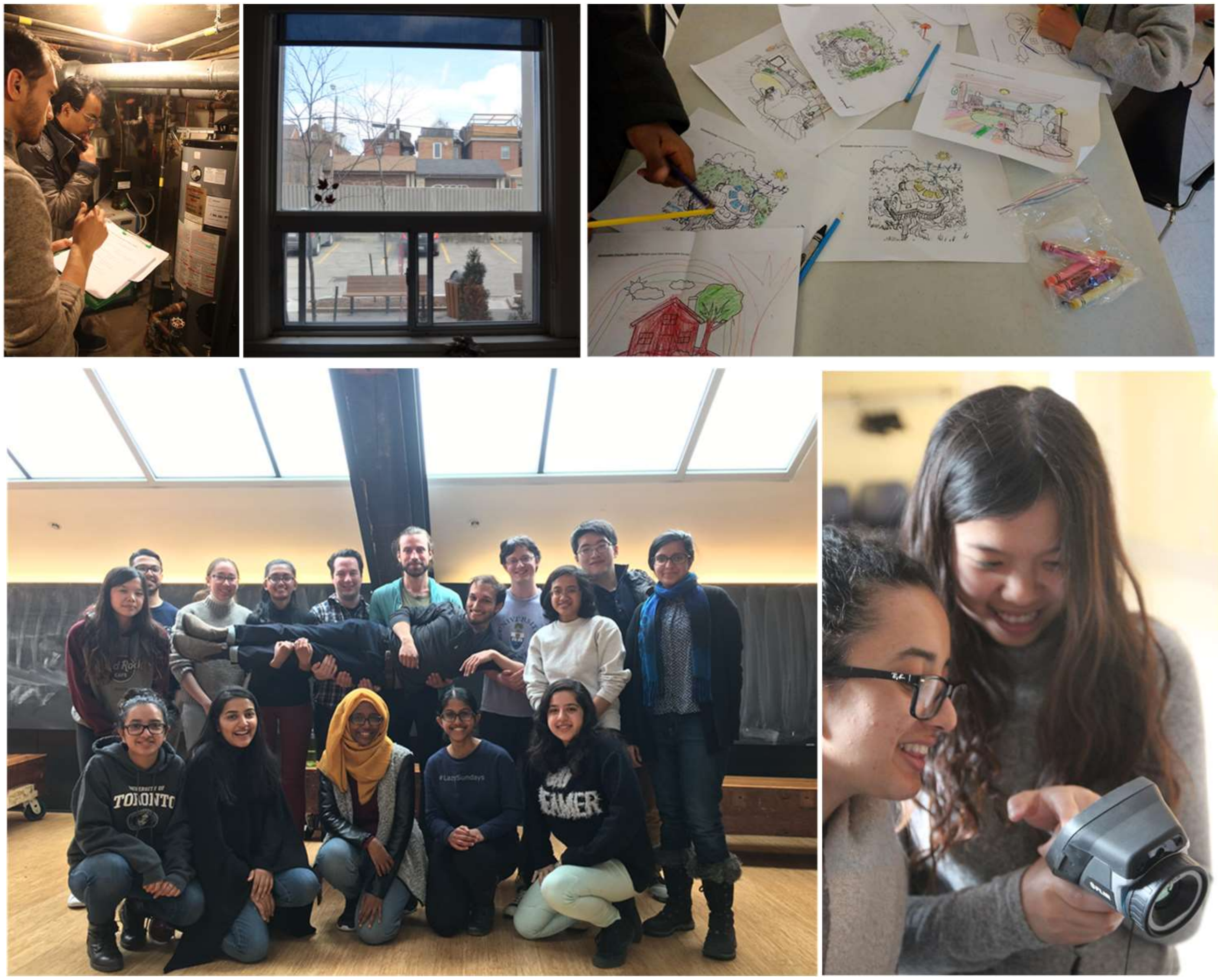
Northern Lights Solutions



2018 Green Energy Challenge Proposal

Submission Date: April 30, 2018

CECA / NECA

University of Toronto Student Chapter

Table of Contents

1 Project Summary

1.1 Executive Summary

Northern Lights Solutions, the official Green Energy Challenge team of the University of Toronto CECA/NECA Student Chapter, is excited to present its proposal for a net-zero energy retrofit for the Christie Refugee Welcome Centre (CRWC) in Toronto, Canada. The Centre helps refugee families arriving in Canada with meals and lodging, activities programs, and support to help them find work and long-term housing. The CRWC is located in three duplex residential buildings. The buildings are of old construction and have high occupant density, providing several opportunities for energy conservation.

Several retrofits are proposed to achieve net-zero energy use on site. Improvements to the insulation and air tightness, mechanical system, and water conservation will reduce total energy demands by 65% (336,332 kWh/year). A lighting retrofit including LED replacements and occupancy sensors will reduce lighting demands by 54% (14,767 kWh/year). A 43.5 kW rooftop solar PV system and solar thermal system will generate 118,312 kWh of energy annually. The projected cost for the project is $527,575, and will reduce energy consumption in the short-term by 89%. NLS has identified $335,360 in energy conservation incentives to support the project, which brings the total project cost to $132,721 with a simple payback of 6.2 years.

NLS has also enacted a comprehensive community engagement program including volunteer leadership to improve awareness about energy conservation and sustainability. This proposal has been presented to the client and feedback has been implemented to ensure the design meets the facility’s needs. Finally, NLS has maintained regular blog posts to maintain our strong connections with industry partners who have supported the creation of this proposal.

1.2 NLS Mission Statement

Our mission is to provide our clients with innovative and sustainable solutions that will best address their needs in a cost-effective manner. We understand that there is no “one size fits all” solution, and our team makes every effort to deepen our understanding of our clients’ needs in every project.

1.3 Project Team

NLS is comprised of 21 dedicated individuals who are led by six key members:

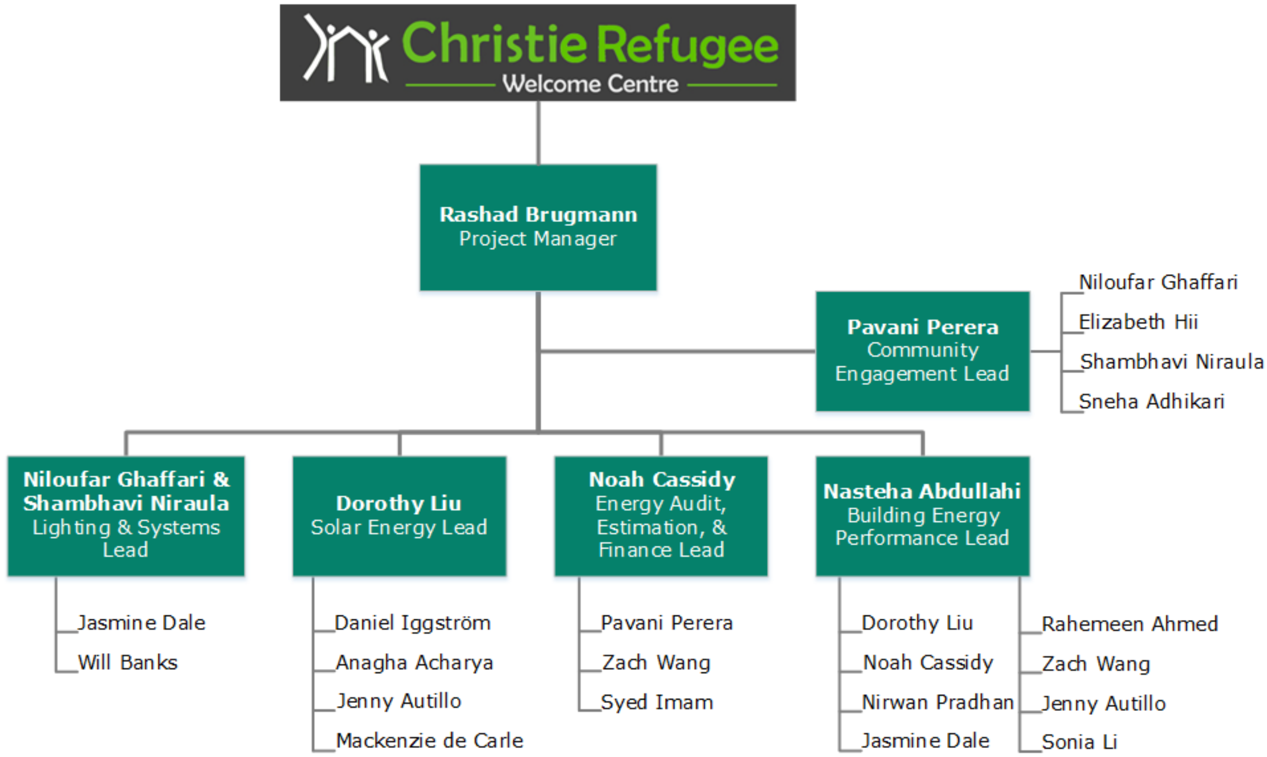
1. **Rashad Brugmann** – Project Manager: Responsible for technical correspondence with client, and providing overall direction for submissions
2. **Pavani Perera** – Community Engagement Lead: Responsible for ongoing promotion of NLS, collaboration and engagement with the client and the community
3. **Nasteha Abdullahi** – Building Energy Performance Lead: Responsible for the technical evaluation of building performance and enclosures
4. **Noah Cassidy** – Energy, Audit, and Finance Lead: Responsible for planning the energy audit, compiling data, and estimating project costs and incentives

5. **Dorothy Liu** – Solar Energy Lead: Responsible for identifying the feasibility and suitability of a solar energy system for on-site renewable energy
6. **Niloufar Ghaffari & Shambhavi Niraula** – Lighting and Systems Lead: Responsible for identifying improvements to lighting quality and power consumption

1.4 Introduction

This proposal puts forward a recommendation for the Christie Refugee Welcome Centre (CRWC), a not-for-profit organization in Toronto, Canada, to achieve net zero energy (NZE) at their three properties. The proposal is written by Northern Lights Solutions (NLS), the official competition team of the University of Toronto Canadian/National Electrical Contractors Association Student Chapter, for the 2018 Green Energy Challenge hosted by ELECTRI International and National Electrical Contractors Association (NECA). In partnership with NLS, CRWC will have the opportunity to become one of the first high density urban net-zero energy facilities in Canada, deliver innovative solutions, all while enhancing building comfort.

While several qualifications and metrics for NZE exist [1], NLS has chosen net-zero site energy to best meet the needs of CRWC. To achieve this target, each year, the buildings must produce at least as much renewable energy as they consume. NLS has taken a holistic approach to achieve this goal, using integrated improvements which overcome numerous technical challenges posed by the high density and urban location of the facilities. This report outlines the justification, costing, and scheduling for a solar energy retrofit, including a net-metered PV solar energy system and a solar hot water system, to deliver on-site renewable energy. Additionally, improvements to the lighting system, mechanical system, building enclosure, and the implementation of water conservation measures, are proposed to enhance building performance, enhance conservation, and reach the client’s NZE target.



1.5 Our Client – Christie Refugee Welcome Centre

The CWRC is a refugee shelter located in downtown Toronto. The Centre offers emergency shelter and initial settlement services to families arriving to Canada from unstable and war-torn countries around the world. Each family's stay at the Centre is 3 to 4 months, and with a capacity of 70 residents, the Centre can host about 300 individuals per year. CRWC provides holistic support through food, shelter, health care, and case management to help navigate the refugee process and secure housing accommodations, education, and banking. Almost 60% of the refugees CRWC serves are female and almost one-third are children under 12 [2]. To support these individuals in their transition to Canada, the Centre also offers several educational and social programs including Children's Literacy, Music Literacy, After-School Fitness, Summer Day Camp for Children, and a Women's Wellness Program, along with numerous events and workshops.

CWRC aims to provide comfortable, healthy, and accessible accommodations to everyone they host, as well as for their 25 office, facility, and program staff. Indoor environmental quality is important for the facilities, and the organization is also conscious of reducing their environmental footprint. Another significant consideration for the Centre is reducing their energy costs. They are a charity organization and receive most of their funding from municipal and provincial sources. Finally, CRWC would like to make their facilities more resilient to power outages, so that they can continue to provide housing services year-round for vulnerable populations in need of refuge.

1.6 Facility Description

CRWC's facilities are housed in three adjacent brick masonry buildings located at 39-49 Christie Street about 20 minutes from the downtown core of the city. The facility is surrounded by mid-rise residential building and is adjacent to Christie Pits Park, a nine-hectare (22 acre) park that provides the building with significant west exposure.

Exhibit 1-1: Typical building floor plan

The three buildings were constructed in 1924 as duplex houses. When CRWC moved into the buildings in the late 1990s, they replaced the deteriorating exterior entrances with an interior stairwell. Doorways were opened in the interior structural walls to join the previously separated duplex units, as shown in **Exhibit 1-1**. In 2011, deteriorating verandas and covered porches were removed and replaced with exterior insulation on the west façade.

The floor plans are labelled by building unit and room number. For example, 41-3 indicates the third room for building unit 41. The type of room, is also labelled within the floor plans. The northern and southern buildings provide living space while the central building contains the kitchen and dining area, administrative services, and healthcare services. The three buildings provide approximately 10,000 square feet of space for around 70 refugees, or approximately 140 square feet per person which suggests a higher energy intensity, on a per area basis, when compared to similar facilities.

The three buildings have a shared parking lot behind them, as well as a playground. The parking space and the building footprints account for nearly all the site land-use. This results in a very limited area to provide solar power generation when compared to energy consumed, as is typical for much of Toronto and other high-density areas.

1.7 Project Team Resumes

Project team resumes are provided below:

RASHAD BRUGMANN

PROJECT MANAGER

PERSONAL SUMMARY

Rashad is a third year Civil Engineering student at the University of Toronto who has knowledge and experience in the green building industry. Rashad's relevant professional work includes sustainability consulting at Sustainable.TO. He brings considerable peer leadership experience to Northern Lights Solutions and past success in the Green Energy Challenge.

EDUCATION

Bachelor of Applied Science, University of Toronto **Sept 2015-Present**
Civil Engineering
Class of 2019+PEY

REVELANT EXPERIENCE

Research Assistant **Sept 2017-Jan 2018**
U of T Expanded Student Engagement Project

- Designed an Excel database of university courses and analyzed it for trends in the curricula
- Managed team of 5 RA's to write 8-page funding proposals and a 40-page annual report
- Presented results to the U of T Presidential Committee on Environment, Climate Change, and Sustainability to promote student engagement in sustainability education

Junior LEED Consultant **May 2017-Jun 2017**
Sustainable.TO Architecture+Building

- Assessed LEED credits for a new-build healthcare facility, and summarized the requirements for architects, engineers, and the client in a PowerPoint presentation
- Produced Excel spreadsheets to document progress, and supported hosting a design charrette
- Developed credit targets to exceed client's LEED target

EXTRA-CURRICULAR ACTIVITIES & AWARDS

- **Project Manager,** CECA/NECA University of Toronto Student Chapter (2017-2018)
- **Curriculum Enrichment Director,** U of T Sustainable Engineers Association (2017-2018)
- **Civils 5T6 Scholarship** (2017)

NASTEHA ABDULLAHI

BUILDING PERFORMANCE LEAD

PERSONAL SUMMARY

Nasteha has completed her third year of Civil Engineering at the University of Toronto and will be working as a 12-month co-op student at the Toronto Transit Commission's Subway Infrastructure Department. Nasteha is the current Building Performance Team Lead for the CECA/NECA University of Toronto Student Chapter.

