP) which supply hot water to the basement and first floor baseboard radiator networks. The hydronic boiler also supplies hot water to an air handling unit to heat zones that do not have baseboard radiators. The building has two thermostats: one in the basement, and one on the first floor. These thermostats are connected to circulation pumps and the furnace. Thermostats monitor temperature and control the pumps and the furnace automatically. The boiler energy consumption data for the whole building was provided in volume of natural gas. The corresponding heat consumption (in kWh) was calculated based on the heat capacity of natural gas. Additionally, two wall air heaters are installed near exit doors to heat up cold air when the doors open.

The building relies on four electrical water heaters that supply hot water to the washrooms, the washing machine, and two kitchens. The water heaters contain an integrated control unit with a set point of 48°C (120F). Similar to thermostats, it controls the water level through a small gate valve.

The building does not have a central cooling unit. Instead, it relies on two single zone ductless split units, a window air conditioning and an air handling unit. The air handling unit covers 80% of building's demand for cold air in summer and remaining 20% is supplied by single zone ductless split units and window AC, installed in administration offices.

Exhibit 2.4 - Cooling System Summary

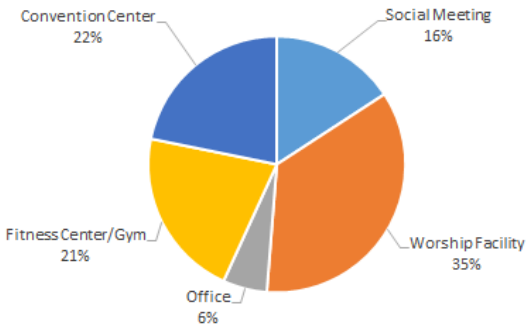
Cooling System	Cooling Capacity (Btu/hr)	EER	Power (kW)
Window AC	-	-	1.1
Single Zone Ductless AC Unit	12300.0	13.5	0.9
Dual Zone Ductless AC Unit	18000.0	12.5	1.4
Air Handling Unit	48000.0	11.0	4.4

The air handling unit has a cooling capacity of 48000 Btu/hr. It is served by a direct-expansion (DX) cooling coil. The air handling unit is connected to two thermostats which control two air flow dampers that control the flows of cooled air to each zone. Thermostats measure the zone temperature and send electrical signals to control the opening angle of dampers to control the flow of cooled air to that zone.

2.2 **Energy Benchmark**

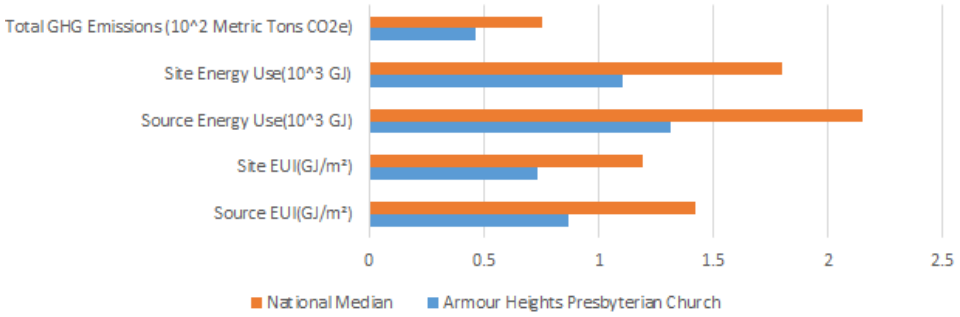
A preliminary energy performance of the property was generated using the Energy Star Portfolio Manager®, the results of which are displayed in Exhibit 2.6. The program estimates both the total and the density of raw fuel required for operation, as well as the annual energy consumption. The results are compared to properties with identical functionalities nationwide. It is compared with buildings of similar use, as defined by its gross floor area. The summary of Armour Heights' floor area by function is shown in Exhibit 2.5. Although the church's property type is not eligible for an Energy Star Score, the gross floor area, electricity and natural gas usage allow comparison of various parameters to the national median.

Exhibit 2.5 – Gross Floor Area of Armour Heights by function



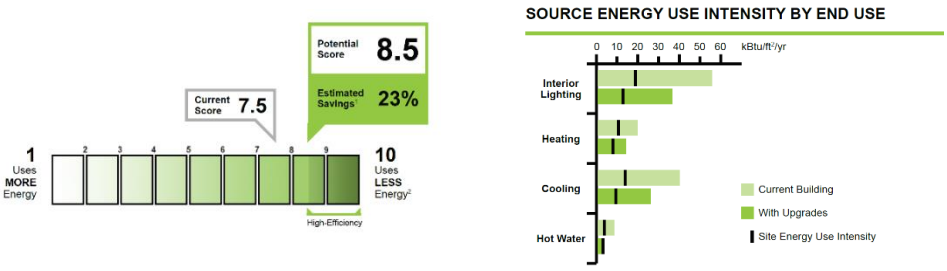
The source EUI (Energy Use Intensity) and site EUI for the Armour Heights Presbyterian Church are 0.87 GJ/m^2 and 0.73 GJ/m^2 respectively. These values are 38% lower the national median. In addition, the total greenhouse gas emission is approximated to be 46.3 metric tonnes (estimated by Portfolio Manager), which is 40% lower than the national median. Overall, the energy performance of Armour Height Presbyterian Church is notably better than similar building types.

Exhibit 2.6 - AHPC Energy Benchmark



2.3 **DOE Building Assessment**

Exhibit 2.7 – DOE Assessment Results



The DOE Building Energy Asset Scoring Tool is an application developed by the US Department of Energy to assess the energy performance of buildings. The application considers the building's use type, physical shape, lighting fixtures, water heaters, and HVAC system. The team gathered the required information through the energy audit and building blueprints. Armour Heights Presbyterian Church's DOE score is 7.5, and a saving potential of 23%. The result is shown in Exhibit 2.7. The application provided retrofit recommendations, with the main focuses being building envelope and HVAC. The DOE report also gives an estimated source energy use of 2.21 GJ/m^2, and site energy use of 0.74 GJ/m^2.

2.4 **Recommendations**

2.4.1 Boiler

The building is currently equipped with Raytherm Hydronic Boiler, model E1125 WT-N-2P**,** which is fueled by natural gas and has an efficiency of 82%. A new boiler with even a small efficiency increase will significantly decrease energy consumption of the building. An electric boiler can achieve a 95% efficiency on average, making it an excellent replacement for the current boiler. Although capital cost is similar between electric and gas boilers, electricity is more expensive than natural gas in Ontario, resulting in a higher operation cost for electric boilers. However, the energy saved by an electric boiler due to its high efficiency will offset the difference in operating costs. Moreover, switch to electric makes the building site-carbon neutral, achieving zero annual carbon emissions.

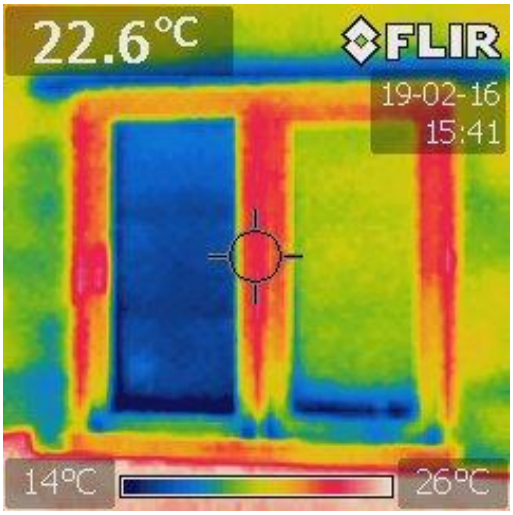
In conclusion, the team recommends AHPC to switch to an electric boiler to reduce energy use of the building. Mini Ultra electric boiler (3kW-12kW) is suggested as the replacement boiler, as it produces less greenhouse gas.

2.4.2 Window insulation - triple pane

Double pane windows are standard for both commercial and residential buildings in Canada. The single insulating glass (IG) unit consists of two panes of glass separated by air, or a more insulating gas such as argon. The energy loss through windows can be reduced by 20-50% when an additional IG unit is connected, creating a triple glazed window. The effectiveness of the IG unit depends on the type of gas

present (argon and krypton exhibit high performances [1]), as well as its service time. Since the inert gas leaks at a rate of about 1% per year, newer windows always have better insulating properties than older ones. Energy loss can be further reduced with low-emissivity (low-E) coatings, that scatter outgoing radiation through a layer of fine metal.

Exhibit 2.8 - Thermal Imaging of a Window in



The procurement of triple pane windows should focus on the type of inert gas, low-E modifications and foam-filled vinyl or fiberglass frames. The Energy Star certified HS2-C180 by All Weather Windows emerges as a suitable replacement. The heat transfer coefficient of the new window is 1.045 m^2K/W [2]. In comparison to the original dual pane window, the combination of triple pane and low-E coating compromises 8% of light transmittance in exchange for 62% reduction in U-value. The total energy saving from this retrofit approximates to 12,285 kWh per year.

2.4.3 Wall insulation - stone wool insulation

As indicated by the DOE report, improving wall insulation of the building is highly cost-effective. The current walls are made of brick and stone with a R-value of approximately 2.5 m^2K/W, permitting a significant amount of heat loss. Adding more insulation can increase the R value of walls, thus decreasing heat loss. A standard insulation material is stone wool insulation, where the fine strands of mineral catch air between their molten rock and mineral to lessen heat transfers between inside and outside [3].

ROCKWOOL COMFORTBATT® is a good option for this upgrade. The material has a unique flexible edge designed to compress as the stone wool is inserted. The edge then springs back after it's put in place, expanding against the edges of the walls for a complete fill. The filled cavity ensures that the expected R-value can be fully achieved and maintained [4]. The R-value of the material is 14.0 m^2K/W, giving the wall an overall R-value of 16.8 m^2K/W, a 14.3 m^2K/W improvement compare to the original wall. ROCKWOOL COMFORTBATT® is also fire-resistant and non-combustible, even in the case of direct exposure to the fire. In addition, 75% of the stone wool insulation material is recycled, making it an eco-friendly choice.

The insulation layer is suggested to be put on the interior because it can be implemented on a room-to-room basis rather than the need to be installed all at the same time for the exterior, making the retrofit process easier. Moreover, adding the insulation layer on the inside in cold climate prevent condensation within walls. Condensation has significant negative impact on insulation performances. However, in order to achieve an R-value of 16.8 m^2K/W, 3.5 inches of insulating materials need to be added. As a consequence, the church would lose a noticeable amount of space in the outer rooms. Yet, the benefits the church would gain through this retrofit are worth the loss in space, as wall insulation alone reduces heat loss by 233,924 kWh per year, cutting heating and cooling demand by 86%. Moreover, during occupant

interviews, church staff brought up the issues with temperature swings in Scott Duncan Hall. This retrofit would keep the indoor temperature constant, thus resolving problem and improving occupant comfort.

2.4.4 Thermostats Replacement and Relocation

Thermostats are an essential component of the HVAC system because they control when AC/boiler turns on or off. Therefore, the quality of thermostat plays an important role in saving energy and money. Currently, the building is equipped with two Honeywell T87F thermostats, one for the basement and one for the first floor. The T87F thermostat is quite old and uses mercury for temperature reading, which presents problems with heat anticipator, as well as with calibration [5]. In addition, older thermostats lack energy efficient technology. Replacing the current thermostats with new programmable or smart thermostats will make a big difference in current energy usage. New thermostats give you more control over the energy usage as it allows people to program and schedule cooling/heating usage when the building is not occupied [6]. Furthermore, the first-floor thermostat needs to be relocated as it is placed in main hall which is right close to entrance door. Cold and hot air leakage from the entrance door will affect the thermostat temperature reading [7]. For example, when cold air leaked through entrance door, it will affect the temperature reading as the thermostat will keep reading temperature below thermal comfort temperature (will be registered as too cold) which will cause the boiler to use more energy than it needs in order to reach thermal comfort temperature. Furthermore, the basement thermostat is placed right near the hydronic boiler room, only separated by an internal wall. Placing thermostat near heat source affects the performance of HVAC device, which in return results in higher energy consumption. Therefore, replacing current thermostats and relocating them will reduce and regulate energy consumption of the building.

2.5 **Recommendations Regarding Net Zero**

Overall, retrofitting wall and window insulation reduces the total annual energy demand in heating and cooling to 75,900 kWh, a 75% reduction in annual energy usage compared to the 2018 data. In addition to a large saving in energy, the shift from a natural gas boiler to electric boiler allows the building to achieve carbon neutrality, making the facility more environmentally-friendly.

3 Technical Analysis 2: Lighting Retrofit

In section 3.1, a detailed description of the existing lighting conditions of Armour Heights Presbyterian Church is provided, including lux readings in specific rooms that do not meet the Illuminating Engineers Society of North America (IESNA) illuminance recommendations. Section 3.2 states the recommended lighting retrofits, which consists of occupancy sensors and dimmer switches, LED bulb replacements, a smart lighting system, and light shelves. The financial benefits of each retrofit are analyzed in sections 3.5 and 3.6 by calculating their capital costs and payback periods.

3.1 **Existing Lighting System**

NLS discovered that out of 66 switches, 7 are dimmer switches, 2 are dial switches, and the remaining are manual. As a result, when lights are in use, they are emitting their highest illuminance which may not be

necessary throughout the day. Thus, it consumes more energy than necessary. The first lighting retrofit NLS recommends is updating the current switch system to occupancy sensors and dimmer switches. Dimmer switches allow control over the brightness while occupancy sensors ensure that lighting in areas like stairwells and hallways will only be used when an individual is present. The interior lighting of the building is mostly composed of T12/ T8 bulb types in the areas where uniform lighting is required, such as hallways, the basement, and the gym. For rooms such as the sanctuary or reading rooms, the lighting type varies between incandescent, halogen, and CFL bulbs. To further reduce the energy usage and increase lighting quality, the second recommendation NLS proposes is LED replacements.

The third recommendation is to upgrade the lighting system to Smart-Controlled LED Light Switches with a user-friendly monitor. This will allow the user/church to have full control over the lights and reduce the potential of lights staying turned on, thus reducing the annual energy consumption. The final retrofit is light shelves. Light shelves allow light to reflect uniformly into the room and reduce the operating hours of artificial light. This reduces glare caused by direct sunlight and total energy use while increasing visual comfort. As lighting alone consumes 25,675 kWh per year, NLS is recommending these 4 retrofits that can reduce the current lighting energy usage and subsequently decreasing operational costs. All product data sheets for recommended retrofits can be found in the appendix (See Appendix B, page 42).

As part of the energy audit, NLS evaluated the lighting quality of each room by taking lux readings. Exhibit 3.1 lists the rooms where the lighting levels did not meet the IESNA illuminance recommendations [8].

Exhibit 3.1- Rooms that do not meet IESNA lighting quality recommendations

Room	Room Type Based On IESNA Lighting Handbook	Average Current Light Level (lux)	Recommended Light Level Range (lux)
Office (1-2)	Office-Open	82.7	300-500
Office (1-3)	Office-Open	48.0	300-500
Lounge (1-7)	Lounge/Breakroom	82.0	100-300
Office (1-11)	Office/Conference Room	174.7	300-500
Activity Room (1-17)	Classroom	248.0	300-500
Large Meeting Hall (B-7)	Conference/Exhibit Space	156.4	300-500
Sanctuary	Conference Room	29.5	300-500

3.2 Proposed Lighting Retrofits

3.2.1 Recommendation 1: Occupancy Sensors and Dimmer Switches

Replacing the traditional switches with occupancy sensors in the hallways, stairwells, and washrooms can benefit the most as lights are only required if there is an individual in that area. For example, during services, lighting in the coat rack hallway can stay off and only turn on when the individuals retrieve their coats at the end of service. Further, rather than leaving the outdoor security lights on, replacing them with occupancy sensors can reduce energy usage while maintaining the church's security [9].

Areas such as the Sanctuary and reading rooms can benefit from dimmer switches as the maximum lighting is not required. The church can use natural lighting throughout the day along with appropriate levels of artificial lighting that can be adjusted by the dimmer switch. This allows the lights to utilize less than their maximum power, thus reducing the consumption and increasing the service life of the light bulbs [10].

3.2.2 Recommendation 2: LED Replacements

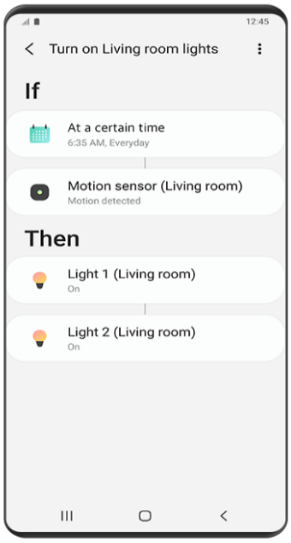
NLS recommends the fluorescent T8/T12 fixtures, halogen, and incandescent light fixtures to be replaced by LEDs. They are energy efficient and have a longer life-span compared to other lighting [11]. LED lights also requires less wattage to achieve the same or higher brightness level than other types of light fixtures [11]. Replacement of LED lights should be made in rooms where the current light fixtures do not provide the recommended lux level standard from IESNA as previously mentioned in Section 3.1. Rooms with lighting that use an extensive amount of wattage are also recommended to be replaced with LEDs.

Fluorescent T8 and T12 fixtures are recommended to be replaced with 18 Watt ballast compatible LEDs [12] [13]. Recommended replacements for 90W halogen lights are 13W LEDs and for the 60W incandescent lights, 8.8W dimmable LEDs are recommended [14] [15]. Specifically, the suspended light fixtures in the Sanctuary containing one incandescent and halogen bulb per fixture is recommended to be replaced with one 23W LED bulb per fixture [16]. The 14 halogen fixtures on the exterior of the Sanctuary's stain-glass windows are recommended to be replaced with solar powered LED lights [17]. A table containing all LED replacements information was used (See Appendix B, page 42).

3.2.3 Recommendation 3: Smart-Controlled LED Light Switches and Monitor

NLS recommends implementing the Samsung SmartThings lighting system with Lutron Caseta Wireless Smart Lighting Dimmer Switches. This retrofit is for separate use from the dimmer switches and occupancy sensors recommendation, but can be applied in addition to the LED bulb replacements retrofit. Smart lighting is an advanced step for additional energy savings. Smart switches are the same as dimmer switches, except they can be controlled manually and remotely through a Smartphone application (Refer to Exhibit 3.2), Google Home, or Alexa [18].

Exhibit 3.2 - Samsung Smart Home app interface



They are compatible with the recommended LED replacement bulbs; therefore, no new fixtures or installations are required [19]. For this recommendation, NLS has considered rooms such as common spaces, rooms located in the basement, the Great Hall, and the Sanctuary due to its large number of light switches. Hallways, stairwells, and washrooms are encouraged to have occupancy sensors from recommendation 1, thus there is no need for smart lighting. Armor Heights Church hosts many classes and children's activities where lights can be left on at the end of the day, increasing operating hours and therefore energy consumption. By implementing smart switches, the client will prevent lights from being left on accidentally for long periods of time. The status of certain lights can be conveniently checked through the app and turned on/off at the end of the day.

The Samsung SmartThings system requires a communications hub with a 130 feet range, which covers the whole building. If another hub is required due to the construction of the building or other obstacles, multiple hubs can be connected to the same account [20]. Each smart switch must be bought separately and installed and can control up to 17 bulbs, 150W of LED/CFL bulbs and 600W of incandescent/halogen bulbs [19]. The system is compatible with Zigbee and Z-Wave devices, which are similar to Bluetooth functions [18]. This allows the client to later install Philips Hue smart bulbs and other smart features that can be controlled through the already installed smart system. Additional features include SmartThings motion sensors and wireless button with a 44m range, which coordinates control of all switches without the use of a device [21]. It is recommended that the hub and switches be installed first, before adding extra features.