EDUCATION

Bachelor of Applied Science, University of Toronto **Sept 2015-Present**
Civil Engineering
Class of 2019+PEY

REVELANT EXPERIENCE

Member, ASHRAE University of Toronto Chapter **Sept 2017-Present**

- Engaged small businesses to reduce energy use by providing free energy assessments
- Conducted ASHRAE Type 1 energy audits for data collection of data in lighting, plug load, building envelope, HVAC, water, and recycling
- Documented results for energy modelling using the Green Energy Management System program

Team Member **Sept 2017-Apr 2018**
Improving Sustainability Through Changes in Infrastructure

- Performed research on the use of green roofs and solar panel installations in the context of Sydney, Australia to reduce fossil fuel consumption
- Proposed the combined use of these two solutions on residential roofs to optimize efficiency in energy input and regulate internal building temperatures
- Presented findings and potential government incentives to outline feasibility in a final 15-minute presentation

EXTRA-CURRICULAR ACTIVITIES & AWARDS

- **Building Performance Team Lead,** CECA/NECA University of Toronto Chapter (2018)
- **Engineering Orientation Head Leader,** University of Toronto (2017-Present)
- **2nd Place Award, Sustainable Building Case Competition,** CECA/NECA University of Toronto Student Chapter (2017)

NILOUFAR GHAFFARI

LIGHTING DESIGN CO-LEAD

PERSONAL SUMMARY

Niloufar has completed her third year of Civil Engineering at the University of Toronto and will start her 12-month co-op placement at York Region as an engineering assistant for the Transportation and Community Planning Department. She is the current Lighting Design Co-Lead at the CECA/NECA University of Toronto Student Chapter's Green Energy Challenge.

EDUCATION

Bachelor of Applied Science, University of Toronto **Sept 2015-Present**
Civil Engineering
Class of 2019+PEY

REVELANT EXPERIENCE

Resident Advisor **May 2017 & 2018**
Girls Leadership Engineering Experience UofT

- Organized and facilitated events for incoming female engineering students to introduce them to the Engineering program at the university

Municipal Services Design Project **Mar –Apr 2018**
University of Toronto

- Design the water distribution, sanitary sewer, and storm drainage systems for a fictional town
- Perform cost estimates and flow calculations, and model systems using EPANET and AutoCAD

Summer Intern (Material Department) **May–Aug 2017**
Super-Pufft Snacks Corp.

- Produced forecast, budgeting, and inventory spreadsheets to manage the company's monthly inventory count and quarterly audits
- Established a new filing system for all customer and supplier documents and contributed to the submission of files on material imports/exports

---

EXTRA-CURRICULAR ACTIVITIES & AWARDS

- **Captain,** Coed Volleyball, UofT Faculty of Engineering (Jan 2017-Present)
- **Mentor,** UofT General/Civil Engineering (Sept 2016-Present)
- **Lighting Design Co-Lead,** CECA/NECA University of Toronto Chapter (2018)

DOROTHY LIU

SOLAR DESIGN LEAD

PERSONAL SUMMARY

Dorothy has just finished second year Civil Engineering at the University of Toronto. She is the current Solar Design Lead for the CECA/NECA University of Toronto Student Chapter's Green Energy Challenge. Moving forward, she is focusing on sustainable energy system and building science in the latter half of her undergraduate studies.

EDUCATION

Bachelor of Applied Science, University of Toronto **Sept 2016-Present**
Civil Engineering
Class of 2020

REVELANT EXPERIENCE

Vice President **Sept 2017-Apr 2018**
UofT Canadian Society for Civil Engineering

- Collaborate with chapter members to implement events that connect civil engineering students with professional engineers and develop their technical skills, including career panels, AutoCAD workshops and career fairs
- Advertise and supervise events to ensure their success and keep students updated on club activities

Social Innovation Lead **Sept 2017-Apr 2018**
Institute for Leadership Education in Engineering

- Connected with and sought feedback from a wide range of stakeholders to address their concerns and develop a solution best suited for them
- Developed leadership skills through initiating the project and leading the team

EXTRA-CURRICULAR ACTIVITIES & AWARDS

- **1st place Award**, ILead Social Innovation Project Competition (2017)
- **Dean's Merit Scholarship** (2017)
- **1st place Award**, Sustainable Building Case Competition, CECA/NECA University of Toronto Student Chapter (2017)
- **Solar Design Lead**, CECA/NECA University of Toronto Chapter (2018)

NOAH CASSIDY

AUDIT/FINANCE LEAD

PERSONAL SUMMARY

Noah has finished his third year of Civil Engineering at the University of Toronto. He has an interest in building science, project management, and has found his business minor courses fascinating. He is the current Audit and Finance Lead at the CECA/NECA University of Toronto Chapter's Green Energy Challenge and will serve as the Junior Project Manager for the Chapter next year.

EDUCATION

Bachelor of Applied Science, University of Toronto **Sept 2015-Present**
Civil Engineering
Class of 2019+PEY

REVELANT EXPERIENCE

Resource Staff/Counsellor **Jul 2014-Aug 2016**
Cairn Family of Camps

- Resource staff duties included creating and running sessions and supervising counsellors. Sessions included high ropes, zipline, and rock wall activities, teaching excellent safety awareness.
- Helped instruct counsellors and other resource on how to run these sessions

Counsellor **Summer 2017**
DEEP Summer Academy

- Coordinated with 2 graduate students to prepare testing of vertical post-tensioned connections that would allow modular buildings to better withstand earthquakes
- Analyzed a numerical model on the behavior of a ceiling to floor connection of a building under seismic loading to identify areas of stress concentration
- Modelled the experimental setup of specimens on AutoCAD and SketchUp to facilitate the presentation of project to faculty and stakeholders

EXTRA-CURRICULAR ACTIVITIES AND AWARDS

- **U of T Seismic Design Team** (2015)
- **Hart House Archery Club** (2015-2017)
- **Audit/Finance Lead**, CECA/NECA University of Toronto Student Chapter (2018)

PAVANI PERERA

COMMUNITY ENGAGEMENT LEAD

PERSONAL SUMMARY

Pavani has completed her third year of Civil Engineering at the University of Toronto and will be employed as a 12-month co-op student at the Region of Peel's Sustainable Transportation Division. Pavani is the current Community Engagement Lead at the CECA/NECA University of Toronto Chapter's Green Energy Challenge and will serve as the Outreach Director for the Chapter next year.

EDUCATION

Bachelor of Applied Science, University of Toronto **Sept 2015-Present**
Civil Engineering
Class of 2019+PEY

REVELANT EXPERIENCE

Engineering Intern, Production Department **May-Aug 2016**
Virelec Ltd.

- Assembled and wired DC monitoring cabinets and link plates to be installed in panels for Hydro One clients
- Interpreted company's engineering drawings to ensure products met quality standards
- Catalogued 40+ surplus inventory items for company's year-end inventory

Research Assistant, Post-Tensioned Connection **May-Aug 2017**
University of Toronto

- Coordinated with 2 graduate students to prepare testing of vertical post-tensioned connections that would allow modular buildings to better withstand earthquakes
- Analyzed a numerical model on the behavior of a ceiling to floor connection of a building under seismic loading to identify areas of stress concentration
- Modelled the experimental setup of specimens on AutoCAD and SketchUp to facilitate the presentation of project to faculty and stakeholders

EXTRA-CURRICULAR ACTIVITIES AND AWARDS

- **Community Engagement Lead**, CECA/NECA UofT Student Chapter (2018)
- **Volunteer Note-taker**, U of T Accessibility Services (2016-Present)
- **Tempest Seat Designer**, U of T Human-Powered Vehicles Design Team (2016-2017)

2 Technical Analysis 1: Energy Efficiency Analysis

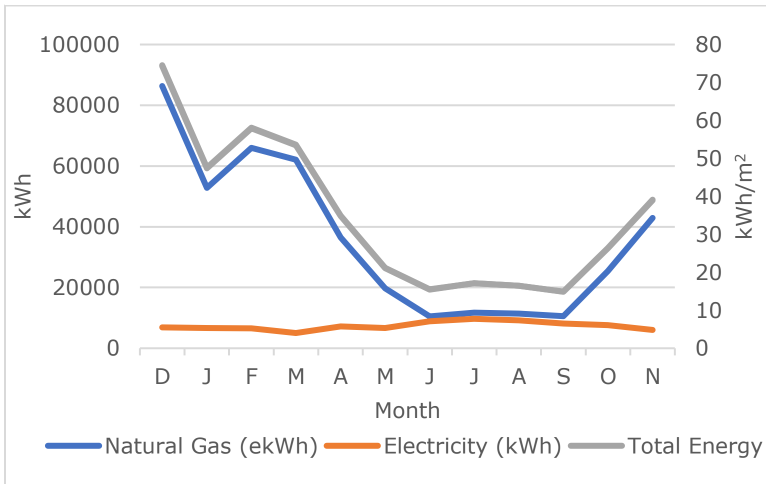
At the beginning of March 2018, NLS performed an audit at CRWC to determine energy consumption, building envelope characteristics, building functions and occupant experiences. Based on the data collected, NLS targeted potential areas of improvement with retrofit recommendations.

2.1 Energy Audit Results

The energy audit followed an ASHRAE type 1 audit procedure, which includes a walk-through to determine energy uses and reviewing the energy bills. Additional visits were conducted to verify and obtain further data.

Exhibit 2-1 shows a summary of total annual energy use by the Centre, determined from electricity and gas metering data. Electricity load is constant throughout the year, while natural gas varies as it is used for heating. The City of Toronto mandates heating from September 15th until the end of April. Natural gas is also used for cooking and laundry, consuming a baseline of approximately 10,000 kWh.

Exhibit 2-1: Energy use through 2017



Electricity breakdown at CRWC is provided in **Exhibit 2-2**. Approximately 40% of the electricity is used to meet the cooling demand via a mini-split air conditioning system. Plug loads represent 36% of the building's electricity use. The three commercial kitchen fridges are Energy Star compliant and would not substantially benefit from a retrofit. Lighting and pumps account for the remaining 24% of electricity.

Exhibit 2-2: Electricity consumption breakdown

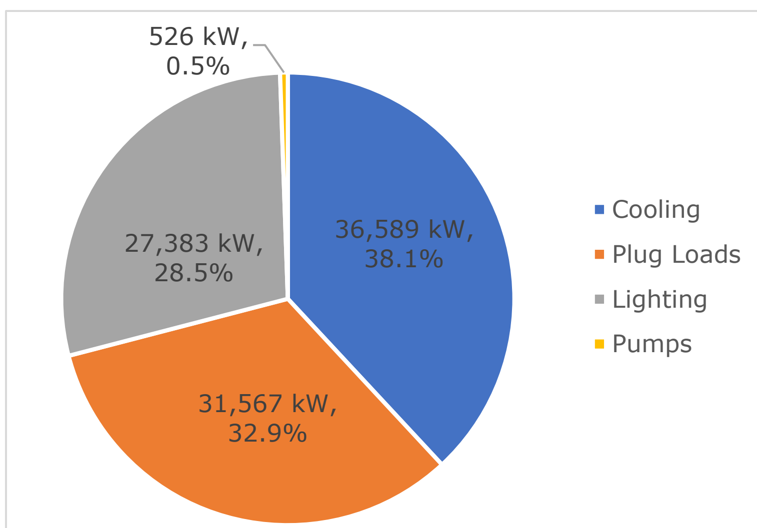
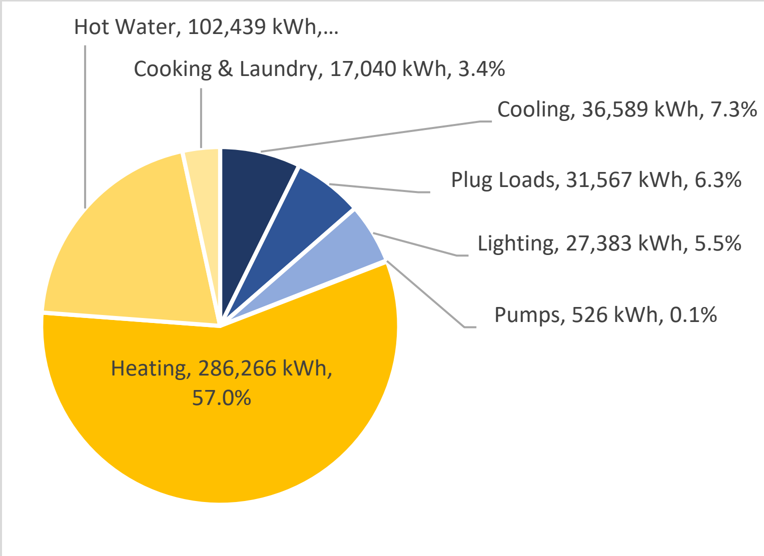


Exhibit 2-3 shows the total breakdown of energy between types and uses. Yellow slices represent natural gas, while blue denotes electricity. Heating accounts for 55% of the total energy, so many retrofits aim to reduce heating.

Exhibit 2-3: Total energy breakdown



2.1.1 Lighting Summary

The energy audit included the collection of data on the building lighting system and an interview with the building manager to determine usage. An assumption of an 8-hour work day was made for the offices, with different hours of usage assumed for different rooms. The results are summarized in **Exhibit 2-4**.

The audit estimated that the annual energy uses for building lighting is approximately 27,383 kWh, which equates to a lighting power density of 2.0 kWh/m^2.