3.2.4 Recommendation 4: Light Shelves

Daylight can be a main source of lighting for rooms if utilized efficiently. Daylight projected through windows are wasted due to the concentration of all the light in one area, but by implementing light shelves, the light can be used more efficiently. Light shelves are surfaces built onto walls in order to help spread the light across the room. In addition, they reduce glare caused by direct sunlight and minimize the imbalance of light that disturbs visual comfort [22]. For best results, mounting the shelves above eye-level and horizontally is ideal. Sunlight is reflected off the upper surface of the shelf into the room and onto the ceiling, where it's diffused further, providing uniform illumination [23]. This reduces the amount of electricity needed by 30 watts per foot along the wall during the day [23]. The shelves are also able to reflect artificial light, thus reducing the number of fixtures being used at one time during the night hours. In the church, the Sanctuary has six windows which can be utilized because of the large amount of daylight being projected. The Great Hall has two windows that can be utilized to install light shelves. Adding the shelves in the Sanctuary and the Great Hall is beneficial because the rooms are spacious and contain many light fixtures, which will allow the sunlight to spread. This decreases the number of fixtures

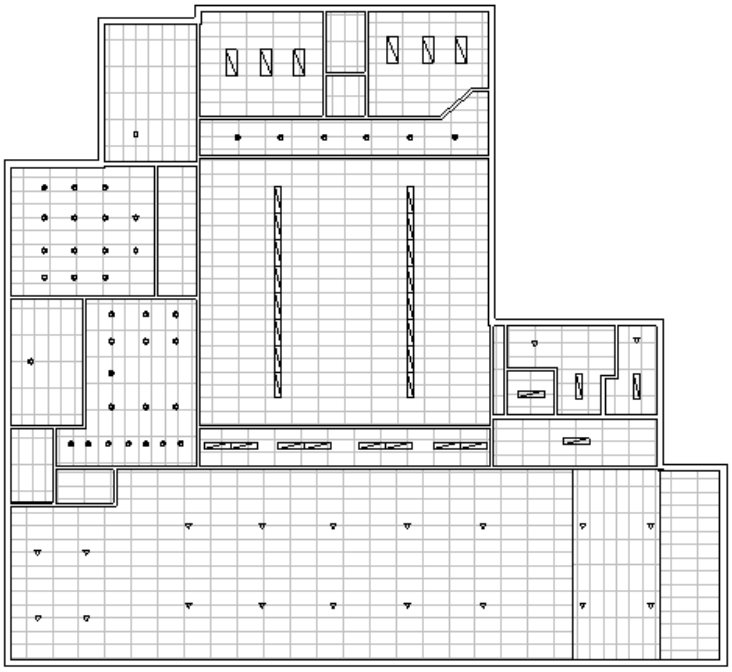
required to provide sufficient light. Not only are the light shelves saving energy, but they can provide increased visual comfort to occupants.

Installment of shelves can be made by anyone with the right equipment and cost about $100 per shelf, but can vary depending on building [23]. The angle of the light shelves can be adjusted to avoid glare, accommodate for the size of the room the daylight needs to reach, and allow for easy maintenance and cleaning. A study was done to determine the maximum energy savings based on multiple light shelf widths and the results showed that the optimal width that allows for maximum savings and minimum glare is 0.6m [24]. Therefore, NLS recommends light shelves shown in Exhibit 3.3 from InLighten, that are made of aluminum with white coating, 0.6m wide, 0.05m high, and approximately the same length as the windows are the best solution and allow for 75% reflectivity [23] [25] [24].

Exhibit 3.3 - Light Shelves

3.3 **Ceiling Plan**

Exhibit 3.4 - Reflected Ceiling Plans with Proposed Retrofits. In order: Basement, 1st Floor

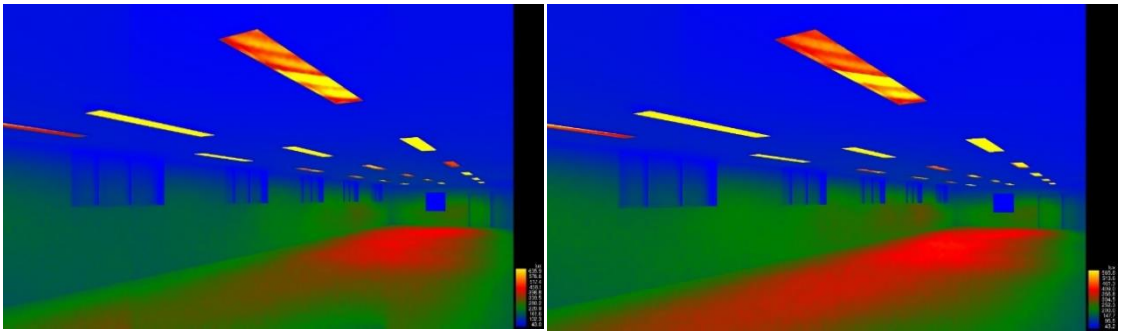


3.4 **Photometric Analysis Drawing**

Too high or too low lighting levels can cause eyestrain, therefore compromising occupants' safety while performing daily tasks. When lighting levels are too low, it can cause other health effects including headaches, falling due to not seeing obstacles, and feelings of depression and claustrophobia [26]. When lighting levels are too high, glare is produced. Glare occurs when bright light is in the field of vision of an occupant, causing them to become distracted or obstruct their vision, resulting in reduced safety and discomfort [26].

Exhibit 3.5 shows photometric analysis drawings of the gym with the replacement LED lights. The drawings confirm that the lux readings in the gym range from 200 to 500 and that the LED bulb replacement retrofit meets the IES illuminance recommendations. A conversion chart of all LED bulb replacements with current and future lux readings of rooms was used (See Appendix B, page 42).

Exhibit 3.5 - Photometric Analysis Drawing of Basement Gym with Replacement LED Lights. 8pm on left, 9am on right.



3.5 **Return on Investment Report**

This section analyzes the financial benefits of the different lighting retrofits. Electricity cost was assumed to be $0.13/kWh and all costs were calculated in Canadian dollars. For a full summary table comparing electricity savings and costs, see Section 3.6. These estimates include material, equipment, and labour costs. For a more detailed estimate, refer to Section 5.

Currently, washrooms, stairwells, and exterior lights consume 6757 kWh/ year. Using motion sensor lighting in these rooms can reduce consumption by 90% resulting in 676 kWh consumed per year [27]. Dimming the light by 25% can save up to 20% of costs [28]. Currently, 16573 kWh/year are being used in the Sanctuary, offices, and kitchen but with dimmer switches, it can be reduced to 13258 kWh/year.

The cost to upgrade the manual switches is $100 to $200. Five dimmer switches can be purchased as a bundle for an additional $150 to $250 [29]. For motion sensor lighting, the cost for one LED outdoor light costs $44.97 and LED indoor light $28.99 [30] [31]. The total costs to implement this option comes to $9216. Typically, most rooms in the church operate for 2-6 hours a day. Taking this into consideration, the payback period for this retrofit comes to 7.5 years.

Recommended LED replacements for the T8/T12, halogen and incandescent lights are determined through comparing the lux readings of all the rooms and the IESNA standard. Lights in rooms which are below or exceed the recommended lux reading will be replaced with LEDs of equivalent or lower wattage of the current lights. NLS assumes the lights in rooms and all washrooms will run 4 hours per day, in stairwells will run 5 hours per day and in hallways will run 8 hours per day 7 days per week and lights in the Sanctuary run 5 hours per week. With these assumptions, replacing existing lights with LEDs will yield an annual electricity saving of 8708 kWh. The LED lights for T8/T12 fluorescent, halogen, and incandescent lights cost $14.99, $4.35, and $2.47 per bulb respectively, specific replacement for the interior and exterior of the Sanctuary costs $14.40 and $9.99 per fixture respectively. The total cost is $3550, resulting in a payback period of 3.1 years.

For the recommended smart light switch retrofit, NLS has considered rooms that are in basement and common spaces, therefore no personal offices. In particular, these rooms include all the basement rooms, the main meeting hall, and the sanctuary since it has switches in 3 different locations. Based on the audit performed by NLS, these chosen rooms require a total of 35 smart switches, at $54.95 per switch and 35 switch wall plates at $3.73 per plate [19] [32]. In addition, this retrofit requires the purchase of a main communications hub called the Samsung SmartThings Hub, which has an upfront cost of $99.99 [33]. This brings the total capital cost to $2154, not including any additional features the client may decide to include.

An assumption of one hour of energy savings per week was made for the sanctuary and one hour per day for the rooms in the basement and the Great Hall, since incorporating smart switches reduces the total energy consumption. Based on these assumptions, 3591.26 kWh of energy would be saved per year, resulting in a payback period of 4.6 years.

By installing light shelves in the Sanctuary and Great Hall, the total energy consumption can be reduced by 30W per foot along the wall where the shelves are placed. For maximum efficiency and savings, it is recommended to install four light shelves in the Great Hall, two shelves under the windows and two on the south wall, under the spotlights, and six shelves in the Sanctuary, one under each stained-glass window. This brings the total number of light shelves to 10, costing $100 per shelf, with an initial equipment cost of $85. The total capital cost for this retrofit is $1085. The Great Hall will require approximately 31 feet of light shelves (5 feet and 10 feet under the windows, 16 feet on the south wall) and the Sanctuary will require 38 feet of light shelves, which means a total of 1653.23 kWh/year will be saved by installing light shelves, resulting in a payback period of about 5 years.

3.6 **Contributions to Net Zero**

A financial summary of the lighting improvements is presented in Exhibit 3.6.

Exhibit 3.6 - Summary of capital cost and payback for lighting recommendations

Retrofit	Capital Cost ($)	Electricity Savings (kWh/yr)	% Electricity Savings/yr	Simple Payback Period (yrs)
Occupancy Sensors and Dimmer Switches	9216.14	9426.00	36.71	7.52
LED Replacements	3550.00	8708.00	33.92	3.14
Smart Light Switches	2153.79	3591.26	13.99	4.61
Light Shelves	1085.00	1653.23	6.44	5.05
TOTAL	14597.43			

NLS recommends proceeding with the implementation of occupancy sensors and dimmer switches, LED replacement of CFL, incandescent, halogen, T8 and T12 fluorescent bulbs, smart-controlled lighting

switches, and light shelves because of their major savings in energy consumption. These retrofits yield a minimum payback period of about 3.14 years and a maximum of 36.71% of annual electricity savings, which contribute to the building's goal of NZE. A detailed estimate and financing plan are presented in Section 5 to assess the true payback period.

4 Technical Analysis 3: Solar Energy System

4.1 Existing Conditions

Armour Heights Presbyterian Church has a large property, providing a tremendous amount of space for solar panels. The large, slanted roofs of the church are excellent for a mechanically attached mounting system. Due to low population density in the suburb, there are no tall buildings around the church that block the sunlight. Overall, AHPC has great potentials for solar generation.

4.1.1 Potential Locations

Armour Heights Presbyterian Church exists on a large property in addition to possessing a large roof. Ideally, a fixed, roof-mounted solar energy systems should be angled equal to the latitude of where it is installed, but between thirty to forty-five degrees also works well. In the case of Armour Heights, the roof is angled at 40 degrees, which is close to Toronto's latitude, 43 degrees.

Another potential location for the PV system is the large parking lot. However, since the lot is to the east of the building, it receives very limited amount of sunlight.

4.2 Component Selection

4.2.1 Panel Selection

Comparing five well known solar panels (See Appendix C, page 43) led to selection of the 60-cell Canadian Solar CS3K-310MS Black Mono Solar Panel for its high-power output and relatively low cost. The limited roof and property area for solar panels at Armour Heights prompted a need for a higher efficiency (18.66%) panel at a reasonable price. Monocrystalline panels are the optimal choice when space is limited, and this Canadian Solar panel has the best ratio of power output to panel area of the panels compared. Furthermore, this established Canadian solar panel manufacturer's products are durable and built for bearing heavy snow loads, ideal for Toronto's climate.

4.2.2 Inverter Selection

The inverter used to convert the DC voltages to AC voltages for daily use was chosen by analyzing through the price, dimension, weight, and performance. The weather conditions of North York are also a factor that determined which inverter would be able to endure the conditions.

In order to provide sufficient 120/240 AC voltage for all daily uses of the church, a pure sine wave inverter had to be implemented. In the market, a string inverter and micro-inverter are the most prominent type of inverter used for photovoltaic panels system. The string inverters are the most conventional and cost-efficient of the two inverters.

Through thorough analysis of inverters and the large potential roof space to place solar panels, string inverters are determined to be more efficient and cheaper. The inverter the team recommends is the Magnum Energy MS4448PAE which can support up to 4400 watts of power. With a 52 kW system, 12 inverters are needed.

4.2.3 Connection Details (Grid/Hybrid/Off-grid)

Exhibit 4.1 - Advantages and Disadvantages of available grid systems

System & Notes	Advantage	Disadvantage
Grid-Tied Most common. Connected to the grid and allows usage of both the power generated from the panels as well as the grid	Both sources of energy are available so if solar panels do not generate enough, power from the grid is supplemented. Customers can get credit for the excess energy generated	Do not provide protection from power outages
Grid-Interactive Charges batteries that can be used during power failures and feeds left-over power into the electricity grid through the inverter	In case of power failure, power generated on site can be used. Draws power from the grid overnight Reliable power supply with lower costs Both energy sources are available	Complex design and installation procedure
Off-Grid	Produces its own power. Convenient when the cost of bringing power connected to the grid is too high.	No energy to rely on as backup if solar panels do not supply enough power.

A grid interactive system is recommended for AHPC. Since solar panels only generate electricity during the day, the church needs to receive electricity from the grid or batteries at night. Due to irregular operating hours, it is predicted that an excessive amount of electricity may be generated on certain days, making batteries a better option than net metering, as Ontario no longer has a buy-in program for onsite electricity generation.

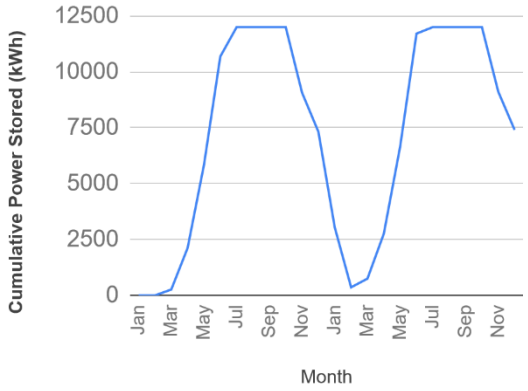
4.2.4 Combiner Box Selection

All solar arrays are combined in series, implying constant amp across each array. Based on the panel selected, the maximum amps for the array is 9.4A, which allows a wide range of combiner box selection. MidNite Solar MNPV3 PV Combiner Box is chosen for this project due to its low cost. With 20 combiner boxes in the system, the cost of combiner boxes adds up to $1,710 total.

4.2.5 Battery Selection

During the summer months, the church will not use all the energy generated by the PV system. A battery system can ensure that this power can be used during the winter, when demand is higher and generation is lower. Exhibit 4.2 shows the cumulative power stored in the batteries during the first two years. During May-Nov, the batteries reach their maximum capacity of 12,000 kWh, and then discharge slowly through the rest of the year, to a minimum in February of about 450 kWh, providing a small buffer for variable electricity use.

Exhibit 4.2 - Cumulative battery power over 2 years



Twelve 12V/100 Ah batteries are suggested, using the UB121000 sealed lead-acid batteries from UPG. These sealed batteries, in exchange for being more expensive than their unsealed analog, require no maintenance. Two extra batteries are suggested to make up for end-to-end efficiency losses. To minimize these losses, the batteries should be kept insulated and indoors, at around 20°C.

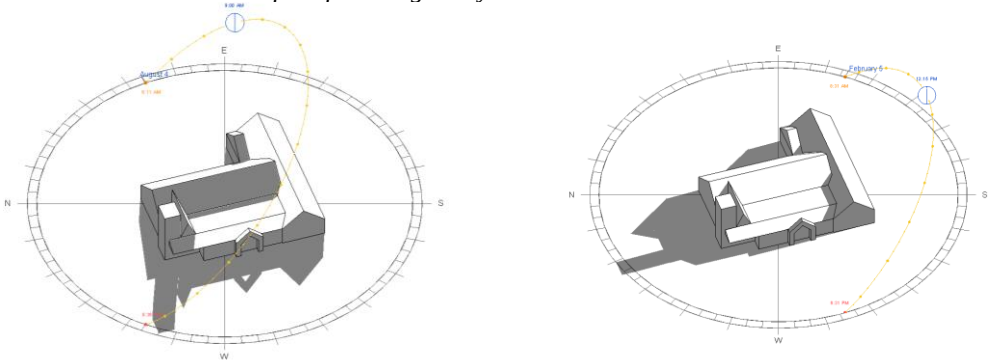
4.2.6 Charge Controller Selection

A charge controller is also needed to control the flow into the batteries, and to act as a transformer. The Midnight Solar Classic 150-SL MPPT charge controller was selected. It can handle 96A, and outputs to 12-72V batteries. The panels as wired output about 200A, and so three charge controllers are required.

4.3 **Shading Studies**

AHPC is located north of downtown Toronto. Surrounded by residential homes, there is little shadowing on its roof from other houses. In order to conduct a thorough shading analysis, Revit was used to model the church.

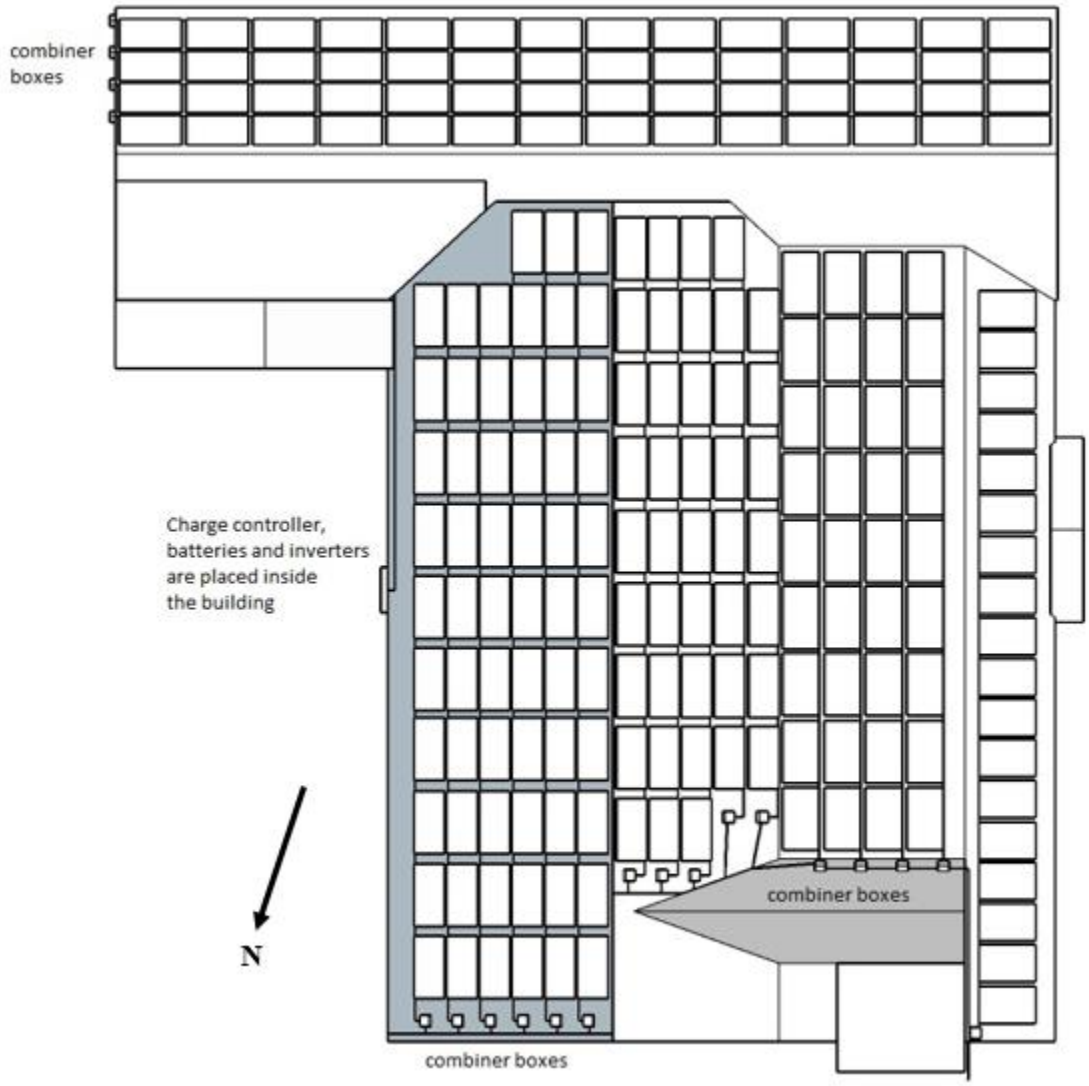
Exhibit 4.3 - Example of shading analysis in Revit



Three roofs are selected for solar panel placement: west facing, south facing, and east facing. South facing room can accommodate 60 solar panels and does not experience shading, generating up to 22,300 kWh of electricity per year. The west and east facing roofs however, experience shading in the morning and in the afternoon, respectively. Overall, the yearly generation from PV system at AHPC totals 71,800 kWh, with an installed capacity of 52.0 kW (for sample calculations, see Appendix C, page 43).

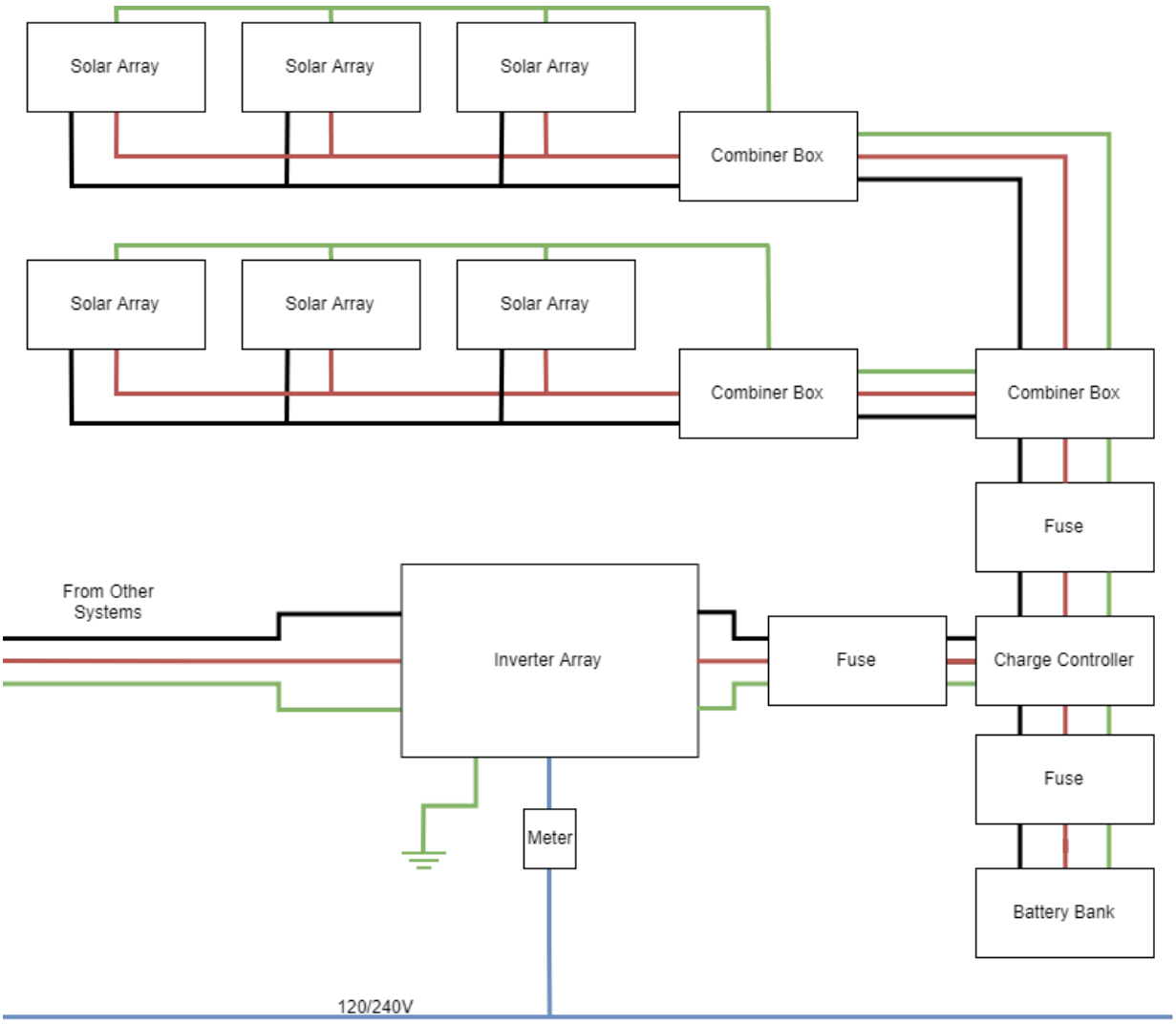
4.4 **Schematic Drawing of PV System**

Exhibit 4.4 - Schematic drawing of AHPC with new PV system



4.5 **Three-Line Diagram**

Exhibit 4.5 - Three Line Diagram. Solar Arrays in the diagram are a generalization of the actual arrangement (For arrangement, see Exhibit X.X, the schematic drawing.)



The PV system is divided into three main sections of panels, shown above in the schematic drawing. Each section consists of up to 8 strings of up to 10 panels, to a total of 226 panels. Each string is joined by a combiner box, which are then grouped into another combiner box for each section. A generalization of this arrangement is shown in the three-line diagram (Exhibit 4.5). The combiner box is connected to one of three charge controllers, which feeds into a central battery bank. The charge controller also sends power to an array of 12 inverters. This number is needed to handle the power sent by all three sections into a central system and is more economical than converting to AC and then back to DC for the batteries.

Efficiency of components of the PV system is subject to temperature change. In order to maximize efficiency and minimize maintenance fees, combiner boxes, batteries and inverters are placed inside the building.

4.6 **Solar Energy Summary**

Overall, NLS recommends the installation of solar panels on the roof of the church, which is able to generate electricity to make the building net zero. Additional solar panels and solar heating devices could be purchased at client's requests. The solar system will cost approximately $112,000 USD to implement up front. This is the cost of 226 panels priced at $215, twelve $1995 inverters, 12 batteries priced at $202 each, 20 combiner boxes at $85.4 each, and $10,200 installation fee ($.59/Watt). Maintenance fees, estimated as 1% of the original cost, are predicted to be about $1,325 annually. The heavy snowfall in the Toronto area will present maintenance challenges as panels must be regularly cleared. Furthermore, the limited roof accessibility of the church may create difficulties for maintenance workers. Currently, there are no incentives for solar energy available in Ontario.

The PV system will generate up to 72,000 kWh of electricity per year, which just offsets the building's annual energy usage. However, slight variations in climate may cause the number to fluctuate. The wear and tear in insulation and other proposed retrofits is likely to increase the energy usage in the future. Therefore, the team recommends a 5kW added capacity to the proposed system, which will bring the total generation to 78,000 kWh per year.

It is estimated that 10% of Ontario's energy comes from natural gas power plants which emits 525g of CO_2 per kWh of electricity generated. Including the GHG emission from operating and maintaining PV system (6.15g/kWh), the annual CO_2 eliminated is roughly 3340 kg (3.7 US tons). Over the 25-year lifetime of the PV system, it will eliminate a total of 83,500 kg (92 US tons) of CO_2 (See Appendix C, page 43).

5 Schematic Estimate, Schedule and Finance Plan

5.1 **Cost Estimate**

A preliminary cost estimate was prepared for the Armour Heights energy retrofit project. This cost estimate includes materials, direct labour, indirect expenses, and general expenses of the project. A summary of all estimates is provided in Exhibit 5.1 with detailed tabulations (See Appendix D, page 44). The project total is approximately $239,039.00 and $1,485.00 annually thereafter.

Cost information was derived from local manufacturers, direct labour and escalation from the NECA manual of Labour Units and Statistics Canada [34] [35], various fees from the City of Toronto [36], and design fees from the Royal Architectural Institute of Canada [37].

Exhibit 5.1 - Quantity take off for AHPC Retrofits

	Materials			Direct Labour			
Item Description	**Quantity**	**Unit Cost**	**Total Cost**	**Man Hours**	**Hourly Wage**	**Total Cost**	**Item Total**
Lighting Retrofit							
LED Replacements	266	varies	$3,550	22.95	N/A	N/A	$3,550
Occupancy Sensors	160	varies	$4,846	56	$40	$2,240	$7,086
Dimmer Switches	30	varies	$1,350	19.5	$40	$780	$2,130
Smart Lighting System Components	varies	varies	$2,154	5	N/A	N/A	$2,154
Light Shelf	10	$100	$1,000	3	N/A	N/A	$1,000
Subtotal			$12,900			$3,020	$15,920
Solar PV System							
Panel	226	$289	$65,303	180.8	$40	$7,232	$72,835
				15	$20	$300	
Inverter	12	$1,995	$23,940	24	$20	$480	$24,420
Battery	12	$203	$2,432	3	$40	$120	$2,552
Charge Controller	3	$595	$1,785	3	$40	$120	$1,905
Combiner Box	20	$85	$1,708	10	$40	$400	$2,108
Subtotal			$95,167			$8,652	$103,819
HVAC Retrofit							
Subtotal			$1,256			$360	$1,616
Enclosure Retrofit							
Subtotal			$29,729			$5,600	$35,329
TOTAL			$139,052			$17,632	$156,684

	Indirect Expenses	
Item Description	**Percentage of Total**	**Subtotal**
Engineering Consulting	6.8%%	$10,654.50

Overhead/Profit	12%	$18,802.05
Labor Escalation	4%	$6,267.35
Ontario Sales Tax	13%	$20,368.89
Insurance and Liability	3%	$4,700.51
Contingency	10%	$15,668.38
Municipal Inspection	-	$686.32
Material Delivery/Handling	2.50%	$3,917.09
TOTAL		$81,065.09

	Maintenance	
Item Description	**Frequency**	**Subtotal**
Solar Panel Cleaning	1/year	$1,325.00
Solar Panel Inspection	1/5years	$800.00
MAINTENACE TOTAL	Per year	$1,485.00

	General Expenses
Item Description	**Subtotal**
Permits	$632.95
Disposal/Recycling	$127.22
Tools/Equipment	$500.00
TOTAL	$1,260.17
PROJECT TOTAL	$239,009.03

5.2 **Scheduling**

The projected schedule shown in Exhibit 5.2 was generated to minimize disturbance to the occupants and activities at Armour Heights and provide timely completion of work. The total projected length from detailed design to project closeout is 106 days. The project time frame occurs from January 6, 2020 to July 8, 2020, with construction beginning after winter and before the busy summer season when the number of programs and activities are expected to increase.

Included in the schedule are the design, pre-construction, construction, and closeout phases. Each phase incorporates all retrofits proposed (lighting, solar PV, and enclosure/HVAC), with work occurring in parallel wherever possible.

The schedule is based on a crew of approximately 8 electricians, 10 professional installers, and volunteers for a 40-hour work week. Additional indirect labour is also expected during all phases of work. Based on church operations during the time of this proposal, work will not occur on Sundays or Wednesdays. These are two days where the church is busiest and uses facilities for the day's majority [38]. On working days, most activities and programs occur very early morning and late evening, making an 8am-5pm workday optimal. These hours will also abide by Toronto's Noise Bylaw in the Municipal Code [39]. A power shutdown will be required for the solar PV installation, which will be coordinated to a day with least impact. NLS acknowledges that the church's daily schedule may change within the next year, and project schedule is required to adapt as necessary.

Exhibit 5.2 – Proposed Schedule for AHPC Retrofits (On next page)

5.3 Safety

Safety will be of utmost importance throughout construction, especially with the large number of young children and seniors that may occupy the building during scheduled activities. This will be a major factor throughout the contractor selection process. In addition to the *Occupational Health and Safety Act* for construction projects, safety discussions will be encouraged at all pre-bid and kick-off meetings. An effort will also be made to educate church occupants on potential hazards and precautions they may need to take during active construction.

5.4 Cash Flow Plan

To finance this project and maintain the church's regular operations, a combination of incentives, rebates, and loans have been considered. A subsequent analysis has been performed using Energy Star's Cash Flow Opportunity Calculator to determine the payback period, assess financing options, and determine the net present value of the retrofit project.

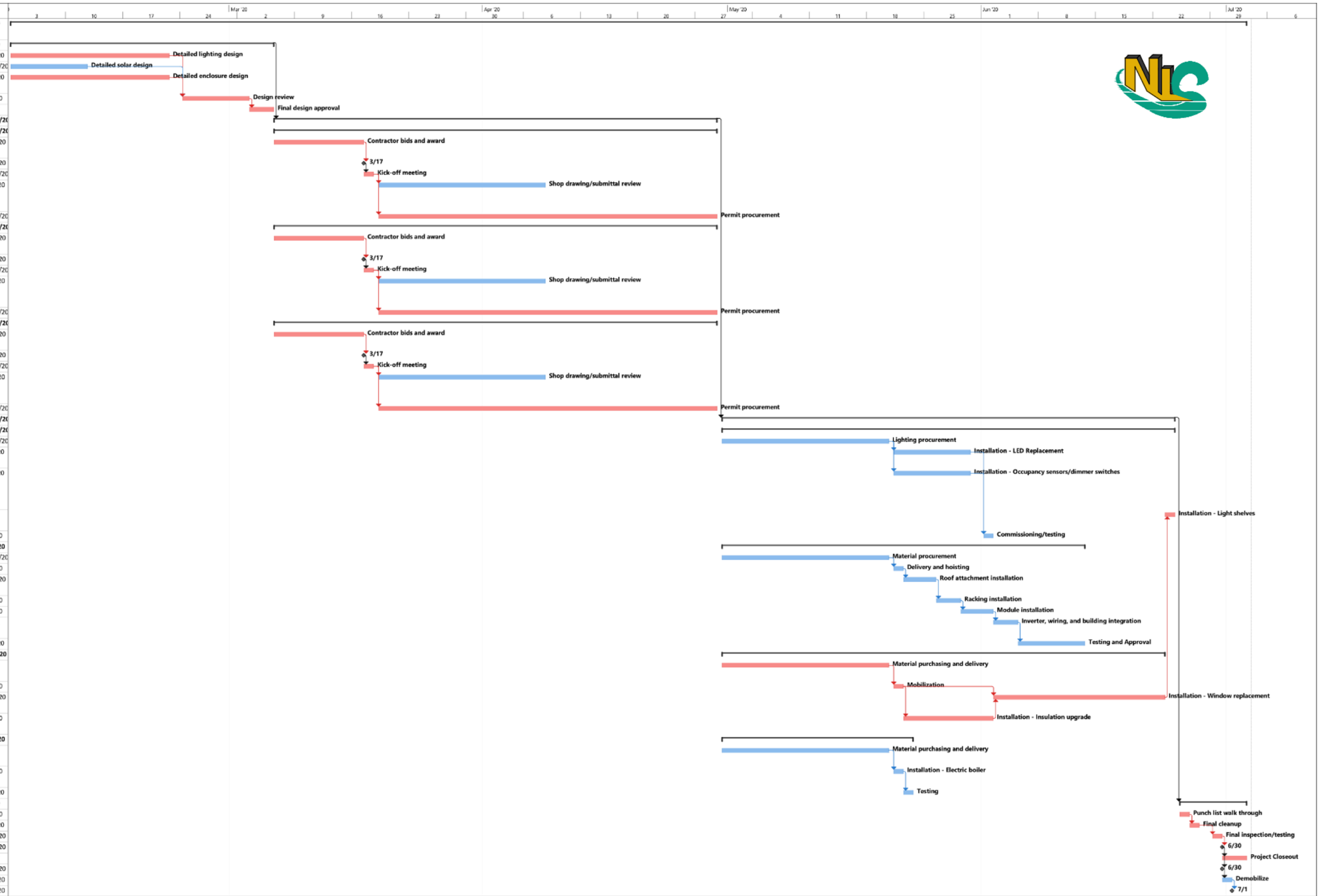
5.4.1 Incentives and Rebates

The Armour Heights energy retrofit project is eligible for numerous incentives and rebates provided by Save on Energy, and Enbridge [40], Ontario's energy distribution company [41] Exhibit 5.3 below summarizes all available options. A total of $4,848.92 in awards is available within the first year of project completion.