Exhibit 2-4: Summary of lights

Location	Light type	Total Wattage (W)	Daily Operating Hours	Total Weekly Operating Hours	Weekly Energy Use (kWh)
Hallways	T8	384	8	56	21.5
	Incandescent	1500	8	56	84.0
	CFL	13	8	56	0.7
	Halogen	56	8	56	3.1
Front/Rear Stairwell	CFL	130	8	56	7.3
	CFL	208	24	168	34.9
	T8	808	24	168	135.7
Bedrooms	CFL	546	8	56	30.6
	Halogen	896	8	56	50.2
Offices	LED	54	8	56	3.0
	T8	536	8	56	30.0
	T12	160	8	56	9.0

Location	Light type	Total Wattage (W)	Daily Operating Hours	Total Weekly Operating Hours	Weekly Energy Use (kWh)
	CFL	13	8	56	0.7
	Incandescent	240	8	56	13.4
Washrooms	CFL	351	4	28	9.8
	LED	18	4	28	0.5
Activity/ Common Rooms	CFL	286	5	35	10.0
	Incandescent	180	5	35	6.3
	T8	56	5	35	2.0
	LED	18	5	35	0.6
Closet	Incandescent	60	1.5	10.5	0.6
Laundry	T8	128	3	21	2.7
Storage Rooms	CFL	169	2	14	2.4
Kitchen	LED	36	8	56	2.0
	T8	320	8	56	17.9
Dining Room	T8	576	4	28	16.1
Electrical/ Furnace Rooms	T8	96	24	168	16.1
	CFL	26	8	56	1.5
Outside	LED	56	24	168	9.4
	CFL	26	24	168	4.4
				Weekly Energy	**526.6**
				ANNUAL ENERGY (kWh)	**27,383**

2.1.2 HVAC

The heating at CRWC is provided through a single-zone system, with a hydronic boiler unit and circulator located in the basement of each building. The boiler feeds a combination of floor-mounted cast iron radiators, baseboard tube-and-fin radiators, and panel radiators of various ages. The boilers in the resident buildings, 39/41 and 47/49, are 8-year-old Slant/Fin Galaxy boilers with a net rating of 150 kBtu/h and an

AFUE of 81.17% [3]. Building 43/45 has a 35-year-old Slant/Fin Galaxy boiler of comparable capacity.

Cooling in the rooms is provided by mini-split ductless air conditioning systems. The two main systems are a 0.7-ton Daikin system with COP 2.7 and a 0.8 ton Fujitsu system with COP 3. There are 3-4 indoor units per rooftop unit, and each room has one indoor unit with a remote to adjust temperature. The basements of 39/41 and 43/45 are cooled with 2 ton single-zone Daikin mini-split systems. The basement of 47/49 does not have a cooling system.

2.1.3 Building Enclosure

The building is constructed of two layers of structural clay masonry bricks, with interior stud framing covered in plaster and lath. Some plaster has been replaced with sheetrock during recent renovations, however there is no insulation in the stud cavities. The exterior walls are about 8 inches thick and have an approximate R-value of 12 (RSI 2.11). The roof is a multi-ply pitch flat roof system installed in 2007. The west façades of the buildings, which face the main avenue, were renovated in 2011 to replace the aging verandas. The façade was refinished with 2-inch EPS insulation beneath stucco, with an R-value of approximately 20. Thermal images of the building envelope revealed locations of air leakage and heat loss. An example is shown in **Section 7.6**.

The fenestration is largely high-efficiency double-glazed fibreglass units, which are either sliding or awning, installed in 2007. Some small stained-glass windows remain in the west façade of the buildings from the original construction. Additionally, the bathroom windows are single-glazed with aluminum frames and broken sliding panes. The client plans to replace them as the bathrooms are renovated in the next five years. The wall-to-window ratio is approximately 3%.

The air tightness of the building envelope was estimated based on a study conducted on a database of buildings across the US [4]. The study suggests that the air leakage of the building is approximately 0.32 air changes per hour (ACH), meaning that it takes 3 hours for the air in the building to be replaced with fresh outdoor air without the use of fans or open windows.

2.1.4 Occupant Comfort

Informal interviews were conducted with 15 residents and staff to assess occupant comfort. Occupants generally reported feeling comfortable with the temperature in the buildings through both summer and winter. Some occupants however report cold rooms in the winter, likely the result of poorly functioning radiators. However, several occupants reported that they left their windows open for some period of the day even during the winter, to allow some ventilation. Stale air may be expected in the buildings, as the resident units house 35 people and do not have mechanical ventilation. The residents at CRWC report that they are very conscious of conserving energy to reduce costs. They turn off their lights during the daytime and when not in use, and they close their windows while they are not in their rooms.

2.2 Energy Use and Benchmarking

Two programs were used to perform an energy benchmark analysis: the Energy Star Portfolio Manager and the Department of Energy Model (DOE) Tool. These programs holistically assess the implications of current facility conditions.

2.2.1 EPA Portfolio Manager

The EPA Portfolio Manager provides assessment metrics for buildings from data retrieved through energy audits, summarized in **Exhibit 2-5**. NLS updated the model with natural gas volumes and electricity usages from each building as a baseline for this facility using CRWC's energy bills over a one-year period. Given the facility's location, estimated floor area, and other features, the tool estimates that the source Energy Use Intensity (EUI) of the facility is 1.52 GJ/m^2. When normalized with weather conditions in Toronto, it demonstrates an EUI of 1.56 GJ/m^2. In addition to the design metric of source EUI, the tool also presents a site EUI of 1.27 GJ/m^2 as well as a total greenhouse gas emissions intensity of 53.8 kgCO2e/m^2.

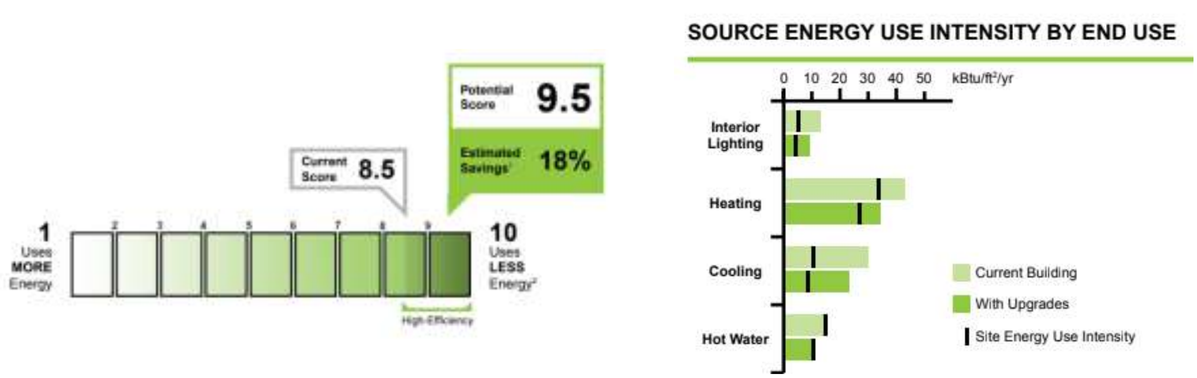
Exhibit 2-5: Energy Inputs for EPA Portfolio Manager Benchmarking

Estimated Design Energy		
Fuel Type	**Usage**	**Energy Rate ($/Unit)**
Electric - Grid	88,555 kWh (thousand Watt-hours)	$ 0.09/kWh (thousand Watt-hours)
Natural Gas	74,169.16 Cubic meters	$ 0.20/Cubic meters

2.2.2 DOE Building Asset Score

The building asset score by the DOE tool focuses on five major categories: lighting, water heating, HVAC, building operations, and physical shape of the building. To address the complexity of the shared mechanical system, the design team used notes from the energy audit, building drawings, and consultations with University of Toronto professors. The results of the evaluation are provided in **Exhibit 2-6**. The WNC's DOE Building Asset Score is 8.5 with an estimated 18% potential for improvement in energy savings. These were concentrated in improvements in heating, specifically insulation, and to a lesser extent, on lighting.

Exhibit 2-6: Results of DOE Building Asset Score



The DOE asset score also provided an estimated source energy use of 134 kBTU/ft^2. In terms of fuel use, the site and source energy use for electricity are 28.5 kBTU/ft^2 and 89.3 kBTU/ft^2 respectively while for gas the site and source EUIs are 42.2

kBTU/ft^2 and 44.3 kBTU/ft^2 respectively. However, the tool does not provide locations in Canada, so the DOE source EUIs are not suitable for analysis. The total site EUI estimated by the Asset Scoring tool is 70.7 kBTU/ft^2 or 0.803 GJ/m^2. The DOE tool estimates a site EUI which is 63% less than the actual value.

2.3 Proposed Improvements

After analyzing the energy consumption and benchmarking estimates of CRWC facility, NLS recommends several improvements to reduce energy consumption. Each recommendation's cost and energy impacts are discussed, and total values of cost, energy savings, and cost savings are summarized at end of this section in **Exhibit 2-8**.

2.3.1 Recommendation 1: Lighting retrofit

NLS recommends investigating a lighting retrofit for CRWC to improve electrical efficiency and achieve NZE. Specific retrofit measures are evaluated in **Section 3**. These retrofits include replacing existing light fixtures with LED bulbs, implementing occupancy sensors and dimmer switches, a smart-controlled lighting system, and making use of task lights instead of area lights in rooms.

2.3.2 Recommendation 2: Solar energy system

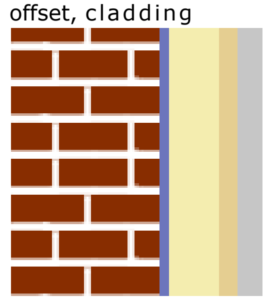
The audit team observed that the building's flat roof has large unused and unshaded areas suitable for a PV array. The proposed solar system is delineated in **Section 4**.

2.3.3 Recommendation 3: Improve insulation and air tightness

As evaluated by the DOE Model, a significant source of energy loss is the building envelope. Both interior and exterior insulation are recommended to reduce heat loss. These recommendations will increase the R-value of 4 to 23 (RSI 0.63 to 4), and will cut air leakage in half to 0.160 ACH.

Inboard of the brick, fiberglass insulation is suggested to fill the stud cavities. Outboard of the current brick, insulation of a vapour permeable air barrier is recommended, as air leakage is a large source of heat loss in any old building. Reducing the building's ACH by adding an air barrier will dramatically reduce heat loss. Blue Skin VP100 air barrier and Rockwool insulation under a new cladding of vinyl are recommended. The new exterior wall section can be seen in **Exhibit 2-7**.

Exhibit 2-7: Illustration of proposed exterior wall section
From brick out: vapour barrier, insulation, wood offset, cladding



The design team recommends Rockwool Comfortboard™ 80 as a continuous, non-structural exterior insulating layer. This product is commercially widely-used, is easily available, and has a competitive R-value of 4 (RSI 0.7). It is a free-draining material, preventing moisture build-up inside the wall. Additionally, it also has a good fire rating, with a flame spread index and smoke developed index of zero. Blue Skin VP100, a very common vapour permeable air barrier material, is recommended for its balance of cost and sufficient permeability rating, and will allow water collecting in the structural brick to dry without causing damage.

2.3.4 Recommendation 4: Plexiglass window inserts

The addition of plexiglass window inserts in the stained-glass single-pane windows will provide extra insulation while mediating heat exchange between the exterior and interior. The current R-value of the windows is 4.66 (RSI 0.8). A 6mm single-glazed acrylic sheet with an R-value of 6.31 (RSI 1.11) improve the overall R-value. The retrofit requires double-sided foam tape, plexiglass planes, and caulking.

The plexiglass is on average $9/sq. ft and is sold in various sizes. The panes will be purchased from a standard set of available sizes, potentially resulting in over-estimation of cost. This retrofit is evaluated for the windows being retrofitted, the R-values, heating degree days and cooling degree days.

Plexiglass inserts allow for 92% of light transmittance, maintaining visual appearance of stained glass details. The intervention is also inexpensive, high impact resistance, and results in a significant insulation improvement. The material's tendency to yellow over time may result in more frequent replacements and challenges with gaps in caulking may require increased attention during construction. It is not expected to disrupt any current building activities.

2.3.5 Recommendation 5: Geothermal energy system

NLS recommends replacing the existing systems of natural gas hydronic boilers and hot water tanks with a vertical loop geothermal energy system beneath the parking lot at CRWC. The geothermal system will provide heating by extracting heat from the earth, which maintains a constant temperature around 10°C throughout the winter [5]. In order to meet the heating demands of the building in the most cost-effective manner, NLS recommends a hybrid geothermal-solar thermal heating system. As discussed in **Section 4**, a solar thermal energy system will also be installed to provide energy to the buildings.

Upon completion of the insulation retrofit, the peak space heating load of all buildings will be reduced from 36 tons to approximately 12 tons. NLS consulted with Hybrid Geothermal Software (HGS) hybrid geothermal design consultants to estimate the optimal size of the geothermal heat pump system. HGS predicts that the optimal heat pump size for this system is 30-50% of the peak load. In consideration of the capacity of the proposed solar thermal system and the available financial incentives, NLS proposes a 10 ton vertical loop system as the most efficient and cost effective solution. NLS recommends retaining HGS to run a Building Energy Simulation for a design heating season and to assess the system sizing.

The system will require 700 vertical feet of heat exchange loops, which can be distributed between 2 to 3 boreholes. The system will include one external compressor unit, and one internal heat exchange unit per building. Buffer tanks of at least 120 L will be required in each building, adjacent to the internal heat pump unit, order to store the thermal energy generated and prevent short-cycling of the heat pump.

The cost of the system is estimated at $18-$20/vertical foot for equipment, material, and drilling. The system will have an average annual COP of 4, and based on analysis, the heat pumps will provide 54% of the annual space heating load and 60% of the annual hot water heating load. When the system is evaluated post-insulation and air tightness measures. The new hybrid heating system will allow both residential buildings, 39/41 and 47/49, to disconnect their gas services entirely allowing these buildings to achieve net-zero on-site carbon.

2.3.6 Recommendation 6: Thermostatic radiator control valves

NLS recommends the installation of new low-temperature radiators with thermostatic control valves, to improve heat distribution throughout building 47/49 to match the 24°C set point in 39/41 and reduce this additional demand for natural gas. Building 39/41, as confirmed during the audit, has been retrofitted with new radiators in recent years, which allows for more efficient heating. As a result, there is a substantial difference in natural gas use between buildings 39/41 and 47/49 despite their similar uses and layouts. To compensate for heating inefficiencies due to features of the older system, such as small delivery pipes with higher thermal losses, the thermostat in 47/49 is currently set at 30°C instead of 24°C as in 39/41.

The additional annual natural gas use in 47/49 is 12,378 kWh, but a portion of this difference can be attributed to the absence of solar heat gains on the south wall due to the position of building 43/45. In calculating annual solar heat gains using monthly values of solar insolation, solar gains of approximately 1,370 kWh can be discounted from the natural gas use difference. The final difference caused by the old radiators then becomes 11,010 kWh.

To address this issue, the thermostatic valves will control the water flow to each radiator based on the temperature in the room and directly adjust heating distribution as it is needed. In addition to the automatic control, this retrofit also allows residents to directly control thermal comfort, and reduce need for heat when possible. This control would balance the distribution of thermal energy in the building and ensure that extreme conditions are not experienced. In addition, retrofitting buildings 39/41 and 43/45 with control valves will further improve heating for the rest of the facility. The savings from this retrofit is evaluated for the replacement of 24 radiators in 47/49 and the implementation of control valves for the entire facility.

2.3.7 Recommendation 7: Heat recovery ventilation

To improve upon the existing ventilation system, NLS recommends the installation of a heat recovery ventilation system (HRV) in each building. An HRV provides the building with balanced ventilation by removing stale indoor air and bringing in fresh outdoor air while maintaining energy efficiency by transferring sensible heat from warm outgoing air to the cool incoming air in the winter, with the reverse in the summer.

NLS recommends the installation of two Vanee G300HE systems in each of the three buildings. The G300HE is designed for the North American climate. With outside temperatures of -25°C, it is able to recover up to 73% of the heat from the outgoing air. Its MERV 11 grade filter captures auto emissions, bacteria, and dust, to ensure a high quality of air entering the building.

Assuming a standard flow rate of 250 cfm (9.1 m^3/min) and a sensible heat transfer efficiency of 75%, each unit will save 121 kWh of heating per year, while drawing 158 kWh of energy. Although the HRV system does provide a net savings in energy directly, it allows for higher quality ventilation to complement the increased air tightness of external insulation retrofits. Due to the high density of the building, NLS recommends implementing two systems in each building to provide adequate ventilation for its residents. NLS recommends the retention of HVAC designers for the HRV system to ensure that the system is adequately installed and operated.

2.3.8 Recommendation 8: Water conservation measures

Finally, NLS recommends installing low flow plumbing fixtures to save energy and costs from domestic hot water heating and consumption. Domestic water use is a high portion of CRWC's maintenance costs and energy consumption. NLS conducted a water audit of CRWC to measure flow rates of current appliances and analyzed CRWC's water bills to determine annual water consumption. Based on the data collected, NLS recommends replacing high-flow toilets, shower heads, and faucets throughout the facility, saving 1,912 m^3 of water annually.

NLS has identified the following low-flow, EPA WaterSense certified appliances for the retrofit:

- Niagara Earth Massage 1.25GPM Low flow showerhead
- American Standard Evolution 2 2-piece 1.6 GPF Single Flush Round Toilet
- Delta Foundations 4 in. Centerset Single-Handle Bathroom Faucet
- Delta Two Handle 8" Wall Mount Service Sink Faucet

The appliances are congruent with appliances currently installed at CRWC, which will make them easy to maintain and repair as needed.

2.4 Summary of Contributions to Net-Zero

The most significant retrofit of adding exterior insulation provides the largest savings in heating by reducing the annual total heating demand to 77,360 kWh. HVAC improvements provide additional savings of 32,560 kWh due to water conservation and radiator retrofits. NLS's recommendations achieve a total energy reduction of 379,300 kWh, leaving the facility with a final energy use of 141,705 kWh after improved building performance, a 73% reduction. In total, the retrofits will cost $148,332, but the annual savings and short payback periods of the retrofits allow for the savings to take effect soon after their implementations. The capital costs, annual energy savings, and annual cost savings are summarized in **Exhibit 2-8**.

For implementation, the radiators shall be replaced first in the short-term, followed by the insulation and plexiglass retrofits in order to maximize the sizing accuracy of the heat pump retrofit. The rest of the retrofits can occur concurrently over the long-term to work towards achieving NZE. The facility will undergo significant changes to its building envelope as well as HVAC system due to the insulation and geothermal retrofits. Including the water retrofits that improve domestic hot water heating and the new HRV systems, these retrofits collaboratively enhance NLS's innovative focus on conserving and supplying higher quality heat and ventilation to the facility.

Exhibit 2-8: Summary of Building Performance Retrofit Savings

Recommendation	Capital Cost	Total annual energy savings	Total annual cost savings
Radiator Retrofit	$27,600	12,000 kWh	$103.95
Insulation Retrofit	$85,000	195,480 kWh	$1695.02
Plexiglass	$270	5,820 kWh	$50.40
Heat Pumps	$14,000	97,239 kWh	$2,893.00
Water Retrofits	$5,446	26,015 kWh	$7,514.89
Energy Recovery Ventilation	$19,326	-222 kWh	-
Total	**$151,642**	**336, 332 kWh**	**$12,257.26**

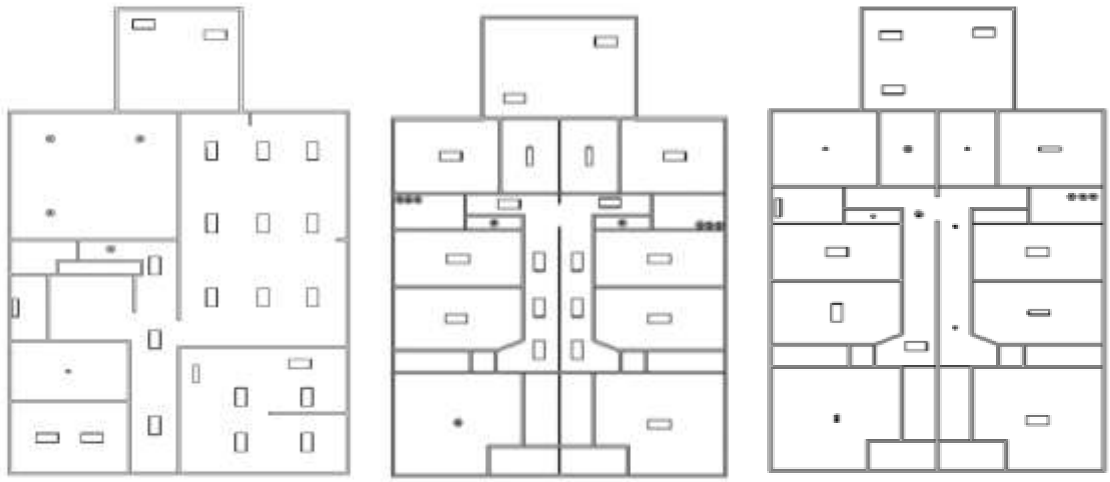
3 Technical Analysis 2: Lighting Retrofit

Building's existing lighting conditions were observed and the measured lux reading of each room were compared to the Illuminating Engineering Society of North America (IESNA) standard. Whichever lux reading yielding to lower wattage while maintaining the user's comfort was proposed as the replacement for current lightings.

3.1 Existing Conditions

The bedrooms in CRWC are composed of mostly CFL light bulbs with a few of halogen lights. All administrative offices are equipped with T8 or T12 fluorescent light tubes. Hallways and stairwells also have T8 fluorescent tubes. Similarly, offices on the second floor have a mix of incandescent light bulbs and T8 fluorescent light tubes. There are also five LEDs in the facilities. The dining room contains the most T8 fluorescent light tubes (18). **Exhibit 3-1** shows a reflected ceiling plan of building 43/45 of the facility. A rendering of the dining facility and reflected ceiling plan is included in **Section 7.5**

Exhibit 3-1: Building 43/45 Reflecting ceiling plan (Basement, 1st Floor, and 2nd Floor, respectively)



As part of the energy audit, NLS evaluated the lighting quality of each room by taking lux readings. **Exhibit 3-2** lists the rooms where the lighting levels did not meet the IESNA recommendations.

Exhibit 3-2: CRWC rooms that do not meet IESNA light quality recommendations

Room	Average Current Light Level (lux)	Recommended Light Level Range (lux) [6]
Activity Room 1	165	300-500
Activity Room 2	68	300-500
Office 4502 1st floor	233	300-500
Office 4503 1st floor	143	300-500
Office 4302 1st floor	152	300-500
Office 4303 1st floor	244	300-500
Office 4502 2nd floor	204	300-500
Office 4503 2nd floor	171	300-500
Office 4302 2nd floor	226	300-500
Bedrooms 41-3, 41A-3, 49-3, 49A-3	57	200-300
Bedrooms 39-3, 39A-3, 47-3, 47A-3	160	200-300
TV Room	81	100-300
Bedrooms 41-2, 41A-2, 49-2, 49A-2	33	200-300

3.2 Evaluation of Lighting Retrofit Options

Four measures are detailed to provide building occupants with better lighting quality and reduce energy requirements to achieve NZE.

3.2.1 Option 1: LED Replacement

NLS recommends replacement of fluorescent T8/T12 light fixtures, incandescent bulbs, and CFL fixtures with LED light fixtures. LED lights have a longer life span, higher efficiency, and lower wattage intake to produce equivalent lighting magnitude.

Replacement of LEDs for the facility can be derived by matching lux readings to the lumen standards defined by IESNA [6] or matching existing lux readings and choosing the highest LED wattage needed in both cases [7]. Considering both methods, NLS recommends 13W CFL, 60W incandescent and 28W Halogen lights to be replaced with 11W LED, 32W and 40W Fluorescent T8 and T12 replaced with 13W and 16W LED bulbs respectively [8].

3.2.2 Option 2: Occupancy Sensors and Dimmer Switches

NLS also recommends the installment of occupancy sensors and vacancy sensors to ensure that lights are only used when rooms are occupied. An occupancy sensor will automatically turn on the light if a person is detected in the room while a vacancy sensor requires the user to manually turn them on when needed [9]. Areas which would benefit from these sensors would be the offices which are only occupied during the weekdays as well as washrooms. Other locations include hallways and stairwells that need illumination at all times and can be equipped with occupancy sensors which have bi-level controls that turn a light down to 50% when it senses vacancy [10].

In addition, NLS recommends user-controlled dimmer switches to be installed in bedrooms where lighting comfort can be controlled by residents. This provide more control over lighting comfort, save energy, and increase longevity of the bulbs [11].

3.2.3 Option 3: Smart-Controlled LED Lights

NLS recommends implementing a smart-controlled lighting system, which allows lights to be controlled from anywhere with the use of a smart phone. Currently, the buildings don't have a central control panel for lights and a smart-controlled system will allow occupants to turn on/off the lights in their rooms using an app on their phone. This will increase accessibility and reduce energy consumption. When replacing the light bulbs as recommended above, smartphone-controlled LED lights can be placed in the desired rooms. The building manager can set up a central control system on their own phone and occupants/staff can have access to the lights in their own rooms/offices and have access to multiple rooms.

Exhibit 3-3: LED Smart Control app interface

Connected by TCP wireless, LED lighting kit is a good option for first-time users. The kit includes 3 LED bulbs, a control hub, and a remote for manual control. The system is very easy to install, and the app is free to download. **Exhibit 3-3** shows a display of the application required to control the LED lights.

3.2.4 Option 4: Task Lighting

Offices in the refugee centre contain desks which can use task lighting, but in most, use overhead area lighting from T8s. The fluorescent T8s draw 32 W of power, while the LED T8s draw 13 W. The lighting provided by these overhead lights is more than required to work from desks effectively, when window-lighting and task lighting (desk lamps) could provide sufficient luminance with less power. LED desk lamps have much lower wattage than the T8s. A VonHaus folding LED desk lamp, for instance, is an 8W lamp with the ability to be angled and swiveled to the desired angle. If room occupants choose to use desk lamps instead of (not in addition to) the overhead T8s when possible, office power usage could be significantly reduced [12].

3.3 Cost of Proposed Lighting Options

This section analyzes the financial and electricity benefits of the different recommendations. Electricity costs were assumed to be $0.20 / kWh. All costs were calculated in Canadian Dollars. For a full summary table comparing electricity savings and costs, see **Section 3.4**. These screening estimates include material and labour only; overhead costs and utility incentives are considered in **Section 5**.

3.3.1 Option 1: LED Replacement

NLS assumed that lights in bedrooms, offices and hallways will run 8 hours a day for entire year and lights in stairwell will run 24 hours. Based on these assumptions, total kWh, net savings, and payback period is calculated. After replacing current lights with LED, the net saving is 5659 kWh with the capital cost for replacing all lights being 3885 CAD. Thus, this yields to payback period of 3.4 years.

3.3.2 Option 2: Occupancy Sensors and Dimmer Switches

The evaluation of occupancy/vacancy sensors and dimmer switches were carried out based on the activity levels observed in all rooms within the facility. For example: all bedrooms were installed with dimmers (10% savings), hallway/stairwell, kitchen and dining areas fitted with bi-level occupancy sensors (40% savings), activity rooms with regular occupancy sensors (20% savings) and the rest had vacancy sensors (25% savings) [9] [10]. Assuming all rooms on average are being used 9 hours a day and 7 days a week, the new switches yield the annual electricity savings as 4,080 kWh/yr. The cost of a four-pack occupancy and vacancy sensor was taken as $15, dimmer switch as $6, and bi-level switch as $16 [13] [14]. Taking these costs into account results in a payback of 1.7 years for this option.

3.3.3 Option 3: Smart-Controlled LED Lights

To consider the addition of Smart-Controlled LED lights, the offices 4302 and 4502 with two 32W T8 tube lights providing 650 lumens of light were studied since these offices have insufficient light levels that don't meet IESNA standards. It is recommended that two 11W LED bulbs be installed in each office to improve lighting as each LED light emits 800 lumens. The offices are assumed to be occupied for 8 hours and 7 days per week. The starter kit costs $110, with $17 for every additional bulb purchased. With four bulbs total, one starter kit and one extra bulb should be purchased. Two new fixtures (average cost of $35) would also need to be purchased to install 2 bulbs inside each. This system if used to replace the T8 fluorescent bulbs in the offices will yield 245.3 kWh/yr in electricity savings with a payback of 4.1 years.

3.3.4 Option 4: Task Lighting

The addition of task lighting is a simple intervention based on a $64, 8W VonHaus folding LED desk lamp replacing the use of an 18W overhead LED T8. Further savings would result from comparing to a 32W fluorescent T8 in a total of 16 offices and 18 desks. With these assumptions, electricity savings of up to 3,363.84 kWh/yr can be expected with a payback of 1.7 years.

3.4 Proposed Lighting Improvements and Contribution to Net Zero

A summary of the lighting improvements is presented in **Exhibit 3-4**.

Exhibit 3-4: Summary of capital cost and payback for lighting improvements

Option	Capital Cost ($)	Simple Payback Period (years)	Electricity savings (kWh/yr)	% Electricity Savings/yr
1: LED retrofit	3885	3.4	5659	20.7
2: Occupancy sensors and Dimmer Switches	1346	2.0	4,080	14.9
3: Smart-Controlled LED Lights	200	4.1	245	0.9
4: Task Lighting	1152	1.7	3,364	12.3
TOTAL	**6583**	**11.2**	**13,348**	**48.8**

NLS recommends proceeding with LED replacement of incandescent, halogen, T8, T12 fluorescent and CFL lights, implementation of occupancy sensors and dimmer switches, smart-controlled LED lights in offices, and task lighting because of their major reductions in energy consumption and payback period of about 11 years. These improvements lead to savings of just under 50% of lighting energy which contributes to the building's goal of NZE. A detailed estimate and financing plan will be developed in **Section 5** to assess the true payback period.

4 Technical Analysis 3: Solar Energy System

NLS has designed a PV system to supply electricity and hot water to CRWC. Solar has been designed as the primary, but not exclusive, energy source for the building.

The proposed system has a capacity of 43.5 kW from 138 solar PV panels, and 5.5 kW from 16 vacuum solar tube collectors. In optimal conditions it will produce 47.1 MWh of electricity per year. The solar tube collectors, on the other hand, will be able to generate 71.6 MWh of thermal energy every year, providing hot water to the residents all year round.