Exhibit 5.3 - Available Incentives

Incentive Name	Amount	Total Amount Eligible
Save on Energy incentive	$0.05/kWh saved	$1,168.92
Enbridge boiler rebate	$750 ea.	$750.00
Enbridge insulation rebate	$1,500 per installation	$1,500.00
Enbridge Energy Star window rebate	$40 ea.	$680.00
Enbridge multiple energy upgrade incentive	$250 ea.	$750.00
	TOTAL AMOUNT	$4,848.92

ID	Task Name	Duration	Start	Finish
1	**Armour Heights Building Retrofit**	**87 days**	**Mon 2/3/20**	**Fri 7/3/20**
2	**Design Phase**	**19 days**	**Mon 2/3/20**	**Fri 3/6/20**
3	Detailed lighting design	2 wks	Mon 2/3/20	Sat 2/22/20
4	Detailed solar design	1 wk	Mon 2/3/20	Wed 2/12/20
5	Detailed enclosure design	2 wks	Mon 2/3/20	Sat 2/22/20
6	Design review	5 days	Mon 2/24/20	Tue 3/3/20
7	Final design approval	2 days	Tue 3/3/20	Fri 3/6/20
8	**Pre-Construction**	**31 days**	**Fri 3/6/20**	**Wed 4/29/20**
9	**Lighting Retrofit**	**31 days**	**Fri 3/6/20**	**Wed 4/29/20**
10	Contractor bids and award	1 wk	Fri 3/6/20	Tue 3/17/20
11	Notice to proceed	0 days	Tue 3/17/20	Tue 3/17/20
12	Kick-off meeting	1 day	Tue 3/17/20	Wed 3/18/20
13	Shop drawing/submittal review	2 wks	Thu 3/19/20	Wed 4/8/20
14	Permit procurement	1 mon	Thu 3/19/20	Wed 4/29/20
15	**Solar PV**	**31 days**	**Fri 3/6/20**	**Wed 4/29/20**
16	Contractor bids and award	1 wk	Fri 3/6/20	Tue 3/17/20
17	Notice to proceed	0 days	Tue 3/17/20	Tue 3/17/20
18	Kick-off meeting	1 day	Tue 3/17/20	Wed 3/18/20
19	Shop drawing/submittal review	2 wks	Thu 3/19/20	Wed 4/8/20
20	Permit procurement	1 mon	Thu 3/19/20	Wed 4/29/20
21	**Enclosure Retrofit**	**31 days**	**Fri 3/6/20**	**Wed 4/29/20**
22	Contractor bids and award	1 wk	Fri 3/6/20	Tue 3/17/20
23	Notice to proceed	0 days	Tue 3/17/20	Tue 3/17/20
24	Kick-off meeting	1 day	Tue 3/17/20	Wed 3/18/20
25	Shop drawing/submittal review	2 wks	Thu 3/19/20	Wed 4/8/20
26	Permit procurement	1 mon	Thu 3/19/20	Wed 4/29/20
27	**Construction Phase**	**32 days**	**Thu 4/30/20**	**Wed 6/24/20**
28	**Lighting Retrofit**	**32 days**	**Thu 4/30/20**	**Wed 6/24/20**
29	Lighting procurement	2 wks	Thu 4/30/20	Wed 5/20/20
30	Installation - LED Replacement	1 wk	Thu 5/21/20	Sat 5/30/20
31	Installation - Occupancy sensors/dimmer switches	1 wk	Thu 5/21/20	Sat 5/30/20
32	Installation - Light shelves	1 day	Tue 6/23/20	Wed 6/24/20
33	Commissioning/testing	1 day	Mon 6/1/20	Tue 6/2/20
34	**Solar PV**	**26 days**	**Thu 4/30/20**	**Sat 6/13/20**
35	Material procurement	2 wks	Thu 4/30/20	Wed 5/20/20
36	Delivery and hoisting	1 day	Thu 5/21/20	Fri 5/22/20
37	Roof attachment installation	2 days	Fri 5/22/20	Tue 5/26/20
38	Racking installation	2 days	Tue 5/26/20	Fri 5/29/20
39	Module installation	2 days	Fri 5/29/20	Tue 6/2/20
40	Inverter, wiring, and building integration	2 days	Tue 6/2/20	Fri 6/5/20
41	Testing and Approval	5 days	Fri 6/5/20	Sat 6/13/20
42	**Enclosure Retrofit**	**31 days**	**Thu 4/30/20**	**Tue 6/23/20**
43	Material purchasing and delivery	2 wks	Thu 4/30/20	Wed 5/20/20
44	Mobilization	1 day	Thu 5/21/20	Fri 5/22/20
45	Installation - Window replacement	2 wks	Tue 6/2/20	Tue 6/23/20
46	Installation - Insulation upgrade	1 wk	Fri 5/22/20	Tue 6/2/20
47	**HVAC Retrofit**	**14 days**	**Thu 4/30/20**	**Sat 5/23/20**
48	Material purchasing and delivery	2 wks	Thu 4/30/20	Wed 5/20/20
49	Installation - Electric boiler	1 day	Thu 5/21/20	Fri 5/22/20
50	Testing	1 day	Fri 5/22/20	Sat 5/23/20
51	**Closeout**	**5 days**	**Thu 6/25/20**	**Fri 7/3/20**
52	Punch list walk through	1 day	Thu 6/25/20	Fri 6/26/20
53	Final cleanup	1 day	Fri 6/26/20	Sat 6/27/20
54	Final inspection/testing	1 day	Mon 6/29/20	Tue 6/30/20
55	Final Acceptance	0 days	Tue 6/30/20	Tue 6/30/20
56	Project Closeout	2 days	Tue 6/30/20	Fri 7/3/20
57	Submit O&M manuals	0 days	Tue 6/30/20	Tue 6/30/20
58	Demobilize	1 day	Tue 6/30/20	Wed 7/1/20
59	Project Completion	0 days	Wed 7/1/20	Wed 7/1/20



Project: Armour Heights Schedu
Date: Wed 4/24/19

Task · Milestone · Project Summary · Inactive Milestone · Manual Task · Manual Summary Rollup · Start-only · External Tasks · Deadline · Critical Split · Manual Progress
Split · Summary · Inactive Task · Inactive Summary · Duration-only · Manual Summary · Finish-only · External Milestone · Critical · Progress

5.4.2 Loans

Armour Heights' annual financial reports were made available to NLS to aid in financial planning of the project. At the end of the 2017 fiscal year, the church had accumulated approximately $84,000 in operating funds. Assuming that a majority of these funds will not be available to the energy retrofit project, NLS has selected the City of Toronto's Energy Retrofit Loan as the most feasible option to finance the project. This loan was established by the city to encourage energy consciousness: It covers up to 100% of the total project costs at a rate equal to the City's cost of borrowing [42]. The bank of Canada's prime rate of 3.95% was used for analysis.

5.4.3 Financial Analysis

A cash flow analysis was performed using a total project cost of approximately $239,000 and annual savings of $33,000, which will be used towards paying for the project. The simple payback will be 7 years. The City of Toronto Energy Retrofit loan at 3.95% interest over 8 years will be used for further analysis.

Parameters used for analysis include:

- Increase in project costs due to labour and material escalation by 4%, from Statistics Canada
- Annual increase in energy costs by 8%, forecasted by the Ontario Energy Board

Exhibit 5.4 - Cash Flow Diagram

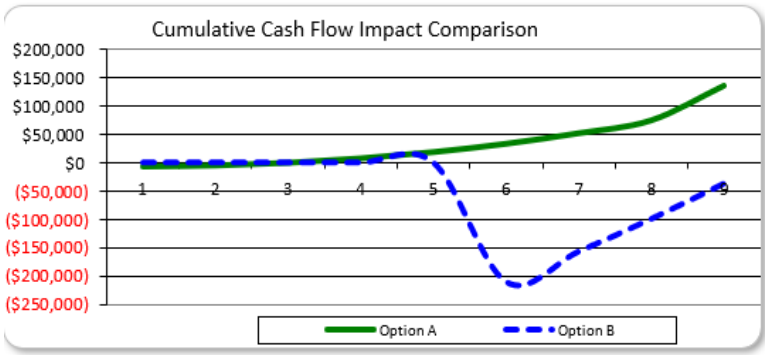


Exhibit 5.4 shows the cumulative cashflow when comparing two options; A and B. Option A chooses to finance the project immediately whereas Option B chooses to wait five years, when church funds are projected to accrue to equal total project costs. Option B avoids interest payments, but potential savings are lost during the waiting period. The net present value of Option A and B after eight years are $101,259 and -$39,654 respectively. The immediate financing option generates $140,912.4 more cash, making it a better financial decision. The break-even-point is projected to occur at 14.3 months.

6 Outreach

During the Green Energy Challenge project development, our team focused significantly on outreach efforts to raise awareness of sustainable systems within our student communities and at AHPC. This has strengthened the quality of our work by providing opportunities for others to learn about and value the purpose behind what we do.

6.1 Energy Awareness Campaign and Volunteering

Our team enthusiastically volunteered at AHPC and connected with the church community. This year, our energy awareness campaign targeted children because we believe it is important to encourage young minds to take care of the natural environment that will sustain them. Our team integrated our programming into three of AHPC's Sunday School classes as well as its Mission Possible Kids Night. Following the proposal's deadline, we will be joining other community volunteers on May 2nd to help AHPC prepare for its annual rummage sale. A volunteering log was created for each session (See Appendix D, page 44).

6.1.1 Sunday School Classes

Our overall goal was to enhance the children's spiritual understanding with new scientific knowledge that they can see in action and apply to their everyday lives. We designed our curriculum to tie the concept of dominion in the Story of Creation to environmental stewardship. Both perspectives taught the children that our planet's natural resources are essential to us, and if we want our future generations to thrive, we must fulfill our special responsibility of taking care of these resources.

Each class started with a Biblical portion run by Rebecca Jess and Sarah Roberts, and transitioned to a science portion presented by our team. To plan for each class, we brainstormed a main theme related to energy conservation and efficiency, decided on main takeaways to communicate to the children, incorporated these takeaways into interactive games, and reviewed our plan based on feedback from AHPC.

In the first session, the children noted how the Story of Creation frequently mentioned different natural resources and all were "good". We discussed about how these valuable resources produce electricity that powers our lives, which we often waste with convenient access to it. An example most children knew of wasting electricity was keeping appliances on when not in use; however, we introduced them to the concept of vampire loads (when appliances that are turned off but plugged in drain energy). The children played tag, in which they were energy generators that had to avoid a secret energy vampire trying to drain their power.

During the second session, the Story of Creation's ending was highlighted where God gave humans dominion over His creations. This led the children to play a game where they were shipwrecked on an island and had to use resources to survive. Each task we gave them (such as building shelter or building power generating plants) filled the island with "waste". The game illustrated to the children that we

Exhibit 6.1 – Island survival game at AHPC's Sunday School

need to produce energy from different resources to live, but this depletes resources and creates pollution, thus highlighting the importance of energy conservation.

Exhibit 6.2 - Waste sorting game setup at AHPC's Sunday School

We wrapped up with our third session on how energy conservation and efficiency can be applied to our everyday lives. The children discussed how they can change their daily habits to use lighting, heating, and water more efficiently in their homes. Following this, we taught them that even practicing reducing, reusing, and recycling saves energy by shortening energy intensive manufacturing processes. Through a waste sorting game, the children practiced this indirect energy saving method.

Overall, our team successfully engaged with about 25 different children ranging from 5 to 13 years old through our Sunday School classes. Several children returned multiple times and were able to recall the new lessons they had learned. Some of the older children even connected what they were learning in their science classes at school to the spiritual teachings from Sunday School. At the end of each class, we joined the community gatherings after Sunday service, where we met some of the parents who were delighted to hear about the activities we organized for their children and were curious about our Green Energy Challenge project.

6.1.2 Mission Possible Kids Night

To reach children in the community beyond Sunday School, we hosted AHPC's Mission Possible Kids Night. Our team designed the underlying mission to focus on empowering children to become stewards of the Earth, covering topics from planting trees to waste reduction to energy conservation. We introduced the children to the Waste Wizard, who loves to waste energy and resources. Their mission was to defeat the wizard and his minions, and save the planet!

Exhibit 6.4 – Rescuing friends in a game of tag at AHPC's Mission Possible Kids

Exhibit 6.3 – Waste themed musical chairs at AHPC's Mission Possible Kids Night

The children found a wanted poster for the Waste Wizard, calling on them to defeat his evil efforts. First, the children snuck into the Waste Wizard's lair to save seeds he wanted to destroy without getting caught by his minions. Then, they played musical chairs, in which each child was assigned a waste item and had to find the correct waste bin it belonged to once the music stopped each round. Those who were eliminated were turned into the Waste Wizard's plastic zombies and taken to his lair. The remaining children had to save their captured plastic zombie friends to reduce the Waste Wizard's plastic waste. To do this, they found a special amulet with the power to turn plastic zombies into humans. Then, at the Waste Wizard's lair, the children formed a chain with the child at front holding the amulet, who would tag and save all the plastic zombies. The children's final task was to secure the energy stones from the lair as the Waste Wizard carelessly threw them away. Finally, the children completed their mission of defeating the Waste Wizard and reflected on the lessons they learned as a group. Altogether, 16 children enthusiastically participated and got to learn about how each of them has the power and the responsibility to help the environment.

6.2 **Local NECA/CECA Chapter Interactions**

Throughout the school year, including fall semester before Green Energy Challenge took place, CECA UofT has maintained contact with several CECA affiliated contractors. Prior to GEC, the club hosted the Sustainable Building Competition (SBC). Contractors were invited to judge the proposals submitted by student groups and their presentations. Angelo Suntres, a contractor from Black & McDonald, has offered a tremendous amount of help since the SBC, as well as during GEC.

CECA UofT had the pleasure to meet Larry Tricinci through our Student Passport Proposal this year. Larry connected the students with a non-CECA affiliated contractor, Nick Iozzo, who assisted in solar designs and three-line diagrams.

The club re-established relationship with contractor Bob Ritzmann from Alltrade Industrial. Bob brought forward suggestions for the solar team as well. A log of exchanges between CECA UofT and contractors was created (See Appendix D, page 44).

6.3 **Letter from Armour Heights Presbyterian Church**

ARMOUR HEIGHTS PRESBYTERIAN CHURCH

CHURCH: 416-485-4000
FAX: 416-485-2304
Discover the Vitality of Faith

105 WILSON AVE., TORONTO M5M 2Z9
www.armourheights.org

April 26, 2019

Northern Lights Solution – Green Energy Challenge 2019
University of Toronto CECA/NECA Student Chapter
Department of Civil Engineering, University of Toronto
35 St. George Street, Toronto, ON M5S 1A4

Re: Armour Heights Presbyterian Church Energy Retrofit - Green Energy Challenge 2019

Dear NLS Team,

I am not an engineer. Until this year I had never heard of CECA. What I *am* is a church minister. A great deal of my work involves living, playing, creating, building, problem solving, worshipping, and engaging in fellowship with communities of people. Being a minster is relational work—it is about bringing people together. Certainly faith plays a large role in things, but engaging in the work and study of our faith is impossible without communities both in and outside of our church to engage with.

When I first heard about CECA and the group of people who wished to partner with Armour Heights Presbyterian Church for the Green Energy Challenge, it could have been easy to view it as a group of students doing their work somewhat distanced from the "real" work of our church. However, the CECA team made it clear that their work extends far beyond simply auditing the energy efficiencies of our building; they made a strong impact on the people who attend Armour Heights both as worshipping members and as community members who participate in our activities and events.

Members of our church community are excited to learn from the CECA team's proposal; how can our community make our building more energy efficient? What can we do better to make our practices more green? What are our next best steps in the short term, and what should we be thinking about for the long term? These questions have all been stimulated by the presence of CECA.

On top of this, members of CECA led interactive discussions and games with the children in our Church School, as well as with children who live in the Armour Heights community. These lessons and activities were creative ways for our children to learn about what energy is, where it comes from, how we can use less energy, waste management, and ways they can make positive changes in their own homes.

Beyond these examples, CECA volunteers will also be helping Armour Heights to organize items for a large rummage sale that the church holds for the greater community each year. Not only will their efforts be appreciated, but their presence also helps us to shift our perspective and see the rummage sale as not simply a fundraising effort, but as a way to encourage people to reuse items rather than tossing them or buying new—in short, to think green.

Armour Heights Presbyterian Church is very pleased to have been selected to partner with CECA. The group has positively impacted our congregation and community-at-large in a number of ways, and those impacts will not be short-lived, which makes the partnership all the more meaningful.

Sincerely,

Rebecca Jess

Rev. Rebecca Jess
Associate Minister, Armour Heights P.C.
Toronto, ON

6.4 **Campus and Local Media Engagement**

6.4.1 University/Departmental Newsletter

Posted April 23rd, 2019 by Keenan Dixon

U of T student team helps local church achieve sustainability and reduce its energy footprint

During the energy audit at AHPC, Noah Cassidy (left) recorded window temperature with a thermal imaging camera while Niloufar Ghaffari (right) recorded lux readings for lighting retrofits.

With energy costs on the rise, organizations all over Canada are looking to reduce their energy consumption wherever possible — and these U of T Engineering students are helping to make that possible.

Northern Lights Solutions (NLS) is a design team within the **student chapter of the Canadian/National Electrical Contractors Association** (CECA/NECA U of T). The group works with client organizations to create retrofit plans, which aim to reduce the client's overall energy consumption and promote onsite power generation.

As a part of their 2019 submission to the ELECTRI International Green Energy Challenge, NLS is working with the Armour Heights Presbyterian Church (AHPC). They have conducted an energy audit that assessed electricity usage, lighting, building enclosures, and mechanical systems at the facility. The team is developing a retrofit proposal that will improve AHPC's building performance and will achieve a net-zero energy footprint.

In addition to the energy audit, NLS introduced an energy conservation awareness campaign for young children at the church through the Sunday School program and Mission Possible Kids Night.

"It means a lot for us to be able to connect with the tight knit community at Armour Heights," said Dorothy Liu (CivE Year 3), President of CECA/NECA U of T. "It was rewarding to inspire the children to take care of the environment each and every day. It made us appreciate our technical work and we couldn't have done it without the support of the incredible church community!"

During the energy audit at AHPC, Noah Cassidy (left) recorded window temperature with a thermal imaging camera while Niloufar Ghaffari (right) recorded lux readings for lighting retrofits.

NLS will submit its retrofit proposal as a part of their entry into the ELECTRI International Green Energy Challenge. If selected as a top team, NLS will travel to Las Vegas this fall to present their proposal.

This competition allows students to expand their knowledge of sustainable buildings and make meaningful contributions through volunteering.

"The Green Energy Challenge bridges theory and application by providing students with the opportunity to use their knowledge to help their community," said Professor Brenda McCabe (CivMin), the team's faculty advisor. "By entering this international challenge, students gain exposure to the industry and have an opportunity to create connections with current CECA/NECA members."

"As a testament to the achievements of this student group, two of the four projects they have previously proposed have been implemented by the client organizations, who were inspired by the team's work," continued McCabe.

Since 2015, NLS has grown to a team of diverse students from various STEM programs, brought together by their passion for sustainable buildings, green energy, and leadership development. Currently, the team includes: Noah Cassidy (CivE Year 4) (Project Manager), Jacqueline Lu (CivE 1T8) (Finance/Audit), Yuexin Liu (Mathematics Year 1) (Building Performance), Niloufar Ghaffari (CivE Year 4) (Lighting), Fariha Oyshee (CivE Year 2) (Solar), and Lauren Streitmatter (ChemE Year 1) (Community Engagement).

"The entire NLS team would like to thank the University of Toronto Department of Civil & Mineral Engineering for providing us with the resources and support, empowering us to make an impact on organizations in our community," said Liu.

6.4.2 NLS Blog

To improve awareness of our Green Energy Challenge project and to attract a larger audience, our team continued to update our blog at https://cecauoft.wordpress.com/ and promoted it through social media, as illustrated in **Error! Reference source not found.**. The blog's first post gives a brief introduction to G EC, the contributions AHPC makes in the community, and why net zero energy consumption is important for us to deliver to the client. This led to our second blog on our energy audit at AHPC. We explained the relevance of some of our collected data on electricity usage, lighting, building enclosures, and mechanical systems to designing improvements for the facility performance. The third post gave insight into our volunteering efforts at AHPC. It explained how we integrated our energy conservation and efficiency lessons into the Sunday School classes and Mission Possible Kids Night and the impact this had on the church community.

6.4.3 3D Model of AHPC

NLS had the pleasure of working with Farid Mirahadi, a graduate student from the University of Toronto, to create a 3D model of AHPC. Through his research position in construction engineering, Farid obtained a 3D camera through Matterport, a company that specializes in 3D modelling and visual tours. The camera works by taking a 360-degree picture of a room and compiling the pictures together to create the 3D effect. AHPC featured this model (See Appendix A, page 41), on their website. This fascinated several community members, who wanted to find out more about our Green Energy Challenge project from us after Sunday service. The AHPC staff also expressed how useful the model would be when external organizations book rooms in the facility.