4.1 Location Selection

Locations considered for the installation of solar panels include the roof, surrounding grounds, and building façade. Due to CRWC's small plot area, electricity production from solar photovoltaic must either be in the forms of building-integrated or building applied photovoltaics. Solar panels can be attached to both roof and walls of a building. For CRWC, we recommend a roof PV system due to the larger complexity and cost of placing solar panels on the facade. Moreover, large parts of CRWC's south-facing façade is shadowed during the day, and east and west facades would only have sunlight for half the day. Thus, the facade panels cannot be justified.

Due to a small roof area compared to the electricity consumption of the buildings, as much area as possible has been used for electricity production. Solar panels will be placed on the roofs of all three buildings. Solar tube collectors, due to their heavy weights and higher point loads, will be placed on the pre-fabricated parking lot cover behind the three main buildings. **Exhibit 4-1** and **Exhibit 4-2** showcase the roof conditions and the location of CRWC.

Exhibit 4-1: Roof Parapet

Exhibit 4-2: CRWC, adjacent building [15]

4.1.1 Panel Selection

A solar panel was selected based on a comparison of five top-rated panels. A decision matrix was used to compare the panels through factors described in **Exhibit 4-3**. The evaluation of the different panel options based on the factors can be found in **Section 7.3**.

Exhibit 4-3: Panel Evaluation Factors [16]

Factor	Justification
Weight (kg/Watt)	A lighter panel is preferred.
Temperature Coefficient Rating	A lower coefficient is preferred.
Efficiency	A higher efficiency is preferred.
Durability (warranty)	Longer warranty is preferred.
Cost ($/Watt)	Lower cost is preferred.
Type: Monocrystalline vs. Polycrystalline	Monocrystalline is preferred due to higher efficiency and better performance [17].

Ultimately, the team chose to recommend the JA Solar JAP6-72/315 due to its low cost, high efficiency and a longer warranty period, meaning CRWC can easily replace and service the panel system without incurring additional costs.

4.1.2 Inverter Selection and Batteries

The team chose an inverter based on an in-depth analysis of available technologies on the market, considering type, efficiency, cost, warranty, and operating temperature range. NLS is recommending the use of the Enphase IQ 6+. Because the roof will experience frequent shading, a micro-inverter system will be optimal in preventing overall drops in voltage across the system, with each panel working independently and keeping the power output consistent. Furthermore, the micro-inverters will not be exposed to high heat loads or temperatures compared to a central string inverter, meaning they will last longer.

The Enphase IQ 6+ was chosen for its history of strong performance and educational opportunity as the Enphase IQ 6+ connects through broadband to the Enphase Enlighten™, a web-based monitoring and management device that can be used to showcase current and historical system performance trends.

Currently, the team does not recommend installing energy storage for CRWC. Ontario's net metering program allows CRWC to sell the electricity generated on site back to grid, hence achieving energy neutrality. Battery banks would greatly increase the capital cost of the solar system, which is not ideal for CRWC as they rely on government funding and donations.

4.1.3 Solar Tube Water Heating

To maximize energy generated on site, the team proposes to install solar water heating system over the parking lot. The designed platform is 31 m x 6.5 m, and 2.5m tall, with structural supports every 5.8 meters apart for two cars to park in between. Oversized vehicles can park beside the platform.

The team recommends purchasing Solar Hot Water Retrofit Kit from Northern Lights Solar Solutions (no relation to NLS). This retrofit kit provides all necessary components needed for a solar heating system, with prominent features like fast installation and safety precautions. The proposed system will work in extreme temperature condition as low as -40°C, suitable for winter in Toronto. A model of the system can be found in **Exhibit 4-6** under **Section 4.2.1**.

Based on historical data, tubes inclined at 43.6 degrees will receive the most solar irradiance per year, at roughly 1455 kWh/m^2. Factoring in the absorption rate of 94%, an efficiency of 73.4%, and 50% shading from November to February, the tube collectors can generate up to 71,626 kWh energy per year, enough to heat 66,518 litres of water from 5 degrees to 45 degrees, and averaging at 182 liters per day. s

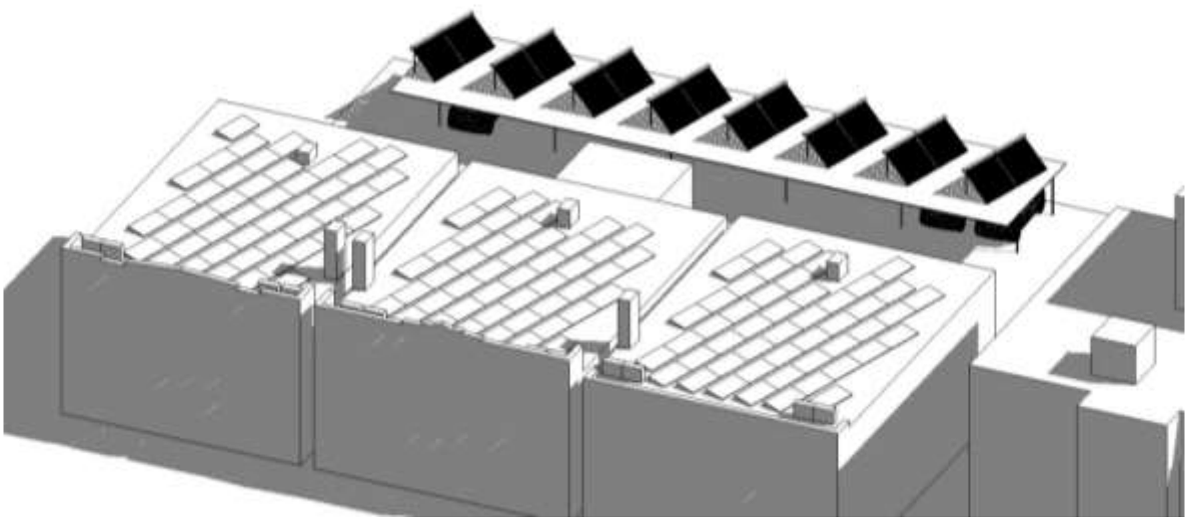
4.2 Shading Study and Racking System

The section below details the shading study and design of the racking systems.

4.2.1 Shading Study - Solar Panels

To conduct a shading study, as shown in **Exhibit 4-4**, the team utilized Autodesk Revit to render the Centre and surrounding buildings. In the study, we found that the adjacent 5-storey building and the parapets on the roofs cause most of the shading.

Exhibit 4-4: Revit solar shading analysis set up for March 31,2018



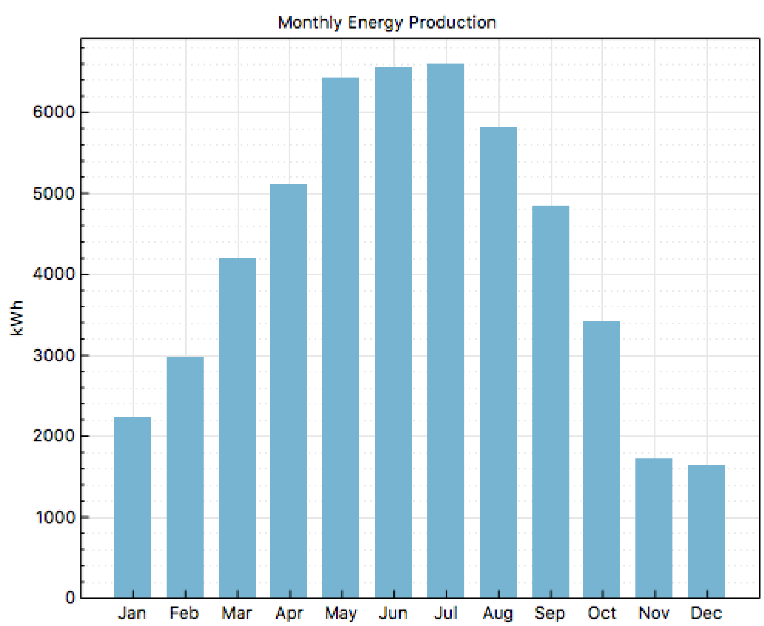
Depending on the time of the year, the number of unshaded solar panels differ. **Exhibit 4-5** shows the energy production for different seasons based on the percent unshaded solar panels. Electricity production calculation has taken panel efficiency and inverter efficiency into account.

Exhibit 4-5: Parapet shading study

Season	% Effective With Parapet	% Effective Without Parapet	Electricity Production With Parapet per year	Electricity Production Without Parapet per year
Winter 21 Dec – 20 Mar	70	71.2	6554.6 kWh	6667 kWh
Spring 20 Mar – 21 Jun	94	97.4	16956 kWh	17569.2 kWh
Summer 21 Jun – 22 Sep	93.8	97.4	16159.2 kWh	16779.4 kWh
Fall 22 Sep – 21 Dec	85.8	89.7	5770 kWh	6032.6 kWh
		Summary	**45.44 MWh**	**47.05 MWh**

Exhibit 4-6: Electricity Production Based on SAM (System Advisor Model) Calculations

Metric	Value
Annual energy (year 1)	51,355 kWh
Capacity factor (year 1)	13.5%
Energy yield (year 1)	1,181 kWh/kW
Performance ratio (year 1)	0.84



NLS recommends installing PV arrays facing true south on all three roofs, with a tilt of 10 degrees. Arrays are to be spaced 1.4 meters apart (front to front) to avoid mutual shading to achieve maximum energy production. The inclination of solar panels, was determined to be 10 degrees as a fixed inclination angle of 36.2 degrees, while producing the most energy 54,630 kWh) would require complex racking described in detail in **Section 4.2.3**. Moreover, the Ontario Building Code requires that rooftop solar energy systems are set back 1.2 metres from the edge of the roof.

With the required setback, even at a 20-degree tilt, the roofs can fit only 92 panels. Thus, it was determined that a 10-degree tilt with 138 panels balances angle and quantity of panels to achieve maximum energy performance. The placing of the solar panels, pursuant to the required edge setback, is shown in **Exhibit 4-4**.

4.2.2 Shading Study - Solar Tubes Heating

CRWC has a 40m x 10m parking lot behind its three buildings. The raised platform allows tube collectors to be spaced 4 meters apart, more than adequate to ensure no mutual shading most time of the year. Based on Revit analysis, the team calculated energy generation based on 50% shading from November to February, and no shading for the rest of the year to be 71,626 kWh, for a 5472 W system.

4.2.3 Racking System

The PV array must be attached to the roof using a racking system that is secure in all weather conditions. Additionally, it must be light weight to ensure the structural integrity of the roof. Two racking systems, mechanically attached and ballasted, are compared below.

A comparison table has been made to evaluate the systems.

Exhibit 4-7: Racking Comparison Table

Factor	Mechanically Attached	Ballasted
Weight	Lighter and more evenly distributed	Heavy weights required for extreme weather in Toronto
Installation	Roof needs to be penetrated for installation	Quick, simple installation
Wind Loads	Withstands more loads	Higher wind speed requires heavier weights
Tilt Angle	Typically fixed at 5, 10, 15 and 20	Typically fixed at 5, 10, 15 and 20
Cost	More	Less

The tilt angle for the solar panel, as mentioned before, is determined to be 10 degrees, which is suited for both racking methods. Cost is a significant factor in this project. Ballasted racking not only has a lower material cost, the installation process requires less labour and time than mechanically attached system, resulting in a lower initial cost and better payback period. Furthermore, the three buildings that belong to CRWC all have flat roofs, making them ideal candidates for a ballasted racking system.

The major concern of ballasted mounting is weight and weight distribution. For CRWC, the team recommends AeroRack 2.0 by KB racking: a non-penetrating, low weight system that can withstand wind speed up to 290 km/h (180mph). Toronto's recent record maximum wind gust speed, caused by Hurricane Hazel in 1954, is 160 km/h. Therefore, AeroRack is a viable, safe racking solution for CRWC. A structural analysis is done in **Section 4.2.4**to demonstrate that the roof is sufficient to support the weight of proposed PV system without additional reinforcement.

4.2.4 Structural Assessment

The team has conducted preliminary consideration of the structural integrity of the roof for the installation of the PV array summarized in **Exhibit 4-8**. The three buildings have small differences in heights. The middle building is approximately 20 cm lower than the south and north building and the three roofs all have small inclines towards their north and south sides. All roofs are made of tar and gravel. The designed solar system weighs 4.2 pounds per square foot. CRWC's roof can support an average distributed weight pf 7 psf, given the design a safety factor of 1.67.

Exhibit 4-8: Racking Comparison Table

Concern	Restriction	With designed solar system
Max point load	50 lb_m per roof connection	Ballasted racking system, thus no roof connections
Average distributed weight	7 psf	4.2 psf

4.3 Three Line Diagram

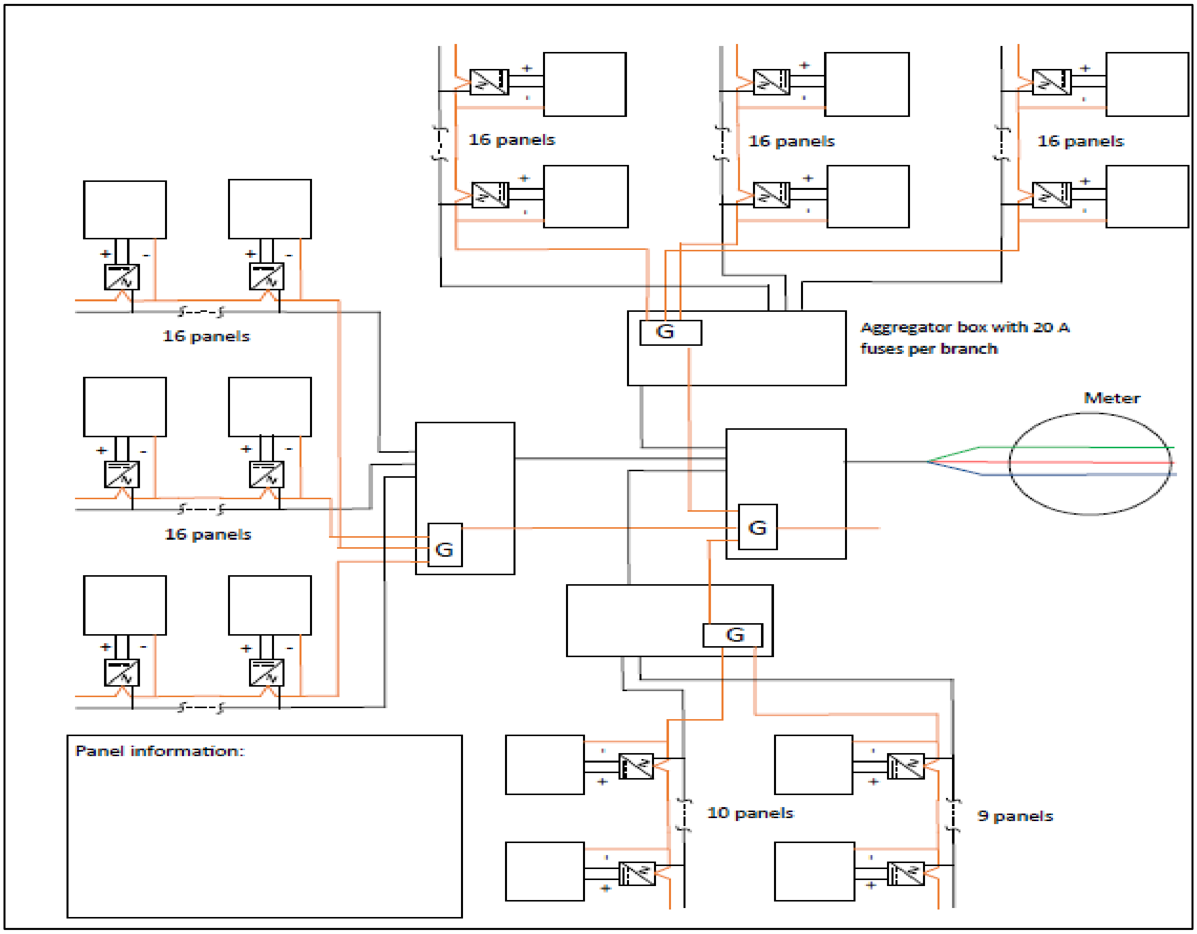
Exhibit 4-9 is an electrical schematic for the proposed solar PV system.

The following is a point by point description of the electrical schematic and its components. A battery and connection to the building's electrical system is not included due to the systems complete connection to the grid.

The system consists of the following components:

- 115 JA
- Micro-inverter
- AC disconnect
- Meter

Exhibit 4-9: Three Line Diagram of Proposed Solar Energy System



4.4 Cost of Proposed Solar Energy System

4.4.1 Cost and Return on Investment:

Exhibit 4-10 demonstrates the cash flows for the PV array over a 20-year period, which reflects the service life of the system.

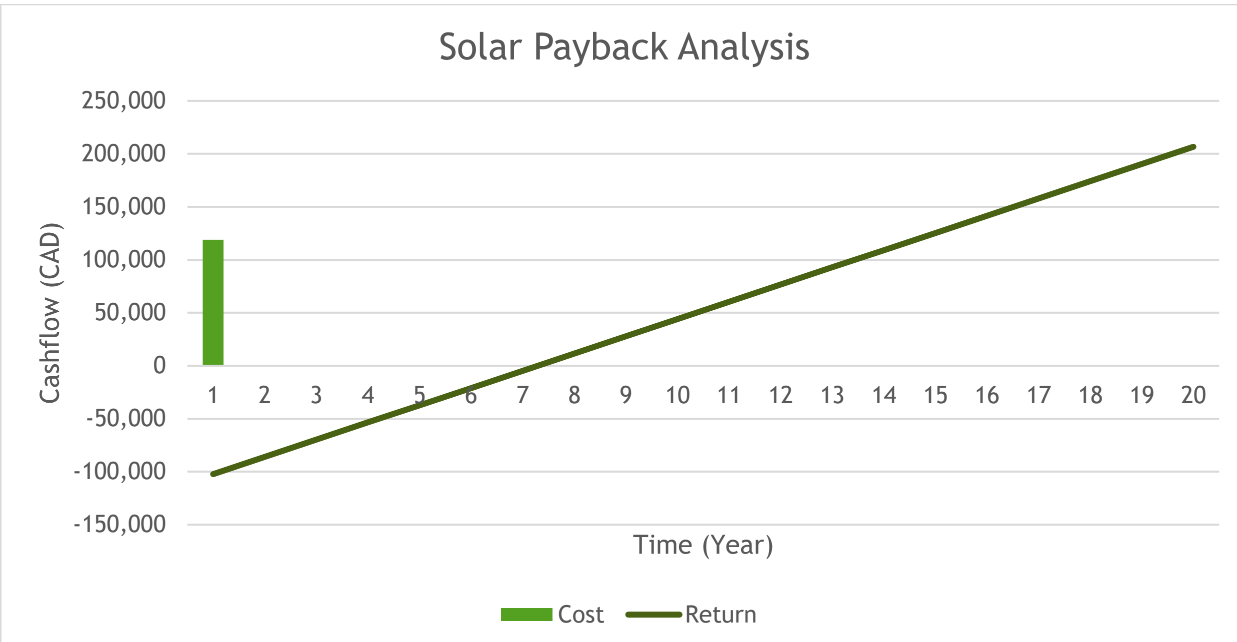
Exhibit 4-10: Costs of Solar Energy System Components

Costs		
Capital Costs	Cost (CAD)	Warranty
Panels	45,775	10 years
Racking	9,615	10 years
Inverter	26,237	25 years
Installation/Labor	11,000	
Solar Tube Collector	53,578	10 years
Electrical Connection	2,500	-
Government Permit and Safety Inspection	2,548	-
Prefabricated Parking Cover	15,000	10 years

Costs		
Recurring Costs	Cost (CAD)	Reoccurrence period
Snow Removal	400	1 year
Total	**400/year**	

CRWC is able to generate 118,676 kWh of energy per year from solar tubes and solar panels. With energy price of $0.20/kWh, the yearly revenue from solar energy is $23,735. As demonstrated in **Exhibit 4-11**, the payback period is approximately 7 years.

Exhibit 4-11: Solar payback analysis



4.5 Solar at CRWC

4.5.1 Education on Solar Energy

CRWC offers children's education program to its residents, which presents a great opportunity for children to learn more about how solar panels work and their environmental advantages. Solar energy education may be particularly a unique insight into Canadian society for refugee children, encouraging them to make environmentally conscious decisions in their future.

4.5.2 Net Zero

Although the proposed PV system is optimal, net zero can be challenging to achieve in the current context. First, CRWC is located in downtown Toronto which limits open space and requiring that solar panels only be installed on the roof. These solar panels would not be able to power all three buildings for all hours of the day. Second, CRWC has a peak capacity of 75 residents, not counting staff. To ensure constant heating, appliance usage and hot water for all residents, it would not be feasible to rely solely on solar energy for the buildings' energy consumption.

In order to achieve 100% net zero, the team recommends that CRWC invests in offsite renewable energy. This can be done through Canadian energy retailer Bullfrog Power. For every kWh CRWC draws from the grid, the retailer would generate 1 kWh electricity from a renewable source on CRWC's behalf. If all retrofits are implemented, CRWC would still require 56 MWh energy from the grid every year. For $115 per month, CRWC could establish a partnership with Bullfrog Power to further reduce their carbon footprint and become net zero.

For even further improvements, CRWC could consider purchasing more solar tube collectors. However, the team does not recommend doing so immediately. Purchasing more solar collectors not only increase the project's initial cost, the installed tubes will not be as effective as the existing ones due to more shading from the three buildings. To offset the 56 MWh energy the building requires from the grid, 16 (2 rows) more solar tube collectors need to be purchased and installed. Factoring in the labour cost and modification to the prefabricated structure, the total cost of such proposal would add up to $61,578.

5 Schematic Estimate, Schedule, and Finance Plan

5.1.1 Cost Estimate

The project total is approximately $527,525, and $2560 annually thereafter. A detailed cost estimate for all retrofits can be found in **Exhibit 5-1**. The data used for analyzing cost was derived from equipment manufacturers and industry partners such as Black & McDonald, as well as data from Statistics Canada [18]. The water conservation is the most cost effective major retrofit, while the radiators have the shortest payback. The total project has a simple payback period of 6.22 yrs.

Exhibit 5-1: Cost breakdown of all retrofits

Item Description	Capital Cost ($)	Energy Savings (kWh)	Operating Cost ($)	Labour Cost ($)	Cost/ Benefit Ratio (saved kWh/$)	Simple Payback Period (yrs)
Insulation	85,000	219,873	0	85,000	1.29	2.97
Plexiglass	270	5,820	0	40	18.77	0.20
GSHP	14,000	97,239	0	12,000	3.74	1.03
Lighting	6,583	0	13,348	5,760	2.03	1.90
Solar	141,753	64,328	400	11,000	0.45	8.68
Green Energy Investment	0	86,800	2,160	0	2.01	2.01

Item Description	Capital Cost ($)	Energy Savings (kWh)	Operating Cost ($)	Labour Cost ($)	Cost/ Benefit Ratio (saved kWh/$)	Simple Payback Period (yrs)
Water conservation	5,446	26,015	0	3,580	2.88	2.88
HRV	8000	158	0	8,000	0.02	194
Radiators	27,600	12,000	0	1,382	0.41	0.41
Project Subtotal				$415,414	-	-
General Conditions					-	-
Insurance and Liability [3%]				12,462	-	-
Contingency [10%]				41,541	-	-
Design Fee [4%]				16,617	-	-
Overhead and Profit [10%]				41,541	-	-
Project Total				**527,575**	**0.83**	**6.22**

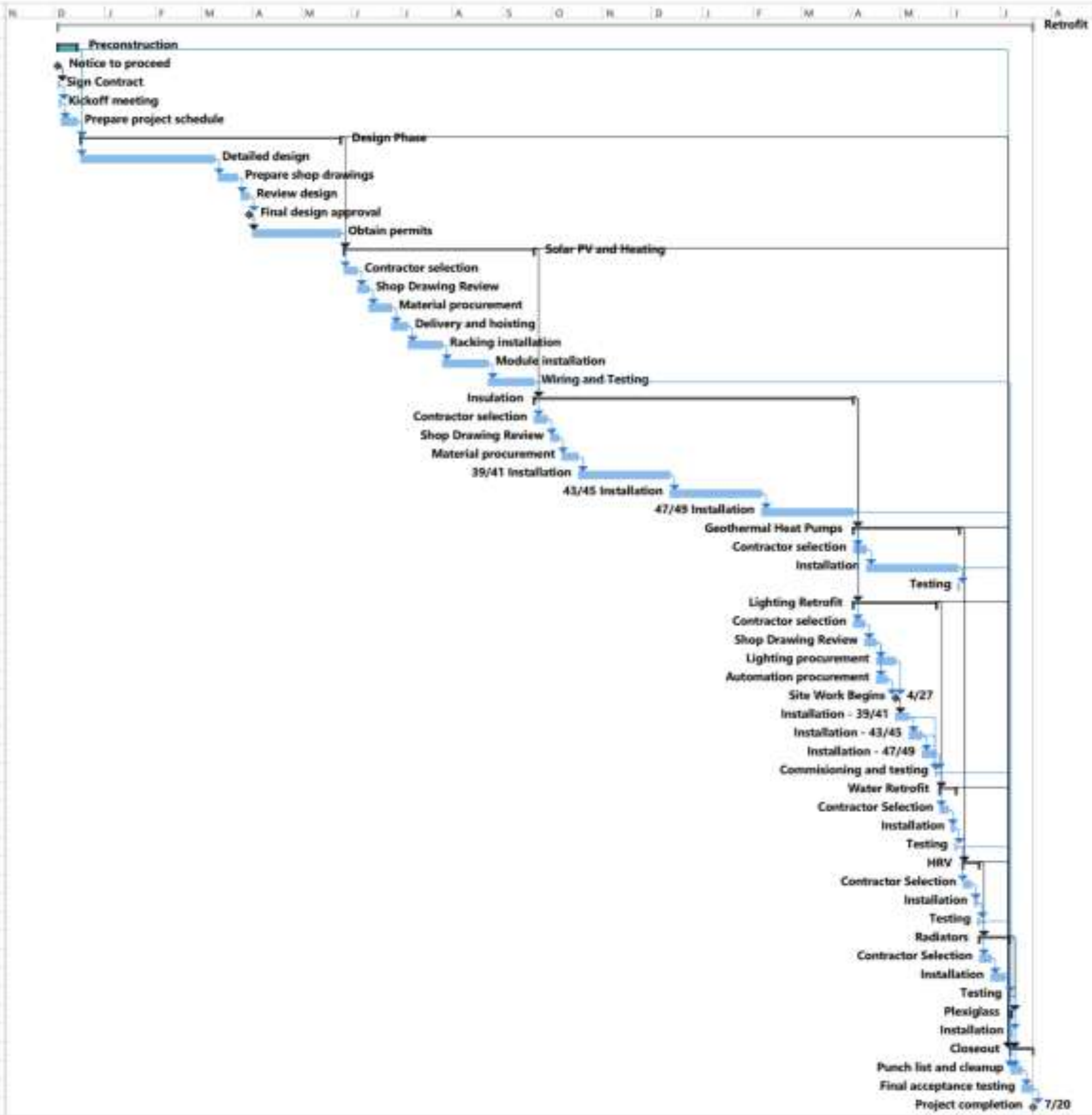
5.1.2 Schedule

The total project length is almost 400 days from design to completion, as seen in **Exhibit 5-2**. Projects are kept mostly separate to minimize disruption to each building. Solar is first installed, and then exterior insulation. Both require lots of materials and would be difficult to have two crews onsite working on both at once. The rest of the scheduled retrofits then occur one after the other, as the lighting retrofit is completed in parallel. Missing from the schedule is interior insulation. This is because it would run separately, being installed as residents move out of rooms. Residents stay at CRWC about 100 days, so they leave often enough for this to be completed in a reasonable amount of time.

One of the main priorities for project scheduling is minimizing disruption at CRWC. The high density of occupants who are dependent on services provided by the facility make it challenging and essential to stage the project, accomplished as noted above. The appropriate working hours would be during the day, when most residents are out, minimizing disruption of their movement throughout the site. Our estimate requires about 22,000 person-hours to complete.