7 Appendix A – Introduction and Technical Analysis 1: Energy Efficiency Analysis

3D Walkthrough Link	https://my.matterport.com/show/?m=k1nftLcfD33&hl=0

8 Appendix B – Technical Analysis 2: Lighting Retrofit

Exhibit 8.1 - LED Replacement Data

Room	Existing Lamp Type	Current wattage	Lux reading	Recommended LED Wattage	Lux or Luminance	LED Unit Price	Wattage Savings	Hours of Operation	# of Bulbs	Savings per Year	Total Price of LED Units	Electricity Savings (kWh/yr)
1-2	T12 F	40	82.7	18	2000	$14.99	22	4	8	$33.31	$119.92	256256
1-3	T12 F	40	48	18	2000	$14.99	22	4	6	$24.98	$89.94	192192
1-8	T12 F	40	69	18	2000	$14.99	22	4	16	$66.63	$239.84	512512
1-10	T12 F	40	596	18	2000	$14.99	22	4	16	$66.63	$239.84	512512
1-11	T12 F	40	174.7	18	2000	$14.99	22	4	10	$41.64	$149.90	320320
1-18	T12 F	40	624	18	2000	$14.99	22	4	54	$224.86	$809.46	1729728
1-13	T12 F	40	762.4	18	2000	$14.99	22	4	9	$37.48	$134.91	288288
1-14	T12 F	40	761.5	18	2000	$14.99	22	4	4	$16.66	$59.96	128128
1-25 (stairwell)	T12 F	40	453.3	18	2000	$14.99	22	5	2	$10.41	$29.98	80080
B-7	T12 F	40	156.4	18	2000	$14.99	22	4	27	$112.43	$404.73	864864
B-8 (kitchen)	T12 F	40	1230	18	2000	$14.99	22	6	9	$56.22	$134.91	432432
B-14 (hallway)	T12 F	40	1260	18	2000	$14.99	22	8	10	$83.28	$149.90	640640
B-18 (washroom)	T12 F	40	457	18	2000	$14.99	22	4	2	$8.33	$29.98	64064
B-12 (stairwell)	T12 F	40	453.3	18	2000	$14.99	22	5	2	$10.41	$29.98	80080
B-16(hallway)	T12 F	40	453.3	18	2000	$14.99	22	8	2	$16.66	$29.98	128128
1-9 (washroom)	T8 F	32	761.5	18	2000	$14.99	14	4	4	$10.60	$59.96	81536
1-24	T8 F	32	762.4	18	2000	$14.99	14	4	6	$15.90	$89.94	122304
1-16 (washroom)	T8 F	32	761.5	18	2000	$14.99	14	4	4	$10.60	$59.96	81536
B-4 (washroom)	T8 F	32	374	18	2000	$14.99	14	4	2	$5.30	$29.98	40768
B-15A	90W Halogen	90	29.5	13	2000	$4.35	77	0.71	4	$10.35	$17.40	79599.52
B-15C	90W Halogen	90	29.5	13	2000	$4.35	77	0.71	16	$41.39	$69.60	318398.08
1-7	Incandescent	60	82	8.8	2000	$2.47	51.2	4	3	$29.07	$7.41	223641.6
1-9 (washroom)	Incandescent	60	761.5	8.8	2000	$2.47	51.2	4	1	$9.69	$2.47	74547.2
1-16 (washroom)	Incandescent	60	761.5	8.8	2000	$2.47	51.2	4	1	$9.69	$2.47	74547.2
B-18 (washroom)	Incandescent	60	457	8.8	2000	$2.47	51.2	4	1	$9.69	$2.47	74547.2
B-1 (stairwell)	Incandescent	60	2850.6	8.8	2000	$2.47	51.2	5	5	$60.57	$12.35	465920
B-15B	1 halogen, 1 incandescent	118	29.5	23	2000	$14.40	95	0.71	20	$63.83	$288.00	491036
B-15C	1 halogen, 1 incandescent	118	29.5	23	2000	$14.40	95	0.71	8	$25.53	$115.20	196414.4
Exterior	Halogen	150		0	2000	$9.99	150	0.2	14	$19.87	$139.86	152880
									Total:	$1,132.03	$3,550.30	8707.90
									Payback period (yrs):	3.14		

9 Appendix C – Technical Analysis 3: Solar Energy System

Exhibit 9.1 - Panel Selection

Panel	Cost (USD)	Power (Watts)	Type	Weight (lbs)	Dimensions
Canadian Solar CS3K-310MS Black Mono Solar Panel	$215.00	310	Monocrystalline	40.8	65.9 × 39.1 × 1.57 in
Canadian Solar CS6U-325P Poly Silver Solar Panel	$239.00	325	Polycrystalline	49.4	77.2 × 39.1 × 1.57 in
Mission Solar 315 Mono PERC Solar Panel	$225.00	315	Monocrystalline	40.1	65.53 × 39.33 × 1.58 in
JA Solar 330W Silver Poly Solar Panel	$178.00	330	Polycrystalline	49.6	77.17 × 39.02 × 1.57 in
Panasonic 330 watt - Black Frame HIT Solar Panel	$399.00	330	Bifacial	40.81	62.6 × 41.5 × 1.6 in

Exhibit 9.2 - Inverter Selection

Name of Inverter	Type of Inverter	Price & Warranty	Size & Weight	Watts	Input Voltage	Output voltage	Efficiency
Magnum Energy MS4448PAE Inverter	String Pure sine waves	$1,995.00 3 year warranty	12.7 x 13.8 x 8 in 55 lbs	4400	48 V DC	120/240 V AC	-20°C to 60°C
Schneider Conext SW4048 Inverter	String Pure Sine waves	1595		3800	48 V DC	120/240 VAC	-20°C to 60°C

Enphase IQ7X	Micro Inverter	185/per	212 mm x 175 mm x 30.2 mm	315	25 - 80	240	-40°C to 60°C

Annual CO_2 saved by switching to PV

$$72{,}000\ kWh \times 10\% \times 525\frac{g}{kWh} - 72{,}000kWh \times 6.15\frac{g}{kWh} = 3{,}337{,}200g = 3340\ kg$$

10 Appendix D – Community and Contractor Engagement

Exhibit 10.1 - Volunteering Log

Date	Type of Volunteer Activity	Hours Volunteered	Number of Volunteers	Volunteers
March 24	Sunday School Class 1	2	4	Lauren, Noah, Pavani, Dorothy
March 31	Sunday School Class 2	2	4	Lauren, Noah, Pavani, Heenal
April 7	Sunday School Class 3	2	4	Lauren, Rose, Pavani, Dorothy
April 12	Mission Possible Kids Night	3	5	Shambhavi, Noah, Jacquelin, Niloufar, Dorothy
May 2	Rummage Sale Preparation	2	3	Pavani, Noah, Niloufar
Total number of hours volunteered = 11 hours Number of different volunteers = 9 volunteers Cumulative “average volunteer hours per team member” = 11/9 = 3.7 hours				

Exhibit 10.2 - Local NECA/CECA Chapter Communications and Interactions Log

Date	Name	Company	CECA affiliated (Y/N)	Reason for contacting
Feb 28	Gregg Whitty	CECA	Y	U of T Chapter Update
March 7	Bob Ritzmann	All Trade Industrial	Y	PV system help
March 8	Larry Tricinci	Beacon Utility	Y	3 Line Diagram
March 9-15	Nick Iozzo	DPM Energy	N	3 Line Diagram (referred through Larry)
March 10	Deborah Halpern	ELECTRI	Y	GEC 2019 Electricity Pricing
March 18	Angelo Suntres	Black & Mcdonald	Y	Scheduling/Finance help
April 9	Bob Ritzmann	Alltrade Industrial	Y	PV system suggestions and comments
April 23	Angelo Suntres	Black & Mcdonald	Y	Final Proposal Review
April 23	Bob Ritzmann	Alltrade Industrial	Y	Final Proposal Review
April 23	Nick Iozzo	DPM Energy	N	Final Proposal Review

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mini

ELECTRIC BOILERS
3 KW TO 12 KW

ULTRA & BTH

mini BTH 240 VAC / 60 Hz / 1 phase[1]

	Power[2]					Recommended electrical supply[4]		
Model	kW	BTU/h	Amps[3]	Electrical Elements	Stages	Cu Wire	Al Wire	Breaker
MINI BTH 3	3	10 236	12.5	1 x 3 kW	1	12	10	20
MINI BTH 4.5	4.5	15 354	18.8	1 x 4.5 kW	1	10	10	30
MINI BTH 6	6	20 472	25.0	1 x 6 kW	1	8	6	40
MINI BTH 7.5	7.5	25 590	31.3	1 x 3 kW + 1 x 4.5 kW	2	8	6	40
MINI BTH 9	9	30 708	37.5	2 x 4.5 kW	2	8	6	50
MINI BTH 12	12	40 944	50.0	2 x 6 kW	2	6	4	70

mini ULTRA 240 VAC / 60 Hz / 1 phase[1]

	Power[2]					Recommended electrical supply[4]		
Model	kW	BTU/h	Amps[3]	Electrical Elements	Stages	Cu Wire	Al Wire	Breaker
MINI ULTRA 3	3	10 236	12.5	1 x 3 kW	1	12	10	20
MINI ULTRA 4.5	4.5	15 354	18.8	1 x 4.5 kW	1	10	10	30
MINI ULTRA 6	6	20 472	25.0	2 x 3 kW	2	8	6	40
MINI ULTRA 7.5	7.5	25 590	31.3	1 x 3 kW + 1 x 4.5 kW	2	8	6	40
MINI ULTRA 9	9	30 708	37.5	2 x 4.5 kW	2	8	6	50
MINI ULTRA 12	12	40 944	50.0	2 x 6 kW	2	6	4	70

[1] Electrical supply 120/240 V or 120/208 V 1 phase (L1-N-L2) with three 90 °C conductors and a ground or two conductors and a ground if the boiler does not require a 120 VAC pump or accessories.

[2] Multiply by .75 for 208 VAC supply.

[3] Multiply by .867 for 208 VAC supply.

[4] The wire gauges and breaker capacity must be in conformity with the standards of the National Electrical Code (NEC), Canadian Electrical Code (CEC) and local codes (if applicable).

MULTI-POSITION INSTALLATION

15-YEAR WARRANTY
ON THE RESERVOIR

2-YEAR WARRANTY
ON ELECTRICAL AND MECHANICAL PARTS

OUR PRODUCTS ARE CERTIFIED

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CHOOSE YOUR GLASS

Good design and correct installation are important factors in ensuring energy efficient windows, but glass performance plays the biggest role.

Different glass options have different benefits, so before choosing your glass, be sure to consider the weather conditions of where you live. Colder climates will require more insulation power and specific glass coatings to improve energy efficiency.

GLASS OPTION RATINGS

GLASS NAME		HEAT SYSTEM	DESCRIPTION	U-VALUE*	R-VALUE*	SOLAR HEAT GAIN*	VISIBLE LIGHT TRANSMITTANCE	ULTRAVIOLET BLOCK
CLEAR		DUAL	Dual pane, clear glass, no coatings	2.725	2.083	0.760	81%	42%
		TRI	Triple pane, clear glass, no coatings	1.760	3.226	0.685	74%	52%
LOW-E		HS1-C180	Dual pane, one Low-E coating, Argon	1.476	3.846	0.685	79%	71%
		HS2-C180	Triple pane, one Low-E coating, Argon	1.045	5.434	0.615	73%	76%
		HS3-C180	Triple pane, two Low-E coatings, Argon	0.755	7.518	0.560	70%	87%
SUNSTOP		HS4-C270	Dual pane, one SunStop coating, Argon	1.408	4.032	0.367	70%	86%
		HS5-C270	Triple pane, one SunStop coating, Argon	1.056	5.376	0.338	63%	88%
		HS6-C270	Triple pane, two SunStop coatings, Argon	0.704	8.064	0.310	54%	96%
SYSTEM V		HS1V-C180/i89	Dual pane, two Low-E coatings, Argon	1.187	4.785	0.623	77%	73%
		HS4V-C270/i89	Dual pane, one Low-E & one SunStop coating, Argon	1.136	5.000	0.361	69%	86%

*Metric values are from centre of glass.

**Rating may vary by product line. See your sales representative for more details. All performance is C.O.G. (centre of glass) ratings based on Vision v4.0 simulations. All C.O.G R-values are based on ASHREA Winter Conditions.

R-Value: A measurement of the resistance of heat transfer through glass. The higher the R-Value, the better the window insulates against heat.

Solar Heat Gain: The amount of the sun's heat that transfers through glass from the exterior to the interior side. The higher the solar heat gain, the more a window allows heat to pass through into a home.

U-Value: A measure of the rate of nonsolar heat flow through a material or assembly. The lower the U-Value, the greater a window's resistance to heat flow and the better its insulating value.

COMFORTBATT®
Thermal Batt Insulation

Technical Data Sheet
Batt Insulation 07210*
Blanket Insulation 07 21 16**

ROCKWOOL COMFORTBATT® is a mineral wool batt insulation designed for thermal resistance in wood and steel framing.

	Performance		Test Standard
Compliance	Mineral Fibre Thermal Insulation for Buildings, Type 1 Compliant		CAN/ULC S702
Reaction to Fire	Flame spread index = 0; Smoke developed index = 0		CAN/ULC S102
	Determination of Non-combustibility of Building Materials - Non-combustible		CAN/ULC S114
Density	> 2 lbs/ft³ (>32 kg/m³)		ASTM C167
Thermal Resistance	Wood Stud	Steel Stud	ASTM C518
	R14 (RSI 2.47) - 3.5" thick (89 mm)	R10 (RSI 1.76) - 2.5" thick (64 mm)	
	R22 (RSI 3.87) - 5.5" thick (140 mm)	R14 (RSI 2.47) - 3.5" thick (89 mm)	
	R24 (RSI 4.23) - 5.5" thick (140 mm)	R22.5 (RSI 3.96) - 6" thick (152 mm)	
	R28 (RSI 4.93) - 7.25" thick (184 mm)	R24 (RSI 4.23) - 6" thick (152 mm)	
	R32 (RSI 5.64) - 8" thick (203 mm)		
Dimensions	Wood Stud 16" (406 mm) on centre: 15.25" x 47" (387 mm x1194 mm)		
	Wood Stud 24" (610 mm) on centre: 23" x 47" (584 mm x 1194 mm)		
	Steel Stud 16" (406 mm) on centre: 16.25" x 48" (413 mm x 1219 mm)		
	Steel Stud 24" (610 mm) on centre: 24.25" x 48" (616 mm x 1219 mm)		

GREENGUARD GOLD

Issued 01-01-18
Supersedes 08-23-17

NOTE: *Master Format 1995 Edition **Master Format 2004 Edition. As ROCKWOOL has no control over installation design and workmanship, accessory materials or application conditions, ROCKWOOL does not warranty the performance or results of any installation containing ROCKWOOL's products. ROCKWOOL's overall liability and the remedies available are limited by the general terms and conditions of sale. This warranty is in lieu of all other warranties and conditions expressed or implied, including the warranties of merchantability and fitness for a particular purpose.

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Description | Specifications | Reviews

EarthLED Total Product Insight

Performance Specifications	
REPLACEMENT FOR:	T8 OR T12 4 FOOT FLUORESCENT TUBE
BRIGHTNESS (LUMENS):	2000
COLOR TEMPERATURE:	4000K | 5000K
COLOR ACCURACY (CRI):	80
DIMENSIONS	1.02" X 47.2"
POWER CONSUMPTION:	18 WATTS
VOLTAGE:	120-277 VOLTS
DIMMABLE:	NO
Dimensions / Additional Data	
CERTIFICATIONS:	UL, DESIGNLIGHTS (DLC)
PRODUCT/ORDER CODE:	4000K - 18WT8P-4F-40K-BYP 5000K - 18WT8P-4F-50K-BYP
Lifespan / Cost To Run	
PROJECTED LIFE: @3 HRS/DAY	50,000 HRS
YEARLY ENERGY COST: 3 HRS/DAY @ .11 KWH	$2.17
WARRANTY	5 YEAR THINKLUX LIGHTING LIMITED WARRANTY EARTHLED PRODUCT PROTECTION PLAN IS AVAILABLE

LED LAMP

SPECIFICATIONS

Ideal For

Table Lamps | Floor Lamps | Ceiling Fans | Wall Sconces | Bath & Vanity

Soft White
2700K

Features

- Instant On To Full Brightness
- Suitable For Damp Locations
- Dimmable
- UL/CUL Listed
- FCC Compliant
- RoHS Compliant
- 100% Mercury Free
- 5 Year Warranty
- Soft White
- Energy Star®
- Title 24 Compliant

Benefits

- Full Range Dimming
- Energy Efficient: Up to 85% less energy than standard incandescent
- No Ultraviolet - Safe for artwork
- Color Consistency
- Low Heat
- Durable
- Long Life

ENERGY STAR

Specifications

Item Number	Input Power (Watts)	Incandescent Equiv. (Watts)	Input Line Voltage
OM60DM/927CA/4	8.8	60	120
Base Type	**Lumens**	**Lumen Efficiency (LPW)**	**CCT**
E26 (Medium)	800	90	2700K
CRI	**Beam Angle**	**MOL**	**Diameter**
90+	300°	4.5″	2.3″
Life Hours	**Minimum Starting Temperature**		
25,000	-13°F		

Feit Electric Company 4901 Gregg Rd. Pico Rivera, CA 90660 1-800-543-Feit www.feit.com

Philips Model # 463810 ★★★★★ (1)

90-Watt Equivalent PAR38 LED Daylight (4-Pack)

Product Overview

Philips Ambient LED Energy Saving 11-Watt PAR38 flood light is ideal for use in kitchens, dining rooms and living rooms. It provides a soft, white light and is perfect for accenting and highlighting your decor. This bulb replaces a 90-Watt halogen bulb and delivers exceptionally long life, significant energy savings, beautiful light and contains no mercury.

- Brightness: 1000-Lumens
- Estimated yearly energy cost: $1.31 (based on 3-hours/day, 11/kWh, cost depend on rates and use)
- Life hours: 10950
- Light appearance: daylight
- Energy used:11-Watt
- Lumens per watt: 90.91
- Philips 90-Watt equivalent Par38 LED indoor flood light bulb delivers exceptionally long life, significant energy savings, beautiful light and contain no mercury, this energy saving 11-Watt LED bulb can replace a standard 90-Watt halogen
- Use in kitchens, living rooms and dining rooms, recessed cans and some track light fixtures
- Spot light provides a light similar to daylight

CREE

LED 120w BR40 FLOOD

SUGGESTED USE:

HIGH BRIGHTNESS FLOOD LIGHT
IDEAL FOR 6" & 8" RECESSED CANS

ENERGY STAR | CA TITLE 20 COMPLIANT | Dimmable

EXPERIENCE EXCEPTIONAL

90+ CRI — RICH, VIBRANT & NATURAL COLORS

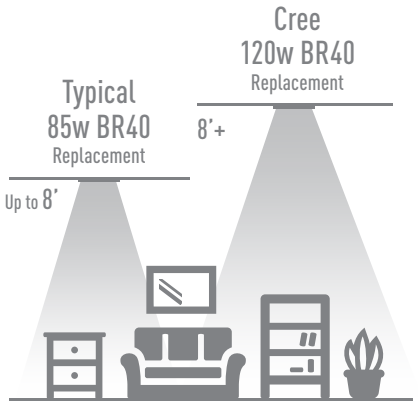
22.8 YEARS — LONGER LIFE 25,000 hour rated life exceeds ENERGY STAR® minimum requirements

DIMMABLE Visit creebulb.com/dimmers for compatible dimmers

10 YEAR 100% SATISFACTION GUARANTEE

SHATTERPROOF

CREE GIVES YOU MORE LIGHT



BETTER LIGHT IS WORTH IT

Beautiful high CRI light delivers **exceptional color quality**— making the colors in your home appear vibrant, rich & natural.