Exhibit 5-2: Project Schedule

ID	Task Name	Duration	Start	Finish
0	**Retrofit**	**426 days**	**Mon 12/3/18**	**Mon 7/20/20**
1	**Preconstruction**	**10 days**	**Mon 12/3/18**	**Fri 12/14/18**
2	Notice to proceed	0 days	Mon 12/3/18	Mon 12/3/18
3	Sign Contract	1 day	Mon 12/3/18	Mon 12/3/18
4	Kickoff meeting	1 day	Tue 12/4/18	Tue 12/4/18
5	Prepare project schedule	8 days	Wed 12/5/18	Fri 12/14/18
6	**Design Phase**	**115 days**	**Mon 12/17/18**	**Fri 5/24/19**
7	Detailed design	3 mons	Mon 12/17/18	Fri 3/8/19
8	Prepare shop drawings	10 days	Mon 3/11/19	Fri 3/22/19
9	Review design	5 days	Mon 3/25/19	Fri 3/29/19
10	Final design approval	0 days	Fri 3/29/19	Fri 3/29/19
11	Obtain permits	2 mons	Mon 4/1/19	Fri 5/24/19
12	**Solar PV and Heating**	**84 days**	**Mon 5/27/19**	**Thu 9/19/19**
13	Contractor selection	6 days	Mon 5/27/19	Mon 6/3/19
14	Shop Drawing Review	5 days	Tue 6/4/19	Mon 6/10/19
15	Material procurement	10 days	Tue 6/11/19	Mon 6/24/19
16	Delivery and hoisting	8 days	Tue 6/25/19	Thu 7/4/19
17	Racking installation	15 days	Fri 7/5/19	Thu 7/25/19
18	Module installation	20 days	Fri 7/26/19	Thu 8/22/19
19	Wiring and Testing	20 days	Fri 8/23/19	Thu 9/19/19
20	**Insulation**	**139 days**	**Fri 9/20/19**	**Wed 4/1/20**
21	Contractor selection	6 days	Fri 9/20/19	Fri 9/27/19
22	Shop Drawing Review	5 days	Mon 9/30/19	Fri 10/4/19
23	Material procurement	8 days	Mon 10/7/19	Wed 10/16/19
24	39/41 Installation	2 mons	Thu 10/17/19	Wed 12/11/19
25	43/45 Installation	2 mons	Thu 12/12/19	Wed 2/5/20
26	47/49 Installation	2 mons	Thu 2/6/20	Wed 4/1/20
27	**Geothermal Heat Pumps**	**47 days**	**Thu 4/2/20**	**Fri 6/5/20**
28	Contractor selection	6 days	Thu 4/2/20	Thu 4/9/20
29	Installation	2 mons	Fri 4/10/20	Thu 6/4/20
30	Testing	1 day	Fri 6/5/20	Fri 6/5/20
31	**Lighting Retrofit**	**37 days**	**Thu 4/2/20**	**Fri 5/22/20**
32	Contractor selection	5 days	Thu 4/2/20	Wed 4/8/20
33	Shop Drawing Review	5 days	Thu 4/9/20	Wed 4/15/20
34	Lighting procurement	8 days	Thu 4/16/20	Mon 4/27/20
35	Automation procurement	5 days	Thu 4/16/20	Wed 4/22/20
36	Site Work Begins	0 days	Mon 4/27/20	Mon 4/27/20
37	Installation - 39/41	6 days	Tue 4/28/20	Tue 5/5/20
38	Installation - 43/45	6 days	Wed 5/6/20	Wed 5/13/20
39	Installation - 47/49	6 days	Thu 5/14/20	Thu 5/21/20
40	Commisioning and testing	1 day	Fri 5/22/20	Fri 5/22/20
41	**Water Retrofit**	**8 days**	**Mon 5/25/20**	**Wed 6/3/20**
42	Contractor Selection	5 days	Mon 5/25/20	Fri 5/29/20
43	Installation	2 days	Mon 6/1/20	Tue 6/2/20
44	Testing	1 day	Wed 6/3/20	Wed 6/3/20
45	**HRV**	**8 days**	**Mon 6/8/20**	**Wed 6/17/20**
46	Contractor Selection	5 days	Mon 6/8/20	Fri 6/12/20
47	Installation	2 days	Mon 6/15/20	Tue 6/16/20
48	Testing	1 day	Wed 6/17/20	Wed 6/17/20
49	**Radiators**	**13 days**	**Thu 6/18/20**	**Mon 7/6/20**
50	Contractor Selection	5 days	Thu 6/18/20	Wed 6/24/20
51	Installation	7 days	Thu 6/25/20	Fri 7/3/20
52	Testing	1 day	Mon 7/6/20	Mon 7/6/20
53	**Plexiglass**	**1 day**	**Tue 7/7/20**	**Tue 7/7/20**
54	Installation	1 day	Tue 7/7/20	Tue 7/7/20
55	**Closeout**	**10 days**	**Tue 7/7/20**	**Mon 7/20/20**
56	Punch list and cleanup	5 days	Tue 7/7/20	Mon 7/13/20
57	Final acceptance testing	5 days	Tue 7/14/20	Mon 7/20/20
58	Project completion	0 days	Mon 7/20/20	Mon 7/20/20



5.2 Funding and Incentives

Additional support for the project is available through programs to incentivise energy efficiency and green retrofits. A summary of all applicable retrofits is found in **Exhibit 5-3**. About $110,000 dollars could be available to help finance the project. This leaves $45,000 dollars in other material costs, and the cost of labour (about $200,000) still to finance for CRWC.

Exhibit 5-3: Total Available Incentives

Program	Value	Improvements
GreenON Insulation	$3,900	Exterior insulation and air sealing
GreenON GSHP	$20,000	Ground Source Heat Pump
Save on Energy: High Performance New Construction	$667	Lighting
Enbridge affordable housing	$1,600	HRV
Enbridge affordable housing	$62	Showerheads
Enbridge affordable housing	$82,462	Natural Gas improvements
Save on Energy retrofit program	$1,335	Total electricity improvements
OP Saver Toronto hydro	$333	Total electricity improvements
Total	$110,361	

5.2.1 Further Incentives

The City of Toronto's Home Energy Loan Program (HELP) offers up to $75,000 per building loan, with rates between 2% and 3.5% depending on the term. This makes CRWC eligible for $225,000 loan for a 10-year term with 2% interest, which would fund most of the rest of the project. Other incentives were also available through the above suppliers but required applications before being able to determine funding amounts. Further exploration of these incentives is recommended.

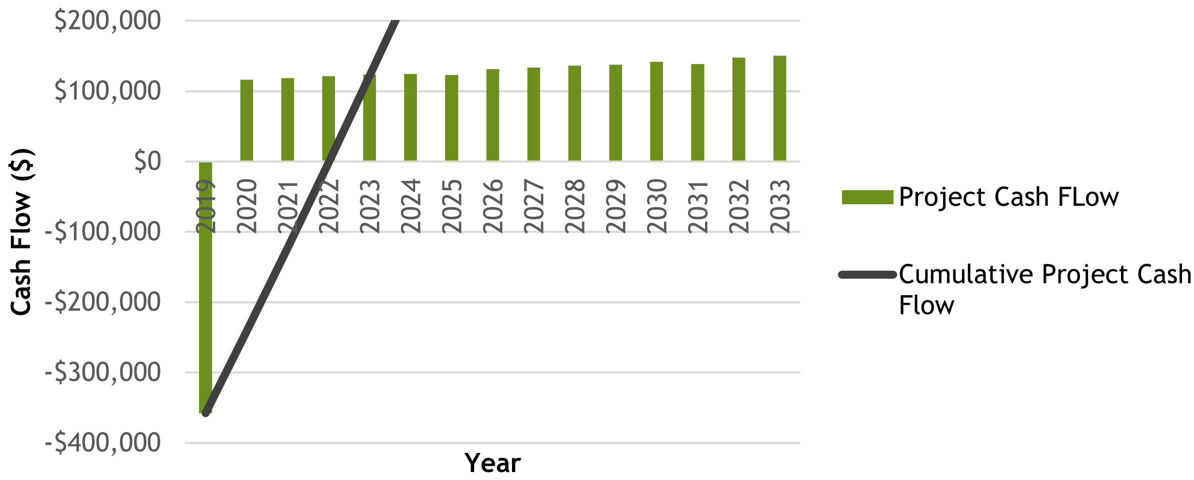
5.2.2 Other Funding Options

CRWC, as a not for profit, has a community of people willing to donate time and money. This would be a practical way to fund the retrofits, putting together a campaign to have contractors and community members donate materials, money, and man-hours towards completing the project. Funding a project through donation would likely mean lower quality work, and so marginally lower savings, and the schedule would be dependant on who was willing to donate time.

5.3 Cash Flow and Finance

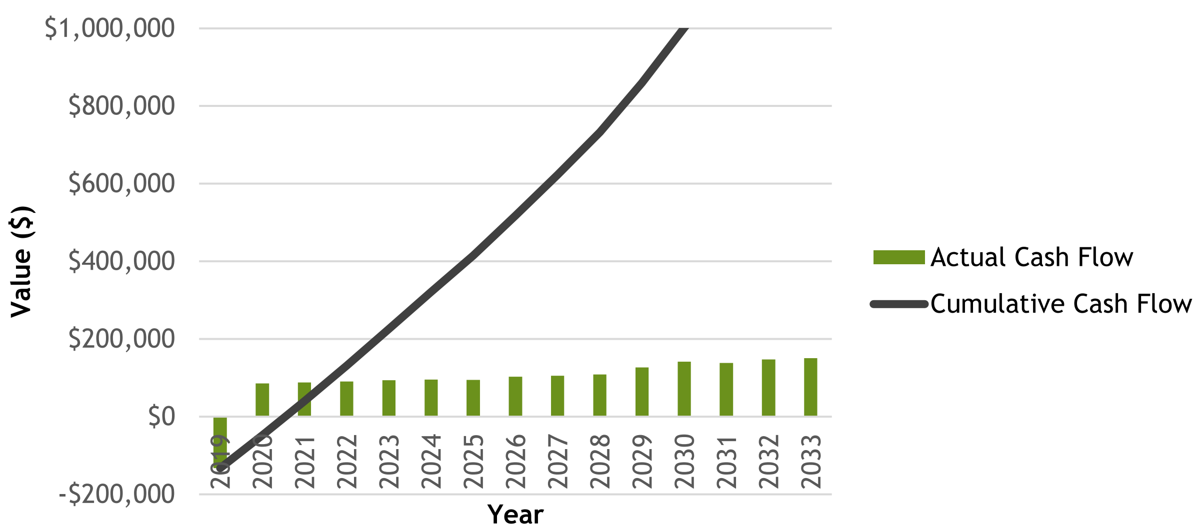
The project is expected to deliver energy savings of $116,000 annually. This offsets the annual cost of maintenance of $2560 and loan payback of $26,500. The project has a simple rate of return of 6.22 years before incentives. The cash flow without the loan (but including incentive grants) is seen in **Exhibit 5-4**. After the initial cost of $247,000, CRWC immediately begins to make money, breaking even in 2022.

Exhibit 5-4: Cash Flow Without Loan



With loan financing, seen in **Exhibit 5-5**, CRWC has an initial cost of $133,000, breaking even in 2020. With loan payments of $26,500 annually for the next year, the loan can be paid off in 10 years, finally experiencing the full $116,000 savings in 2029.

Exhibit 5-5: Cash flow with Loan Financing at 2% Interest



Annual average operations and maintenance costs for the project are $2,560, mostly stemming from the green energy investment. The majority of components are expected to have a lifetime of at least 20 years before requiring a replacement. Energy prices are expected to rise at a 2% inflation rate, and all figures are presented in nominal Canadian dollars.

The values here are likely an overestimation of actual savings, as real world performance of components such as insulation are hard to predict. However, even 80% reduction in savings would still be sufficient to keep costs positive. Furthermore, there would be a large difference between reported values here and practical implementation. Toronto Hydro's cost of 13¢/kWh peak electricity cost, and Enbridge's cost of about 9¢/m^3 for gas are very different from the 20¢/m^3 or kWh mandated by the report. With the actual values, the payback is approximately 17 years, and the cash flows are negative for the first 10 years of the project.

6 Outreach

Throughout this year and during the GEC project development, our team focused significantly on outreach activities to fulfill our mission of engaging with student communities and our GEC client to raise awareness of sustainable systems. Our outreach work is central to strengthening the quality of our team's work through learning opportunities that make more people value the purpose behind our work.

6.1 Energy Awareness and Community Outreach

This section outlines the variety of contributions that NLS had made to the U of T student community and to CRWC this year with outreach that raises awareness on the importance of sustainable designs. It also describes how we interacted with our local NECA/CECA Chapter to expand our team.

6.1.1 Volunteering at CRWC

Our outreach efforts had a significant positive impact on CRWC because it allowed our client to understand how our work contributes to their mission of serving the public. CRWC's core values revolve around demonstrating humanity through community-orientated work that helps new families with their first living experiences in Canada. We were enthusiastic about supporting this valuable work by volunteering in CRWC's children's programs to provide young kids with educational and social support to welcome them into a new culture. Also, we are passionate about inspiring their young minds to think about taking care of the natural environment that will sustain current and future generations. To achieve these goals, we collaborated with CRWC facilitators to volunteer in their three children's programs.

At CRWC's Children's Literacy Program, pictured in **Exhibit 6-1**, NLS hosted three workshops for a group of ten elementary school children. The first two workshops were colouring activities that challenged the children to think about electricity usage and the impact of generating this energy with renewable sources. Although the children were familiar with household appliances, they were not aware of how these appliances were powered by energy sources or of the harmful impacts of carbon dependency. It also taught them

Exhibit 6-1: NLS Volunteers with CRWC Facilitators at the Children's Literacy Program

about simple actions they can take to save energy, such as unplugging appliances when not in use. Along with this, our third workshop gave the children a chance to work in teams to figure out how to properly dispose of common household items. Many of them were surprised at how many items they could recycle to reduce landfill waste that endangers the environment. At the end of this program, we awarded each child with a sustainability certificate and candy for their participation and encouraged them to apply what they have learned to become powerful stewards of the environment.

Furthermore, our NLS volunteers joined CRWC's Children's Fitness and Children's Music Literacy Programs. Through more interactive activities, our team enjoyed seeing familiar faces and teaching the children to improve their communication skills and build strong friendships.

Overall, volunteering at CRWC has enabled us to demonstrate to our client the value of the work that our team is doing. Our proposal ultimately provides better living and working environments for the residents and the employees of CRWC to improve the organization's community service. It also gave us opportunities to give back to programs that help families to establish their lives in a new country. Finally, we hope to have motivated new Canadians to learn more about their connections to the environment and how net zero energy, among many other sustainable initiatives, will impact their futures.

6.1.2 NLS Blog

To improve awareness of our CECA U of T Chapter's work and to attract a larger audience, the team decided to revamp the club's website (cecauoft.wordpress.com), as illustrated in **Exhibit 6-2**.

Exhibit 6-2: NLS Blog homepage

The blog's first post gives a brief introduction to net zero energy consumption to explain how our designs are important to the building users. Also, it provides further readings on how people can take the initiative to achieve net zero energy consumption in their own houses. This led to the second part on our kickstart to the Green Energy Challenge with our energy audit at CRWC. We explained the relevance of some of our collected data on electricity usage, building enclosures, and mechanical systems to designing improvements for the buildings' performance.

The blog's second post gives brief updates on the focus of each sub team and their contributions so far to the final design proposal. Also, it provides readers with resources on doing energy flow analysis of buildings along with some insight into how the concepts we are applying are being used for sustainable building developments in industry.

The blog's third post centres on our volunteering efforts at CRWC. It outlines the three workshops we held at CRWC's Children's Literacy Program and the interactive games we played at the Children's Fitness Program. It reflects on the positive impacts we had on the children as they became more aware of their responsibility to care for the environment.