CREE® BR40 REPLACEMENT LED LIGHT BULBS

	120-Watt Soft White Replacement	120-Watt Bright White Replacement	120-Watt Daylight Replacement
Color Temperature	2700K	3000K	5000K
Lumens	1750	1750	1750
Energy Used (Watts)	23W	23W	23W
Color Rendering Index	90+	90+	90+
Rated Life (Hours)	25,000	25,000	25,000
Beam Angle	110°	110°	110°

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04.18

DETAILS

FEATURES

- NOMA Solar High Output Spotlight emits a large amount of light for poorly lit or dark areas
- Brightness: 100 lumens and dims to 25 lumens
- Photocell technology detects dusk and dawn to turn on or off automatically
- Place in direct sunlight to charge fully
- Up to 8 hours of runtime on a full change
- Finished in black
- Body made from aluminum
- Lens made from plastic
- Light dimensions: 15.3 x 5.9" (39 x 15 cm)

Defiant Model # DF-5416-WH-A ★★★★☆ (431)

180 Degree White Motion-Sensing Outdoor Security-Light

$34.97

Details

Adjustable Detection Sensitivity	Yes	Maximum Wattage (watts)	240
Adjustable Lamp Head	Yes	Motion Sensing	Yes
Compatible Bulb Type	Halogen	Number of Bulbs Required	2
Detection Range (ft.)	70	Number of Lights	2 Lights
Dusk to Dawn	Yes	Outdoor Lighting Features	Adjustable Detection Sensitivity,Adjustable Lamp Head,Dusk to Dawn,Motion Sensing,Timer,Weather Resistant
Exterior Lighting Product Type	Spotlights	Power Options	Hardwired
Fixture Color/Finish	White	Power Type	Hardwired
Fixture Material	Alloy	Product Weight (lb.)	2.35lb
Glass/Lens Type	No Glass/Lens	Recommended Light Bulb Shape Code	PAR38
Included	Hardware Included,Motion Sensor,Timer	Returnable	90-Day
Light Beam Angle	180	Timer Included	Yes
Light Bulb Base Code	E26	UL Listing	Yes
Maximum Bulb Wattage	120	Voltage	Line Voltage

SECTION 122600 INTERIOR DAYLIGHTING DEVICES

This suggested guide specification has been developed using the current edition of the Construction Specifications Institute (CSI) "Manual of Practice", including the recommendations for the CSI 3 Part Section Format and the CSI Page Format. Additionally, the development concept and organizational arrangement of the American Institute of Architects (AIA) MASTERSPEC Program has been recognized in the preparation of this guide specification. Neither CSI, AIA, USGBC nor ILFI endorse specific manufacturers and products. The preparation of the guide specification assumes the use of standard contract documents and forms, including the "Conditions of the Contract," published by the AIA.

PART 1 - GENERAL

1.1 Related Documents

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.

1.2 Summary

A. Section includes: Kawneer InLighten™ Aluminum Lightshelf System, including accessories, mountings, and panels. Lightshelves are anchored directly to the vertical curtain wall or storefront mullions and is an interior product.
   1. Compatible Systems:
      a. Curtain wall system mounting mullion with face width of 2" (51 mm) or greater and wall thickness greater than 0.080" (2 mm).
      b. Center or Front Set Storefront system with single piece tubular mounting mullion, with face width of 2" (51 mm) or greater and mounting mullion wall thickness greater than 0.080" (2 mm)

EDITOR NOTE: BELOW RELATED SECTIONS ARE SPECIFIED ELSEWHERE HOWEVER KAWNEER RECOMMENDS SINGLE SOURCE RESPONSIBILITY FOR ALL OF THESE SECTIONS AS INDICATED IN PART 1.6 QUALITY ASSURANCE.

B. Related Sections:
   1. 072700 "Air Barriers"
   2. 079200 "Joint Sealants"
   3. 083213 "Sliding Aluminum-Framed Glass Doors"
   4. 084113 "Aluminum-Framed Entrances and Storefronts"
   5. 084313 "Aluminum-Framed Storefronts"
   6. 084329 "Sliding Storefronts"
   7. 084413 "Glazed Aluminum Curtain Walls"
   8. 084433 "Sloped Glazing Assemblies"
   9. 085113 "Aluminum Windows"
   10. 086300 "Metal-Framed Skylights"
   11. 088000 "Glazing"
   12. 107113 "Exterior Sun Control Devices"

1.3 Definitions

A. Definitions: For fenestration industry standard terminology and definitions, refer to American Architectural Manufactures Association (AAMA) – AAMA Glossary (AAMA AG).

1.4 Performance Requirements

EDITOR NOTE: LIGHTSHELF IS DESIGNED TO HOLD ITS OWN WEIGHT ONLY.

A. Structural Performance:
   1. Dead load on Lightshelf is designed to hold its own weight only.

EDITOR NOTE: LIGHTSHELF IS A SELF-SUPPORTING STRUCTURE THAT REFLECTS DAYLIGHT AND SHOULD NOT BE USED FOR ANY OTHER PURPOSE, SPECIALLY AS A SHELF FOR HOLDING OTHER OBJECTS WHICH CAN NOT ONLY IMPACT PERFORMANCE BUT ALSO RESULT IN INJURY DUE TO STRUCTURAL FAILURE.

   2. Panel deflection shall not exceed L/120 of span length.
   3. Mullion spacing not to exceed 6' (1.83 m).
   4. Panel projection not to exceed 30" (762 mm).

B. Daylighting Performance:
   1. Design will allow for tiltability of the panel in the anchor to allow for cleaning of the reflecting surface.
   2. Design of standard configurations will allow for minimal direct sunlight to show through the gaps between two adjacent shelves based on project location, latitude, altitude, building orientation, surrounding conditions, and aesthetic requirements.
   3. Design shall allow for flexibility of either using opaque aluminum composite panels or translucent polycarbonate panels as panel material.
   4. Design will allow for coverage around 90° corner conditions by providing for attachment method on specified corner conditions.

C. Thermal Movements: Allow for thermal movements resulting from the following maximum change (range) in ambient and surface temperatures:
   1. Temperature Change (Range): 120°F (49°C), ambient; 180°F (82°C), material surfaces.

D. Environmental Product Declarations (EPD): Shall have a Type III Product-Specific EPD.

1.5 Submittals

*EDITOR NOTE: ADD RECYCLED CONTENT SECTION **IF REQUIRED TO MEET PROJECT REQUIREMENTS** AND/OR GREEN BUILDING CERTIFICATIONS SUCH AS LEED, LIVING BUILDING CHALLENGE (LBC), ETC. ARE REQUIRED.*

** IF RECYCLED CONTENT REQUIREMENTS **ARE NOT SPECIFIED - PRIME (ZERO RECYCLED CONTENT) ALUMUNUM COULD BE SUPPLIED.***

A. Product Data: For each type of product indicated. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
   1. Recycled Content:
      a. Provide documentation that aluminum has a minimum of 50% mixed pre- and post-consumer recycled content with a sample document illustrating project specific information that will be provided after product shipment.
      b. Once product has shipped, provide project specific recycled content information, including:
         1) Indicate recycled content; indicate percentage of pre- and post-consumer recycled content per unit of product.
         2) Indicate relative dollar value of recycled content product to total dollar value of product included in project.
         3) Indicate location recovery of recycled content.
         4) Indicate location of manufacturing facility.
   2. Environmental Product Declaration (EPD):
      a. Include a Type III Product-Specific EPD created from a Product Category Rule.

B. Shop Drawings: For aluminum lightshelves. Include plans, elevations, sections, and attachments to compatible systems.

C. Samples for Initial Selection: For units with factory-applied color finishes.

D. Samples for Verification: For each type of exposed finish required, in manufacturer's standard sizes.

E. LEED Submittals:
   1. Materials and Resources: Provide product information and certification letter indicating percentages by weight of post-consumer and pre-consumer recycled content for products having recycled content.
   2. Optimize Energy Performance: Provide information confirming that products contribute to increasing levels of energy performance above the baseline in the prerequisite standard to reduce environmental and economic impacts associated with excessive energy use.
   3. Daylighting 75 Percent of Spaces: Provide information confirming that products provide the building occupants a connection between indoor spaces and the outdoors through the introduction of daylight and views into the regularly occupied areas of the building.

1.6 Quality Assurance

A. Installer Qualifications: Installer who has had successful experience with installation of the same or similar systems required for the project and other projects of similar size and scope.

B. Manufacturer Qualifications: A manufacturer capable of fabricating lightshelves, and glazed aluminum curtain walls and storefront systems that meet or exceed performance requirements.

C. Source Limitations: Obtain aluminum lightshelves and glazed aluminum curtain walls and storefront systems through one source from a single manufacturer.

D. Product Options: Information on Drawings and in Specifications establishes requirements for aesthetic effects and performance characteristics of assemblies. Aesthetic effects are indicated by dimensions, arrangements, alignment, and profiles of components and assemblies as they relate to sightlines, to one another, and to adjoining construction.
   1. Do not modify intended aesthetic effects, as judged solely by Architect, except with Architect's approval. If revisions are proposed, submit comprehensive explanatory data to Architect for review.

E. Mockups: Build mockups to verify selections made under sample submittals and to demonstrate aesthetic effects and set quality standards for materials and execution.
   1. Build mockups for type(s) of lightshelf elevation(s) indicated, in location(s) shown on Drawings.

F. Pre-installation Conference: Conduct conference at Project site to comply with requirements in Division 01 Section “Project Management and Coordination”.

1.7 Project Conditions

A. Field Measurements: Verify actual locations of structural supports for lightshelves by field measurements before fabrication and indicate measurements on Shop Drawings.

1.8 Warranty

A. Manufacturer’s Warranty: Submit, for Owner’s acceptance, manufacturer’s standard warranty.

1. Warranty Period: Two (2) years from Date of Substantial Completion of the project, provided however that the Limited Warranty shall begin in no event later than six months from date of shipment by manufacturer.

PART 2 - PRODUCTS

EDITOR'S NOTE: RETAIN BELOW ARTICLE FOR PROPRIETARY METHOD SPECIFICATION; ADD PRODUCT ATTRIBUTES, PERFORMANCE CHARACTERISTICS, MATERIAL STANDARDS, AND DESCRIPTIONS AS APPLICABLE. DO NOT USE THE PHRASE "OR EQUAL" / "OR APPROVED EQUAL," OR SIMILAR PHRASES. USE OF SUCH PHRASES CAUSES AMBIGUITY IN THE SPECIFICATIONS BECAUSE OF THE DIFFERENT INTERPRETATIONS AMONG THE DIVERGENT PARTIES OF THE CONSTRUCTION PROCESS AND READERS OF THE SPECIFICATIONS. SUCH PHRASES REQUIRE EXTENSIVE AND COMPLETE REQUIREMENTS (PROCEDURAL, LEGAL, REGULATORY, AND RESPONSIBILITY) FOR DETERMINING "OR EQUAL."

2.1 Manufacturers

A. Basis-of-Design Product:
   1. InLighten™ Light Shelf System by Kawneer Company Inc.

EDITOR'S NOTE: RETAIN BELOW FOR ALTERNATE MANUFACTURERS/PRODUCTS AS SPECIFIED IN THE CONTRACT DOCUMENTS. COORDINATE BELOW WITH BID DOCUMENTS (IF ANY), AND DIVISION 1 ALTERNATES SECTION. CONSULT WITH KAWNEER COMPANY FOR RECOMMENDATIONS ON ALTERNATE MANUFACTURERS AND PRODUCTS MEETING THE DESIGN CRITERIA AND PROJECT REQUIREMENTS. KAWNEER RECOMMENDS OTHER MANUFACTURERS REQUESTING APPROVAL TO BID THEIR PRODUCT AS AN EQUAL MUST SUBMIT THEIR REQUEST IN WRITING TEN (10) DAYS PRIOR TO CLOSE OF BIDDING.

B. Subject to compliance with requirements, provide a comparable product by the following:
   1. Manufacturer: (_____)
   2. Series: (_____)
   3. Profile dimension: (_____)

C. Substitutions: Refer to Substitutions Section for procedures and submission requirements.
   1. Pre-Contract (Bidding Period) Substitutions: Submit written requests ten (10) days prior to bid date.
   2. Post-Contract (Construction Period) Substitutions: Submit written request in order to avoid lighshelf installation and construction delays.
   3. Product Literature and Drawings: Submit product literature and drawings modified to suit specific project requirements and job conditions.
      Certificates: Submit certificate(s) attesting that the substitute manufacturer (1) adheres to specification requirements for lightshelf performance criteria, and (2) has been engaged in the design, manufacturer and fabrication of aluminum curtain walls, storefront systems, sunshades, and lightshelves for a period of not less than ten (10) years. (Company Name)
   4. Test Reports: Submit test reports verifying compliance with each test requirement required by the project.
   5. Samples: Provide samples of typical product sections and finish samples in manufacturer's standard sizes.

D. Substitution Acceptance: Acceptance will be in written form, either as an addendum or modification, and documented by a formal change order signed by the Owner and Contractor.

2.2 Materials

A. Aluminum Extrusions: Alloy and temper recommended by glazed aluminum curtain wall and storefront system manufacturer for strength, corrosion resistance, and application of required finish, and complying with ASTM B 221: 6063-T6, 6105-T5, or 6061-T6 alloy and temper. Wall thickness at any location for the main frame to be not less than 0.070" (1.78 mm).

*EDITOR NOTE: ADD RECYCLED CONTENT SECTION **IF REQUIRED TO MEET PROJECT REQUIREMENTS** AND/OR GREEN BUILDING CERTIFICATIONS SUCH AS LEED, LIVING BUILDING CHALLENGE (LBC), ETC. ARE REQUIRED.*

** IF RECYCLED CONTENT REQUIREMENTS **ARE NOT SPECIFIED - PRIME (ZERO RECYCLED CONTENT) ALUMUNUM COULD BE SUPPLIED.***

   1. Recycled Content: Shall have a minimum of 50% mixed pre- and post-consumer recycled content.
      a. Indicate recycled content; indicate percentage of pre-consumer and post-consumer recycled content per unit of product.
      b. Indicate relative dollar value of recycled content product to total dollar value of product included in project.
      c. Indicate location recovery of recycled content.
      d. Indicate location of manufacturing facility.

B. Aluminum Composite Material (ACM): Panels shall be Reynobond® Aluminum Composite Material (ACM) as manufactured by Alcoa Architectural Products.

C. Polycarbonate Panel: Monolithic or multilayered extruded cellular polycarbonate panels.

D. Tolerances: Reference to tolerances for wall thickness and other cross-sectional dimensions of glazed curtain wall and storefront system members are nominal and in compliance with AA Aluminum Standards and Data.

2.3 Lightshelves

A. Lightshelf Members: Manufacturer's standard extruded or formed-aluminum framing members of thickness required and reinforced as required to support imposed loads.

B. Panel Materials: Aluminum composite or polycarbonate materials.

C. Fasteners and Accessories: Nonmagnetic stainless steel to be non-corrosive and compatible with aluminum members, anchors, and other components.

D. Perimeter Anchors: When steel anchors are used, provide insulation between steel material and aluminum material to prevent galvanic action.

E. Packing, Shipping, Handling, and Unloading: Deliver materials in manufacturer's original, unopened, undamaged containers with identification labels intact.

F. Storage and Protection: Store materials protected from exposure to harmful weather conditions. Handle lightshelf materials and components to avoid damage. Protect lightshelf materials against damage from elements, construction activities, and other hazards before, during and after installation.

2.4 Accessory Materials

A. Bituminous Paint: Cold-applied asphalt-mastic paint complying with SSPC-Paint 12 requirements except containing no asbestos, formulated for 30-mil (0.762 mm) thickness per coat.

2.5 Fabrication

A. Form or extrude aluminum shapes before finishing.

B. Fabricate components that, when assembled, have the following characteristics:
1. Profiles that are straight, and free of defects or deformations.
2. Accurately fitted joints with ends coped or mitered.
3. Physical and thermal isolation of glazing from framing members.
4. Accommodations for thermal and mechanical movements of glazing and framing to maintain required glazing edge clearances.
5. Fasteners, anchors, and connection devices that are concealed from view to greatest extent possible.

C. Lightshelf: Fabricate components for assembly following approved shop drawings and/or manufacturer's standard installation instructions.

D. After fabrication, clearly mark components to identify their locations in Project according to approved shop drawings.

2.6 Aluminum Finishes

EDITOR NOTE: SELECT BELOW FINISH AND COLOR FROM KAWNEER'S STANDARD COLORS. CUSTOM COLORS ARE AVAILABLE UPON REQUEST FROM THE KAWNEER COMPANY. OTHER PIGMENTED ORGANIC COATINGS CONFORMING TO AAMA 2603 ARE AVAILABLE. CONSULT WITH YOUR KAWNEER REPRESENTATIVE FOR OTHER SURFACE TREATMENTS AND FINISHES.

A. Finish designations prefixed by AA comply with the system established by the Aluminum Association for designating aluminum finishes.

B. Factory Finishing:
1. Kawneer Permanodic™ AA-M10C21A44 / AA-M45C22A44, AAMA 611, Architectural Class I Color Anodic Coating (Color _____).
2. Kawneer Permanodic™ AA-M10C21A41 / AA-M45C22A41, AAMA 611, Architectural Class I Clear Anodic Coating (Color #14 Clear) (Optional).
3. Kawneer Permanodic™ AA-M10C21A31, AAMA 611, Architectural Class II Clear Anodic Coating (Color #17 Clear) (Standard).
4. Kawneer Permafluor™ (70% PVDF), AAMA 2605, Fluoropolymer Coating (Color _____).
5. Kawneer Permadize™ (50% PVDF), AAMA 2604, Fluoropolymer Coating (Color _____).
6. Kawneer Permacoat™ AAMA 2604, Powder Coating (Color _____).
7. Other: Manufacturer _____ Type _____ Color _____.

PART 3 - EXECUTION

3.1 Examination

A. Examine areas, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of the Work.

B. Proceed with installation only after unsatisfactory conditions have been corrected.

EDITOR NOTE: COORDINATE BELOW ARTICLE WITH MANUFACTURER'S RECOMMENDED INSTALLATION DETAILS AND INSTALLATION INSTRUCTIONS.

3.2 Installation

A. General:
1. Comply with manufacturer's written instructions. Refer to installation instructions of the compatible curtain wall or storefront system.
2. Please note that the installation instructions can differ from one compatible system to another one.
3. Do not install damaged components.
4. Fit joints to produce hairline joints free of burrs and distortion.
5. Rigidly secure non-movement joints.
6. Install anchors with separators and isolators to prevent metal corrosion and electrolytic deterioration and to prevent impeding movement of moving joints.
7. Weld components in concealed locations to minimize distortion or discoloration of finish. Protect glazing surfaces from welding.
8. Seal joints watertight where shown on approved shop drawings and/or manufacturer's standard installation instructions.

B. Metal Protection:
   1. Where aluminum will contact dissimilar metals, protect against galvanic action by painting contact surfaces with primer or by applying sealant or tape or installing nonconductive spacers as recommended by manufacturer for this purpose.
   2. Where aluminum will contact concrete or masonry, protect against corrosion by painting contact surfaces with bituminous paint.

C. Install components plumb and true in alignment with established lines and grades.

D. Separate aluminum and other corrodible surfaces from sources of corrosion or electrolytic action at points of contact with other materials.

E. Install glazing as specified in Division 08 Section "Glazing".

3.3 Adjusting, Cleaning and Protection

A. Protection: Protect installed product's finish surfaces from damage during construction. Protect aluminum lightshelf system from damage from grinding and polishing compounds, plaster, lime, cement, acid and/or acid wash, or other harmful contaminants.

B. Cleaning: Repair or replace damaged installed products. Clean installed products in accordance with manufacturer's instructions prior to owner's acceptance. Remove construction debris from project site and legally dispose of debris.

C. Remove and replace glass that has been broken, chipped, cracked, abraded, or damaged during construction period.

DISCLAIMER STATEMENT

This guide specification is intended to be used by a qualified construction specifier. The guide specification is not intended to be verbatim as a project specification without appropriate modifications for the specific use intended. The guide specification must be used and coordinated with the procedures of each design firm and the particular requirements of a specific construction project.

END OF SECTION 122600

SmartThings Hub 2018 Specs

The SmartThings Hub 2018 is the newest version of SmartThings core hardware, released in August 2018. Learn about the different specifications for your SmartThings Hub.

Read on to learn about the features and specifications of the SmartThings Hub 2018.

Local Processing Capabilities

Some functionalities can run locally with the SmartThings Hub. Some processing that previous existed in the cloud, like for certain automations and device types, automatically occurs locally

Hub. This means much faster response time, improved performance, and reduced latency. Check out **local processing** for more information.

Range

50-130 feet, depending on your home's construction.

Hardware

The SmartThings Hub has 528 MHz ARM Cortex-A7, 256MB DDR RAM, and 4GB FLASH.

Communication Protocols

The Hub contains a Zigbee radio (2.4GHz) and a Z-Wave radio (900MHz). These allow the Hub to communicate with your Zigbee and Z-Wave devices. The SmartThings Hub (2018) also supports Zigbee 3.0 and Z-Wave Plus.

LED Indicator lights

Red/green (blinking)

- **What it means**: The Hub is ready to connect.
- **What to do**: You will see this when the Hub is first plugged into a power source right out of the box, or after a factory reset. If you havenundefinedt already, open the SmartThings app to connect your Hub.

Blue (blinking)

- **What it means**: No LAN connection, Hub doesnundefinedt have an IP address.

- **What to do**: This is likely an internet connection issue. If your Hub is connected via Wi-Fi, try **changing the Wi-Fi network** or connecting the Hub directly to the router via ethernet. Make sure your ethernet cable is securely plugged into the back of the Hub and not loose. If the ethernet cable is snug but the blue light keeps blinking, the cable may be defective. Swap it for another shielded cable. This may also be caused by strict network security settings preventing the Hub from connecting.

Blue (solid)

- **What it means**: Attempting connection to the SmartThings cloud/servers.
- **What to do**: A solid blue light is expected during the normal setup process and when downloading firmware updates, in some cases. However, if the light remains solid blue for longer than 5 minutes, this indicates the Hub is unable to establish a connection with our servers. This problem can occur when outbound traffic from a local network is being blocked. Double-check your network settings and make sure the following ports are open during initial setup: 11111, 9443, 443, 39500, and 37.

Magenta (blinking)

- **What it means**: Downloading firmware update.
- **What to do**: This blinking pinkish color indicates that the Hub is downloading a firmware update, which can occur during initial setup or with the release of a Hub firmware upgrade. Do not unplug the Hub while firmware is being downloaded.

Magenta (solid)

- **What it means**: Applying firmware update.
- **What to do**: Expect to see this pinkish color during initial setup or whenever the Hubundefineds firmware is upgraded. Do not unplug the Hub while firmware is being applied.

Green (blinking)

- **What it means**: Hub is looking for devices to connect with.
- **What to do**: This is perfectly normal and expected. The LED will blink green when you start to connect a new device through the app, and it will stop when the device is connected or when you navigate away from the connection screen.

Green (double-blinking)

- **What it means**: Z-Wave Exclusion Mode is active.
- **What to do**: This is expected when you remove a Z-Wave device or activate General Device Exclusion through Z-Wave Utilities.

Green (solid)

- **What it means**: Hub connected to LAN and cloud.
- **What to do**: The Hub is successfully connected and ready to go. When you see this during initial setup, you can also begin connecting devices to the Hub.

  The LED may also be solid green while the Hub is downloading firmware updates.

  If the LED is solid green but the Hub is inactive, restart the app. If this doesnundefinedt solve the problem, **contact support**.

Red (blinking)

- **What it means**: Hub is experiencing power issues.
- **What to do**: The blinking red LED can indicate issues with either the backup batteries or power cable connection. To narrow down the issue, unplug the Hub, and plug it into a different outlet. If the LED is still blinking red, **contact support**.

Lutron | Model # P-PKG1P-WH-R-C | Store SKU # 1000720944 ★★★★★ (1)

Caseta Wireless Smart Lighting Lamp Dimmer and Remote Kit, …

Specifications

Dimensions

Assembled Depth (in inches)	1.80	Assembled Height (in inches)	3.10
Assembled Weight (in lbs)	0.60	Assembled Width (in inches)	2.20
Item Depth	2	Item Height	6.75
Item Weight	0.5	Item Width	5.94

Details

Certified	Yes	Colour Family	White
Country of Origin	CN-China	Dimmer Type	Remote Control Dimmer, Remote Control Dimmer
Indoor/Outdoor	Indoor	Light Bulb Compatibility	0
Smart Technology	Yes	Wattage	100
Wireless	Yes		

Product information

Color Name: **Cool White 4000K**

Technical Details

Item Weight	458 g
Parcel Dimensions	26.2 x 22.9 x 3 cm
Size	220*220*18
Color	Cool White 4000K
Style	Modern
Finish	Matte
Material	Aluminum + Plastic
Shape	Circular
Power Source	Hardwire
Voltage	120 volts
Wattage	15 watts
Installation Method	Flush mount
Number of Pieces	1
Type of Bulb	LED
Brightness	1200.00
Switch Style	Motion Sensing
Usage	indoor outdoor, Stairs, Closet Room, Basement, Hallway
Included Components	LED ceiling light,1 bracket, 11 mounting hardware
Batteries Included?	No
Batteries Required?	No

Product information

Style: **Button**

Technical Details

Part Number	GP-U999SJVLEAA
Item Weight	22.7 g
Product Dimensions	4.1 x 4.1 x 1.5 cm
Origin	Imported
Batteries:	1 CR2 batteries required. (included)
Item model number	GP-U999SJVLEAA
Color	White
Style	Button
Material	Plastic
Power Source	AC
Item Package Quantity	1
Usage	Smart Home
Included Components	QSG, HSG, 3M adhesive strips
Batteries Included?	Yes
Batteries Required?	Yes
Battery Cell Type	Lithium Ion
Warranty Description	1 Year

NEW

CanadianSolar

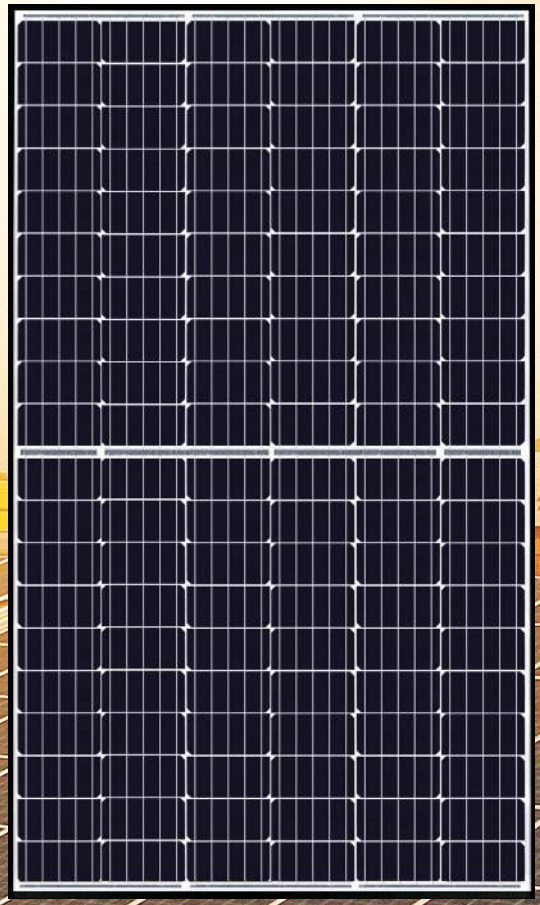
KuPower

HIGH EFFICIENCY MONO MODULE CS3K-300|305|310|315MS

With Canadian Solar's industry leading mono-PERC cell technology and the innovative LIC (Low Internal Current) module technology, we are now able to offer our global customers high power mono modules up to 315 W.

The KuPower mono modules with a dimension of 1675 ×992 mm, close to our 60 cell SuperPower modules, have the following unique features:

- Higher power classes for equivalent module sizes
- High module efficiency up to 18.96 %
- LOW hot spot temperature risk
- LOW temperature coefficient (Pmax): -0.37 % / °C
- LOW NMOT (Nominal Module Operating Temperature): 42 ± 2 °C



More power output thanks to low NMOT: 42 ± 2 °C

Low power loss in cell connection

Safer: lower hot spot temperature

Heavy snow load up to 5400 Pa, wind load up to 2400 Pa*

25 years linear power output warranty

10 years product warranty on materials and workmanship

PRODUCT CERTIFICATES**

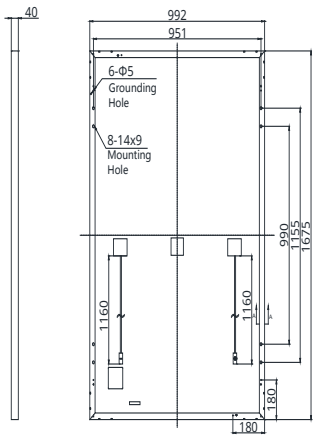
IEC 61215 / IEC 61730: 2005 & 2016: VDE / CE / UL 1703: CSA

* For detailed information please refer to Installation Manual.

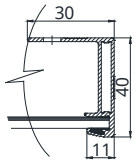
** Please contact your local Canadian Solar sales representative for the specific product certificates applicable in your market.

ENGINEERING DRAWING (mm)

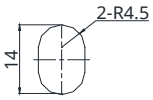
Rear View



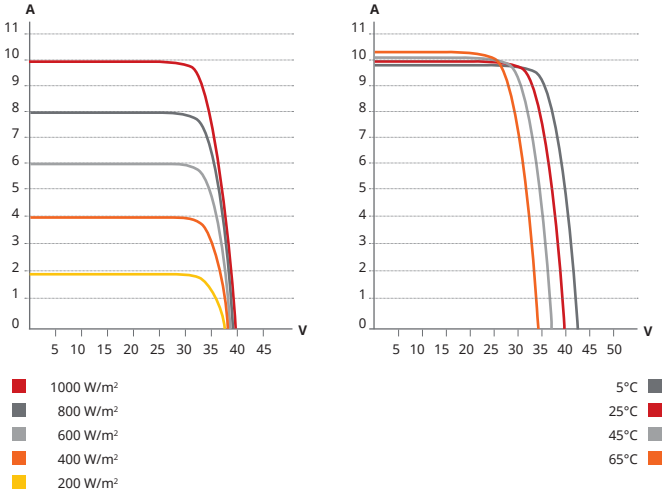
Frame Cross Section A-A



Mounting Hole



CS3K-305MS / I-V CURVES



ELECTRICAL DATA | STC*

CS3K	300MS	305MS	310MS	315MS
Nominal Max. Power (Pmax)	300 W	305 W	310 W	315 W
Opt. Operating Voltage (Vmp)	32.5 V	32.7 V	32.9 V	33.1 V
Opt. Operating Current (Imp)	9.24 A	9.33 A	9.43 A	9.52 A
Open Circuit Voltage (Voc)	39.3 V	39.5 V	39.7 V	39.9 V
Short Circuit Current (Isc)	9.82 A	9.90 A	9.98 A	10.06 A
Module Efficiency	18.05 %	18.36%	18.66%	18.96%
Operating Temperature	-40°C ~ +85°C			
Max. System Voltage	1000 V (IEC / UL)			
Module Fire Performance	TYPE 1 (UL 1703) or CLASS C (IEC 61730)			
Max. Series Fuse Rating	30 A			
Application Classification	Class A			
Power Tolerance	0 ~ + 5 W			

* Under Standard Test Conditions (STC) of irradiance of 1000 W/m2, spectrum AM 1.5 and cell temperature of 25°C.

MECHANICAL DATA

Specification	Data
Cell Type	Mono-crystalline, 156.75 × 78.38 mm
Cell Arrangement	120 [2 × (10 × 6)]
Dimensions	1675 ×992 ×40 mm (65.9 × 39.1 × 1.57 in)
Weight	18.5 kg (40.8 lbs)
Front Cover	3.2 mm tempered glass
Frame	Anodized aluminium alloy
J-Box	IP68, 3 diodes
Cable	4.0 mm² & 12 AWG,1160 mm (45.7 in)
Connector	T4 (IEC / UL)
Per Pallet	27 pieces
Per Container (40' HQ)	756 pieces

ELECTRICAL DATA | NMOT*

CS3K	300MS	305MS	310MS	315MS
Nominal Max. Power (Pmax)	223 W	227 W	230 W	234 W
Opt. Operating Voltage (Vmp)	29.6 V	29.8 V	30.0 V	30.2 V
Opt. Operating Current (Imp)	7.54 A	7.62 A	7.67 A	7.75 A
Open Circuit Voltage (Voc)	36.8 V	37.0 V	37.2 V	37.4 V
Short Circuit Current (Isc)	7.92 A	7.98 A	8.05 A	8.12 A

*Under Nominal Module Operating Temperature (NMOT), irradiance of 800 W/m2, spectrum AM 1.5, ambient temperature 20°C, wind speed 1 m/s.

TEMPERATURE CHARACTERISTICS

Specification	Data
Temperature Coefficient (Pmax)	-0.37 % / °C
Temperature Coefficient (Voc)	-0.29 % / °C
Temperature Coefficient (Isc)	0.05 % / °C
Nominal Module Operating Temperature	42±2 °C

PARTNER SECTION

The aforesaid datasheet only provides the general information on Canadian Solar products and, due to the on-going innovation and improvement, please always contact your local Canadian Solar sales representative for the updated information on specifications, key features and certification requirements of Canadian Solar products in your region.

Please be kindly advised that PV modules should be handled and installed by qualified people who have professional skills and please carefully read the safety and installation instructions before using our PV modules.

MS-PAE 120/240V SERIES INVERTER / CHARGER

Pure Sine Wave

24, 48
Battery Voltage Options

4000-4400 VA
Continuous Output Options

The MS-PAE 120/240V Series Inverter / Charger from Sensata Technologies is a pure sine wave inverter designed specifically for the most demanding renewable energy applications. The MS-PAE Series is powerful, easy-to-use, and best of all, cost effective.

No series stacking required: The unique design of the MS-PAE Series can provide 120 and 240 volts output in one unit, eliminating the need to stack two units together to get 240 volts.

Parallel stacking: You can parallel up to four inverter / chargers for up to 17.6kw of power at 120/240V. The MP panels and router are required for parallel stacking the MS-PAE Series.

Power Factor Corrected (PFC) Charger: Our PFC charger is built into all of our inverter chargers. It uses less energy from a generator than a standard charger – using 25-30% less AC current than standard chargers.

Safe and reliable: The MS-PAE Series is ETL Listed to the stringent requirements of UL 1741, 1st edition, and CSA C22.2 #107.1-01 for renewable energy installations.

Model Numbers

- MS4024PAE
- MS4448PAE

Available For

- Renewable Energy Systems
- Off-grid Power
- Back-up Power

Available Accessories

- Auto Generator Start - ME-AGS-N
- Battery Monitor Kit
- Conduit Box
- Fuse Blocks
- Remote - ME-ARC
- Remote - ME-RC
- Router - ME-RTR
- MP and MMP Panels

New Warranty!

- Three-year warranty standard.
- Five-year warranty if installed on an MP or MMP panel.

FEATURES

Pure sine wave:

Power your T.V.s, stereos, plasma screens, and other sensitive electronics without worry. The pure sine wave inverter and power factor corrected charger provide clean, reliable inverter power with low total harmonic distortion (THD) of less than 5%.

Choices:

The MS-PAE Series comes in 24 and 48 volt configurations, allowing you to choose the model that is right for you.

Versatile mounting:

Mount the MS-PAE Series on a shelf or wall.

Lightweight:

The lightweight aluminum base and cover also provides noise reduction and corrosion resistance.

Multiple ports:

The MS-PAE Series provides multiple ports, including an RS485 communication port for network expansion, and a remote port.

Accessible design:

The extra large AC access cover with terminal screw block and 360° DC connection terminals with covers make this inverter more accessible when it needs to be.

Convenient switches:

The MS-PAE Series comes with an on/off inverter-mounted switch with an easy-to-read LED indicator.

Buy with ease:

The MS-PAE Series is backed by a three-year (36-month) limited warranty, and a five-year limited warranty when installed on an MMP or MP system.

MS-PAE 120/240V SERIES SPECIFICATIONS

	MS4024PAE	MS4448PAE
INVERTER SPECIFICATIONS		
Input battery voltage range	18 - 34 VDC	36 - 64 VDC
Nominal AC output voltage	120/240 VAC split phase (± 5%)	120/240 VAC split phase (± 5%)
Output frequency and accuracy	60 Hz ± 0.1 Hz	60 Hz ± 0.1 Hz
Total Harmonic Distortion (THD)	< 5%	< 5%
1 msec surge current (amps AC)	Line-Neutral: 120, Line-Line: 70	Line-Neutral: 120, Line-Line: 70
100 msec surge current (amps AC)	Line-Neutral: 72, Line-Line: 40	Line-Neutral: 75, Line-Line: 40
5 sec surge power (real watts)	5800	8500
30 sec surge power (real watts)	5200	6000
5 min surge power (real watts)	4800	5400
30 min surge power (real watts)	4500	4800
Continuous power output at 25° C	4000 VA (L-L)	4400 VA (L-L)
Maximum continuous input current	266 A	144 ADC
Inverter efficiency (peak)	93%	94%
Transfer time	16 msecs	16 msecs
Search mode (typical)	< 6 watts	< 6 watts
No load (120 VAC output, typical)	27 watts	25 watts
Waveform	Pure Sine Wave	Pure Sine Wave
CHARGER SPECIFICATIONS		
Continuous output at 25° C	105 ADC	60 ADC
Charger efficiency	85%	85%
Power factor	> .95	> .95
Input current at rated output (AC amps)	15 AAC per leg at 120/240 VAC split phase	17.5 AAC per leg at 120/240 VAC split phase
GENERAL FEATURES AND CAPABILITIES		
Transfer relay capability	2 legs at 30A per leg transfer standard on all models	
Five stage charging capability	Bulk, Absorb, Float, Equalize (requires remote), and Battery Saver™	
Battery temperature compensation	Yes, 15 ft Battery Temp Sensor standard	
Internal cooling	0 to 120 cfm variable speed drive using dual 92mm brushless DC fans	
Overcurrent protection	Yes, with two overlapping circuits	
Overtemperature protection	Yes on transformer, MOSFETS, and battery	
Corrosion protection	Yes, PCB's conformal coated, powder coated chassis/top, and stainless steel fasteners	
Listings	ETL Listed to ANSI / UL1741, 1st edition, and CSA STD C22.2 No.107.1-01	
Warranty	Three years parts and labor (five years when installed on MMP or MP system)	
ENVIRONMENTAL SPECIFICATIONS		
Temperature (Operating/Non-operating)	-20° C to +60° C (-4° F to 140° F) to -40° C to +70° C (-40° F to 158° F)	
Operating humidity	0 to 95% RH non-condensing	
PHYSICAL SPECIFICATIONS		
Dimensions (l x w x h)	13.75" x 12.65" x 8.0" (34.9 cm x 32.1 cm x 20.3 cm)	
Mounting	Shelf, wall (no vents on bottom), MP or MMP panels	
Weight	55 lb (24.9 kg)	55 lb (24.9 kg)
Shipping weight	62 lb (28.2 kg)	63 lb (29.6 kg)
Max operating altitude	15,000' (4570 m)	

Sensata Technologies

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Everett, Washington 98204 USA

425-353-8833

4467 White Bear Pkwy
St. Paul, MN 55110 USA

800-553-6418

www.SensataPower.com

Testing for specifications at 25° C. Specifications subject to change without notice.

MIDNITE SOLAR

MidNite Solar offers a range of PV Combiners from our MNPV3 to the MNPV16. This range of combiners accommodates PV systems as small as a two string off grid cabin up to 16 strings for a 100KW commercial grid tie inverter. The MNPV series of combiners are the result of 20 years of design and manufacturing experience in the renewable energy industry. Each unit has the same quality features such as:

* Aluminum rainproof type 3R enclosure
* Internal plastic injection molded dead front covers
* Knock outs that accept waterproof strain reliefs, conduit or panel mount MC type connectors
* Knock outs for lightning arrestors
* Uses 150VDC & 300VDC breakers or 600VDC fuses depending on model number
* ETL listed to UL1741for use in the US and Canada
* Adaptable for two separate inverters or charge controllers on certain models

MNPV 3

Installation photo courtesy of APRS World

Configured for 600VDC Fuses (Gridtie)

Configured for 150VDC Breakers (Offgrid)

MidNite SOLAR, inc

Been mooned lately?

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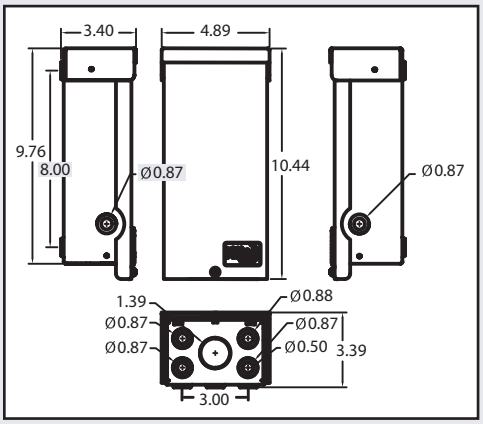
PV Combiner: MNPV3

			PV Source Circuits			PV Output Circits					
Model	Max VDC	Max # of Strings	Max OCPD Rating Amps	OCPD	Wire Range AWG	Max # of Output Strings	Max Output Amps	Wire Range AWG	Approved Mounting Angle	Enclosure Type/ Material	Rating
MNPV3 (LV)	150	3	63	CB 150V	14-6	1	60	14-1/0	90 to 14^0	3R/Alum	UL1741
MNPV3 (HV)	600	2	30	FUSE	14-6	1	60	14-1/0	90 to 14^0	3R/Alum	UL1741
MNPV6 (LV)	150	6	63	CB 150V	14-6	2	120	14-1/0	90 to 14^0	3R/Alum	UL1741
MNPV6 (HV)	600	4	30	FUSE	14-6	2	80	14-1/0	90 to 14^0	3R/Alum	UL1741
MNPV6 -250	300	3	63	CB 300V	14-6	1	120	14-1/0	90 to 14^0	3R/Alum	UL1741
MNPV12 (LV)	150	12	63	CB 150V	14-6	2	200	14-2/0	90 to 14^0	3R/Alum	UL1741
MNPV12 (HV)	600	10	30	FUSE	14-6	2	200	14-2/0	90 to 14^0	3R/Alum	UL1741
MNPV12-250	300	6	63	CB 300V	14-6	2	168	14-2/0	90 to 14^0	3R/Alum	UL1741
MNPV16 (HV)	600	16	30	FUSE	14-6	1	240	14-250mcm	90 to 14^0	3R/Alum	UL1741
MNPV16-250	300	12	63	CB 300V	14-6	1	240	14-2/0	90 to 14^0	3R/Alum	UL1741
MNPV16-24	150	24	63	CB 150V	14-6	1	240	14-250mcm	90 to 14^0	3R/Alum	UL1741
PREWIRED											
MNPV2-HVPR	600	2	30	FUSE	14-6	1	60	14-1/0	90 to 14^0	3R/Alum	UL1741
MNPV4-HVPR	600	4	30	FUSE	14-6	2	80	14-1/0	90 to 14^0	3R/Alum	UL1741
MNPV6-HVPR	600	6	30	FUSE	14-6	2	200	14-2/0	90 to 14^0	3R/Alum	UL1741

* Installer to confirm number of input circuits vs. specified OCPD rating vs. continuous current rating of Buss bar
NOTE: All of the connections have a 90 deg C rating except the 2/0 positive lug that carries a 70 deg C rating. MidNite can supply 1/0 lugs to substitute in these cases where 90 deg C is required.

MNPV3 (For 150 VDC charge controllers and 600 VDC gridtie inverters)
(The second most popular PV combiner in North America.) Gray aluminum type 3R rainproof enclosure with insulating deadfront, will accept three 150VDC (MNEPV) breakers or two 600/1000 VDC fuse holders. With modifications to the deadfront 3 dinrail fuse holders can be used. Includes a 60 amp plus bus bar, 6 position PV negative bus bar and a 6 position ground bus bar. Punch out tabs on the plastic deadfront make for a clean installation using circuit breakers. An included vsnap in adapter makes for a professional looking installation when installing fuse holders. A single 300VDC breaker from 7 to 50 amps may be installed as a disconnect (no combining busbar) . The enclosure may be mounted to a pole or wall indoors or out.

Breakers/fuse holders sold separately
Boxed size: 11 x 5 x 4 weight: 2 Lbs.



Configured with 2 600 VDC fuses

Configured with 3 150 VDC breakers

ETL Listed for US & Canada

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Ph 360.403.7207 Fax 360.691.6862
http://www.midnitesolar.com

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UPG No. D5751

UB121100

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Absorbant Glass Mat (AGM) technology for superior performance. Valve regulated, spill proof construction allows safe operation in any position. Approved for transport by air. D.O.T., I.A.T.A., F.A.A. and C.A.B. certified. U.L. recognized under file number MH 20567.

Specification

Nominal Voltage	12 volts
Nominal Capacity	77º F (25º C)
20-hr. (5.50A)	110.0 Ah
10-hr. (10.23A)	102.3 Ah
5-hr. (18.70A)	93.5 Ah
1-hr. (66.00A)	66.0 Ah
Approximate Weight	65.7 lbs (29.8 kgs)
Internal Resistance (approx.)	5mΩ

Shelf Life (% of normal capacity at 77º F (25º C))

3 Months	6 Months	12 Months
91%	82%	64%

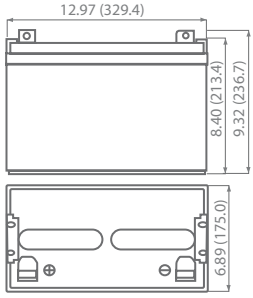
Temperature Dependancy of Capacity (20 hour rate)

104˚ F (40˚C)	77˚F (25˚C)	32˚F (0˚C)	5˚F (-15˚C)
102%	100%	85%	65%

AGM Operational Temperature	
Charge	32˚F to 104˚F (0˚C to 40˚C)
Discharge	5˚F to 113˚F (-15˚C to 45˚C)
AGM Storage Temperature	5˚F to 104˚F (-15˚C to 40˚C)

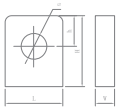
Charge Method (Constant Voltage)	
Cycle Use (Repeating Use)	
Initial Current	33 A or smaller
Control Voltage	14.6 - 14.8 V
Float Use	
Control Voltage	13.6 - 13.8 V

Physical Dimensions: in (mm)



L: 12.97in (329.4 mm)
W: 6.89in (175.0 mm)
H: 8.40in (213.4 mm)
TH: 9.32in (236.7 mm)
Tolerances are +/- 0.04 in. (+/- 1mm) and +/- 0.08 in. (+/- 2mm) for height dimensions. All data subject to change without notice.

Terminals



L Series (L Type Terminal)

Dimension / Type	L	W	H	h	⌀
L3	25.5	7.0	22.0	10.5	8.5

Constant Current Discharge Characteristics Unit:A (25°C, 77°F)

F.V/Time	5MIN	10MIN	15MIN	30MIN	1HR	2HR	3HR	4HR	5HR	8HR	10HR	20HR
9.60V	361.1	269.3	189.5	114.7	59.9	34.9	25.6	20.0	16.5	11.6	10.5	5.7
10.20V	325.2	245.4	169.6	108.7	56.3	33.3	24.9	19.5	16.2	11.4	10.2	5.5
10.50V	313.2	233.4	159.6	105.7	54.9	32.5	24.3	19.2	16.0	11.3	10.0	5.5
10.80V	301.2	221.4	149.6	102.7	52.9	31.7	23.7	18.9	15.6	11.0	10.0	5.4
11.10V	289.3	209.5	139.7	99.8	50.9	30.9	22.9	18.3	15.2	10.7	9.5	5.1

Constant Power Discharge Characteristics Unit:W (25°C, 77°F)

F.V/Time	5MIN	10MIN	15MIN	30MIN	1HR	2HR	3HR	4HR	5HR	8HR	10HR	20HR
9.60V	3919.2	2959.6	2013.0	1217.9	693.3	404.0	297.3	231.4	190.5	134.7	121.7	65.5
10.20V	3610.0	2724.2	1882.3	1207.0	651.4	386.0	289.3	225.4	149.7	131.7	118.7	63.8
10.50V	3552.1	2647.4	1809.5	1199.0	630.4	377.1	282.3	221.4	184.5	130.7	116.7	63.0
10.80V	3506.2	2577.5	1741.6	1196.0	613.5	369.1	276.3	217.5	181.5	127.7	115.7	62.7
11.10V	3442.4	2492.8	1661.8	1187.0	605.5	368.1	273.3	216.5	180.5	126.7	112.7	60.8

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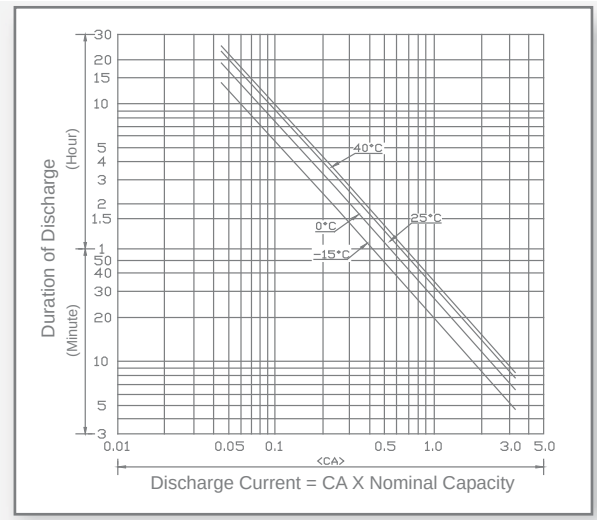
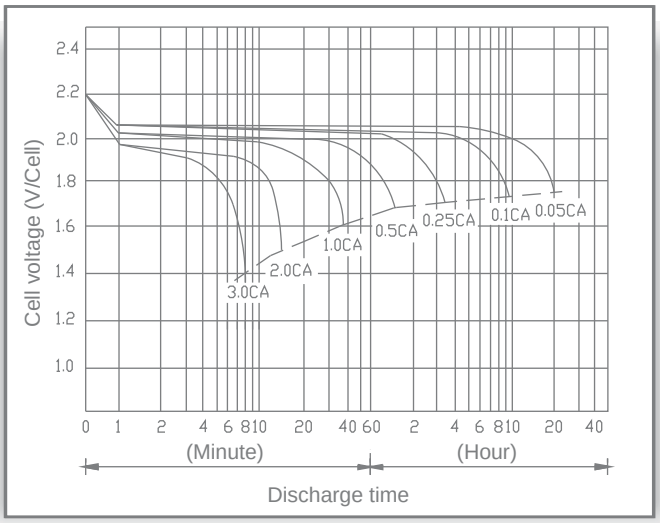
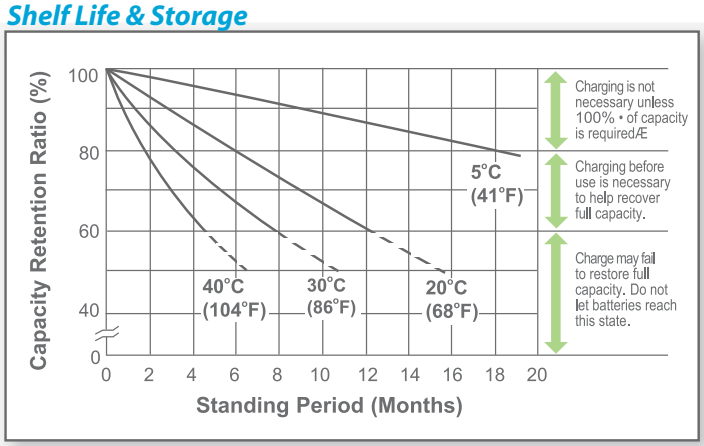
Discharge Time vs. Discharge Current



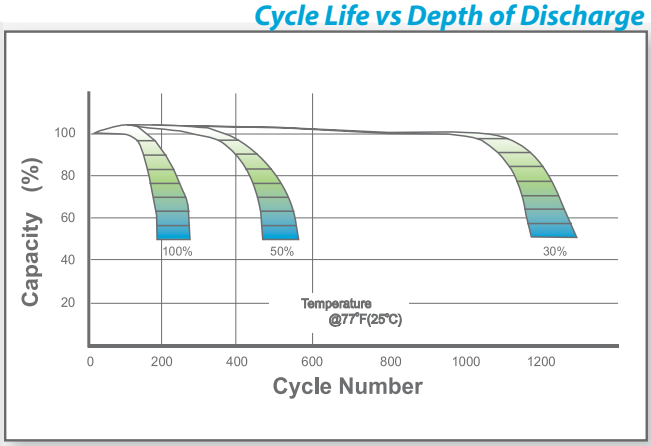
Discharge Characteristics



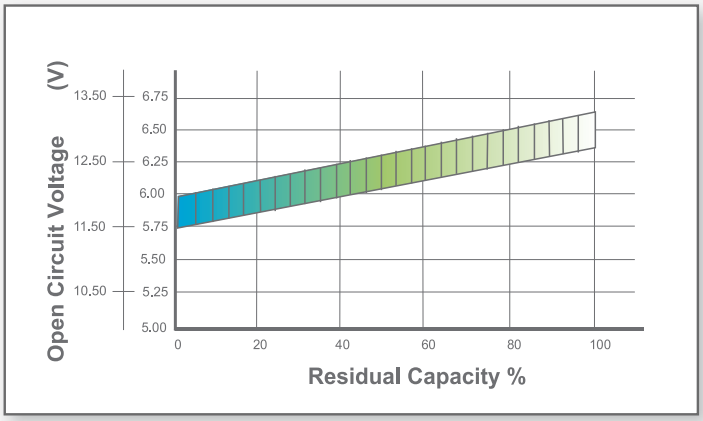
Shelf Life & Storage



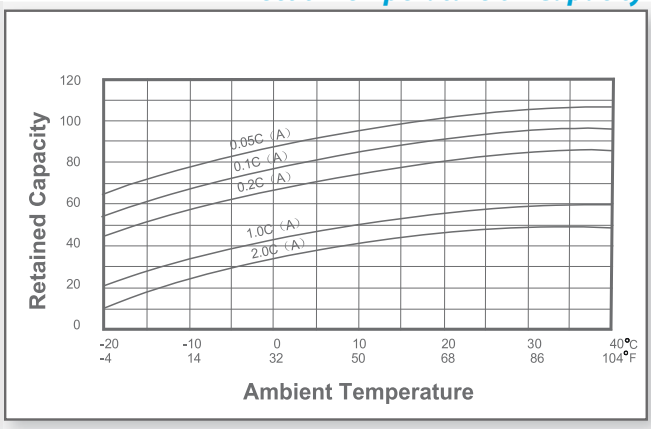
Cycle Life vs Depth of Discharge



Open Circuit Voltage vs Residual Capacity



Effect of Temperature on Capacity



Charge Current & Final Discharge Voltage

Application	Charge Voltage(V/Cell)			Max.Charge Current
	Temperature	Set Point	Allowable Range	
Cycle Use	25℃(77℉)	2.45	2.43~2.47	0.30C
Standby	25℃(77℉)	2.285	2.27~2.30	

Final Discharge Voltage V/Cell	1.75	1.70	1.60	1.30
Discharge Current(A)	0.2C>(A)	0.2C<(A)<0.5C	0.5C<(A)<1.0C	(A)>1.0C

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Classic 150, 200 or 250 MPPT Charge Controllers

Nominal Battery Voltage	12 Through 72 volts on Classic's
Maximum Output Current	Classic 150 = 96A on 12V, 94A on 24V and 86A on 48V battery Classic 200 = 79A on 12V, 78A on 24+48V and 65A on 72V battery Classic 250 = 61A on 12V, 62A on 24V, 55A on 48V and 43A on 72V battery
PV Open Circuit Voltage VOC *(NOTE: See HyperVOC at bottom)*	Classic150 = 150V + HyperVOC (battery voltage up to 48V) *Example 150V + 48V = 198VOC* Classic200 = 200V + HyperVOC (battery voltage up to 48V) Classic250 = 250V + HyperVOC (battery voltage up to 48V) *(NOTE: See HyperVOC at bottom)*
Power Conversion Efficiency	98% (Typical system)
Maximum Stand-By Self-Consumption (12V)	2.8W - 4W
Reverse Current At Night	Zero - Internal relay for reverse current
Low Battery Voltage	Low Battery voltage disconnect and re-connect of loads fully programmable with 2 Auxiliary outputs to control external load disconnect /re-connect switches
Hyper VOC *(NOTE: See HyperVOC at bottom)*	Standard all models - Extended VOC range for cold climates
Arc Fault Protection	Standard on Classic, 0.25 second detect and trip speed
Ground Fault Protection	Standard all models - resettable, no fuse to blow
Charging Regulation	Bulk, Absorb, Float as well as Equalization
Battery Voltage Regulation Set Points	10-100VDC
Equalization Charging	Adjustable Voltage and Duration, Manual or Auto
PV Reverse Polarity	Protected to Max VOC (Classic MPPT Charger Controllers are fully protected from reverse current on both input and output)
Battery Reverse Polarity	Fully protected (Classic MPPT Charger Controllers are fully protected from reverse current on both input and output)
Battery Over Voltage	Fully protected (Classic MPPT Charger Controllers are fully protected from over current on both input and output)
Battery Short Circuit	Fully protected
Battery Temp Compensation	Automatic when BTS is installed, Adjustable mV per degree C per 2V cell
Programmable Auxiliary Control Output	2 Auxiliary outputs, Aux1 can be 12V out or dry contact, Aux2 is 12V out or Logic IN
Graphic Display	Graphical display
Networking Cabling	Standard 4 conductor phone cable, no hub needed
Communications	ModBus openly published over Ethernet and RS232
Remote Display	Display (MNGP) can be relocated and a second display can be added
Remote Monitoring And Control	Local Application software included allows viewing and control from the network or over the Internet. MyMidNite.com - online status monitoring
Terminal Rating	75 C
Internet Ready	All models
Data Logging	380 days of daily history, 24 hours of data at 5 minute intervals
Wind And Hydro Applications	Standard on all models
Positive Ground Applications	Requires 2 pole input and output breakers
Operating Temperature	Minimum of -40C to 50C - Controller will auto derate as temperature rises above 25C
Environmental Rating	Indoor type IP30 (The Classic is IP22 Rated to 60529 when used with Classic Drip Shield)
Conduit knock Outs	Single 1" conduit (35.05mm) on left and right sides. Two 1" conduit (35.05mm) on bottom. Two 3/4" conduit (27.76mm) on back.
Warranty	5 Year
Weight & Dimensions	12 Lbs. (5.45 kgs) - 14.9" x 6" x 4" (378mm x 152mm x 102mm)
Shipping Dimensions HxWxD	19" x 8.5" x 5.7" (482.6mm x 215.9mm x 144.78mm)
Options	MNGP graphical display, 3ft networking cable
Certifications	Listed by ETL for US & Canada, CE Certified, FCC Class B

HyerVOC: A non-operative VOC safety zone over and above the maximum input voltage for cold climates.

NOTE: Turbine short circuit protection is provided by the additional MidNite Clipper
Turbine voltage and speed protection provided when used with MidNite Clipper