These blog posts were also shared through the CECA UofT Chapter Facebook page. Also, we have shared various posts on the CECA U of T Instagram page showing our team's progress through the design project and engaging our followers with sustainability initiatives. The blog posts and social media platforms have reached an audience of over 950 people.

6.1.3 University of Toronto Sustainability Conference

Every year, the University of Toronto Sustainable Engineers' Association holds a conference to bring experts from all areas of sustainability for a daylong event. Our team was invited to attend and engage with industry leaders as well as student leaders interested in the topic of sustainability. Pictured in **Exhibit 6-3**, NLS acquired a booth during the event for the tradeshow to talk about our previous projects, and to recruit new students on the team.

Exhibit 6-3: NLS at UofT's Sustainability Conference

6.1.4 Gemini House Tour

NLS had a big focus on student engagement at the University of Toronto and planned events to meet that goal. On November 2017, the team hosted its second annual tour of "Gemini House", a project led by University of Toronto and Ryerson University. The complex project included the retrofit of an 1880s masonry home which was turned into a low-energy residence. The tour of the house was led by Professor Kim Pressnail from the University of Toronto Civil Engineering Department (**Exhibit 6-5**). The tour gauged a large interest from students and was therefore, split into two 1.5-hour tours accommodating a total of 30 students.

Exhibit 6-5: Gemini House Tour

6.1.5 Sustainable Building Case Competition

A new initiative for this year, NLS wanted to further increase our presence at the University of Toronto by hosting a "Sustainable Building Case Competition" in Fall 2017. NLS developed a competition package providing data on electricity and natural gas consumption to ensure that solutions proposed would incorporate technical and holistic design elements.

The case competition itself included participation from three student teams as well as five judges pictured in **Exhibit 6-6**. Judges included Dejan Skoric and Wayne Chu, two representatives from the City of Toronto's Renewable Energy group; Greg Peniuk, IESO (Independent Energy System Operator) employee and NLS alumni; Professor Brenda McCabe, University of Toronto's Building Engineering Research Group; and Tom Vivian, a consultant at CECA.

Exhibit 6-6 Case Competition Participants

The competition also included a seminar event focused on energy economics, and savings in municipal buildings led by Dejan Skoric, Wayne Chu and Greg Peniuk. The competition was a great success and provided students with an opportunity to familiarize energy retrofit design and its local industry leaders. Most of the students who participated in the competition decided to join NLS in pursuit of this project.

6.2 Feedback Letters and Documentation of Volunteer Efforts

6.2.1 Feedback Letters

The feedback letter from our client, Sam Chaise, the Executive Director of the Christie Refugee Welcome Centre, is provided below. The letter highlights the impact of NLS' outreach to refugees at the facility and the energy retrofits proposed.

Christie Refugee Welcome Centre

43 Christie Street
Toronto, ON
M6G 3B1

tel: 416.588.9277
fax: 416.536.6329
general@christiestreetrc.com

April 27, 2018

Northern Lights Solutions - Green Energy Challenge 2018
University of Toronto CECA/NECA Student Chapter
Room GB 314, Galbraith Building
Department of Civil Engineering
University of Toronto
35 St. George Street, Toronto, ON M5S 1A4

Re: Christie Refugee Welcome Centre Energy Retrofit - Green Energy Challenge 2018

Dear NLS Team,

On behalf of the Christie Refugee Welcome Centre (CRWC), I would like to extend my gratitude for your volunteering with our community this spring, and your services to design an energy efficiency retrofit for our buildings. I am writing to thank you for choosing CRWC as your client for the Green Energy Challenge this year.

I have heard great reports from my staff about your involvement in our children's literacy, after-school fitness, and music literacy programs. I am impressed by your preparedness and enthusiasm shown for these programs. In the children's literacy program, I learned that you designed activities to teach the children about energy literacy, including colouring activities and a friendly waste sorting competition. I am happy that you received and incorporated feedback from our programs director on how to design activities which were well suited to the children's educational backgrounds. Thank you for your hard work and creative ideas to teach them about such an important topic.

Additionally I would like to thank you for your thoughtful proposal to retrofit our buildings to become net zero energy. Your hard work was evident as you collected data at your energy audit, and you have provided a very in-depth analysis of conservation measures which will help us reduce our energy footprint. We appreciate the effort you have made to correspond with our facility manager to understand the unique needs of our buildings, which were constructed nearly 100 years ago. I appreciate the fantastic job you have done to design a retrofit which will cut our energy consumption by more than 75%. Particularly, I am impressed by your design for occupancy sensors and dimmer switches, which will meet the lighting requirements for our buildings while reducing unnecessary energy consumption. The $225,000 in incentives, rebates, and low-interest loans that you have identified make this retrofit much more feasible for us. Your proposal shows a strong understanding of our need to avoid major disruptions to our operations, and for improvements which reduce our operating costs and provide resiliency to CRWC.

On behalf of myself and the Christie Refugee Welcome Centre, I provide my full support to your team's report for the Green Energy Challenge 2018. I wish you great success in the competition and thank you for volunteering your time in educating the community about the importance of energy conservation. I look forward to further considering the exciting proposal you have put forth.

With thanks,

Sam Chaise
Executive Director

A place of welcome, safety and support for refugees

6.3 Article in Department / University Newsletter

U of T's Department of Civil & Mineral Engineering provides our CECA/NECA Chapter with incredible support and recognition for our work that engages undergraduate students with global engineering challenges. The guidance and resources that the Department provides us with allows us to diversify our team to inspire more young engineers to get involved with innovative sustainable infrastructure projects. This year, our meaningful work for GEC was featured in the April 2018 Civil & Mineral Engineering newsletter, as shown in **Exhibit 6-7**.

Exhibit 6-7: U of T Civil & Mineral Engineering Department Newsletter Feature on NLS

U of T CECA/NECA Competes in the 2018 Green Energy Challenge

Aiming to best their third place honours received last year, the University of Toronto student chapter of the Canadian/National Electrical Contractors Association (CECA/NECA) is competing in the 2018 ELECTRI International/NECA Green Energy Challenge.

Leading up to the Green Energy Challenge, the team has hosted several events to spread awareness about sustainable buildings among U of T students.

"Our club has become smarter about the way we explain our work to others," said President Sneha Adhikari (CIV 1T8+PEY). "Throughout this school year, we have implemented activities to get people engaged in sustainability and make this competition more approachable, allowing our team to grow."

The U of T team leads include: Rashad Brugmann (CIV 1T9), Noah Cassidy (CIV 1T9), Dorothy Liu (CIV 2T0), Niloufar Ghaffari (CIV 1T9), Shambhavi Niraula (CIV 2T0), Nasteha Abdullahi (CIV 1T9), and Pavani Perera (CIV 1T9).

For this competition, the team is partnering with the Christie Refugee Welcome Centre (CRWC) in Toronto to design a net-zero energy retrofit for their buildings. CRWC is an emergency shelter that warmly welcomes about 300 refugees from around the world each year. This organization is driven by its mission to offer hope and dignity and allow each person they serve to thrive. U of T CECA/NECA is working to contribute to this mission by creating a proposal to both provide cost-saving improvements and to enhance the living experiences of new Canadians. Also, the team is volunteering at CRWC's children's programs to get younger generations engaged in becoming stewards of the environment.

The team has conducted an energy audit on site at CRWC. They are using this data (measuring electricity usage, building enclosures, and mechanical systems) in combination with insights from resident interviews to recommend and design improvements for the buildings' performance. Recently, several members joined CRWC's Children's Literacy Program to teach a group of eight children about energy saving, renewable energy, and waste reduction through interactive activities.

6.4 CECA/NECA Chapter Interaction

NLS has continued to extend our connection with the Canadian Electrical Contractors Association and their affiliated local contractors. In addition, NLS has sought out technical advice from Black & McDonald, assistance regarding cost estimates from Fitzpatrick Electric, and support for the geothermal analysis and proposed capture technologies design from SGS. Both the CECA Treasurer and Operations Manager met with NLS to discuss project specifics and direct us to members of industry. Our team has sent personal resumes to the CECA chapter, which they plan to share with electrical contractors across the country for prospective careers and internships. NLS also plans to present its work at the CECA Annual General Meeting in Toronto on June 19th, 2018. Finally, NLS continues to correspond with Dalhousie University's CECA/NECA Student Chapter, the only other Canadian student chapter, as they build their capacity and undertake projects.

7 Works Cited

[1] P. Torcellini, S. Pless, M. Deru and D. Crawley, "Zero Energy Buildings: A Critical Look at the Definition," in *ACEEE Summer Study*, Pacific Grove, California, 2006.

[2] Christie Refugee Welcome Centre, "About," 2018. [Online]. Available: https://christiestreetrc.com/about/. [Accessed 16 4 2018].

[3] Slant/Fin, "Ratings Chart - Gas boilers," 2007. [Online]. Available: http://www.slantfin.ca/docs/199.pdf. [Accessed 18 March 2018].

[4] W. Chan, W. Nazaroff, P. Price, M. Sohn and A. Gadgil, "Analyzing a database of residential air leakage in the United States," *Atmospheric Environment,* pp. 3445-3455, 2005.

[5] M. Alavy, *CIV380 Lecture: Ground Source Heat Pumps,* Toronto: University of Toronto, 2018.

[6] archtoolbox, "Recommended Lighting Levels in Buildings," [Online]. Available: https://www.archtoolbox.com/materials-systems/electrical/recommended-lighting-levels-in-buildings.html. [Accessed 28 April 2017].

[7] ArchToolbox, "Recommended Lighting Levels in Buildings," 2012. [Online]. Available: https://www.archtoolbox.com/materials-systems/electrical/recommended-lighting-levels-in-buildings.html. [Accessed 30 April 2018].

[8] Lamps Plus, "75W Equivalent Frosted 11W LED Dimmable Standard Base Bulb," 2018. [Online]. Available: https://www.lampsplus.com/products/75w-equivalent-frosted-11w-led-dimmable-standard-base-bulb__43w49.html. [Accessed 30 April 2018].

[9] Lutron, "Occupancy/Vacancy Sensors: Design and Application Guide," Lutron Electrics Co. Inc., 2014.

[10] K. Papamichael, T. Pistochini and J. Xu, "Bi-Level Switching in Office Spaces," California Lighting Technology Centre, 2010.

[11] U.S. Department of Energy, "How to Select Lighting Controls for Offices and Public Buildings," 2000.

[12] Amazon.com, "VonHaus Aluminum Folding LED Desk Lamp with USB Charger, 7 Level Dimmer, Touch Control & Timer -," [Online]. Available: https://www.amazon.ca/VonHaus-Aluminum-Folding-Charger-Control/dp/B01958W8ZM. [Accessed 18 April 2018].

[13] Amazon, "Sunco Lighting 4 Pack Vacancy & Occupancy Motion Sensor Wall Switch," Sunco Lighting, n.d.. [Online]. Available: https://www.amazon.com/Sunco-Lighting-Occupancy-Qualifed-Automatic/dp/B01M1C7K82/ref=pd_sim_60_4?_encoding=UTF8&pd_rd_i=B01M1C7K82&pd_rd_r=Z6YZYHT5T1WXJC3V9TVE&pd_rd_w=5zmYv&pd_rd_wg=usUX3&psc=1&refRID=Z6YZYHT5T1WXJC3V9TVE.

[14] Amazon, "Lutron Q-603P-IV 600W 3-way Qoto Dimmer and Switch," Lutron, [Online]. Available: https://www.amazon.com/Lutron-Q-603P-IV-3-Way-Dimmer-Switch/dp/B004EUJTMC/ref=sr_1_3?s=lamps-light&ie=UTF8&qid=1523227742&sr=1-3&keywords=dimmer%20switch.

[15] City of Toronto Community Planning, "Bathurst Quay Neighbourhood Plan," City of Toronto, 2017. [Online]. Available: http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=d7ea37130161a410VgnVCM10000071d60f89RCRD. [Accessed 15 04 2017].

[16] EnergyMatters, "Choosing The Best Solar Panel," [Online]. Available: http://www.energymatters.com.au/panels-modules/choosing-solar-panels/. [Accessed 15 March 2017].

[17] Solar Panels Exposed, "Types of Solar Panels – Discover the Pros and Cons of the Most Used PV Solar Panels," [Online]. Available: http://solarpanelsvenue.com/types-of-solar-panels-most-used-pv-solar-panels/. [Accessed 20 March 2017].

[18] Statistics Canada, "Table 327-0003 - Construction Union Wage Rates, monthly (dollars)," 18 04 2018. [Online]. Available: http://www5.statcan.gc.ca/cansim/a26?lang=eng&id=3270003. [Accessed 29 04 2018].

[19] CivicSolar, "Canadian Solar Quartech MaxPower CS6X-315P 315W Poly SLV/WHT 1000V Solar Panel," [Online]. Available: https://www.civicsolar.com/product/canadian-solar-quartech-maxpower-cs6x-315p-315w-poly-slvwht-1000v-solar-panel. [Accessed 20 March 2017].

[20] CivicSolar, "Canadian Solar CS6U-345M 345W Mono Quintech SLV/WHT Solar Panel 5BB," [Online]. Available: https://www.civicsolar.com/product/canadian-solar-cs6u-345m-345w-mono-quintech-slvwht-solar-panel-5bb. [Accessed 20 March 2017].

[21] Heliene Inc., "Heliene Photovoltaic Modules," 2012. [Online]. Available: https://cdn.enfsolar.com/Product/pdf/Crystalline/520199d5aa2fb.pdf. [Accessed 23 March 2017].

[22] GrapeSolar, "Panels," [Online]. Available: http://www.grapesolar.com/panels.html. [Accessed 24 March 2017].

[23] Hanwha Solar, "HSL 60 | Poly," 26 September 2013. [Online]. Available: http://hespv.ca/hesproductspecs/Hanwha/HanwhaHSL255.pdf. [Accessed 24 March 2017].

[24] R. Crist, "Connected by TCP Wireless LED Lighting Kit review," 7 March 2014. [Online]. Available: https://www.cnet.com/products/connected-by-tcp-led-lighting-control-system/review/. [Accessed 18 April 2018].

[25] Provident, Morrison Hershfield, Integral Group, "Zero Emissions Buildings Framework," The City of Toronto, Toronto, 2017.

Appendix

7.1 Acknowledgements

Northern Lights Solutions would like to thank the following individuals for their support and assistance throughout the project:

University of Toronto

- Brenda McCabe, Professor, Civil Engineering, Faculty Advisor to Student Chapter
- Marianne Touchie, Professor, Civil Engineering
- Jeffrey Siegel, Professor, Civil Engineering
- Kim Pressnail, Professor, Civil Engineering
- Ernesto Diaz Lozano Patino, M.A.Sc. Student, Civil Engineering

CECA & Industry Partners

- David Mason, President, CECA
- Gregg Whitty, Operations Manager, CECA
- Garry Fitzpatrick, Treasurer, CECA
- Robert O'Donnell, Executive Vice-President, Greater Toronto Electrical Contractors Association
- Douglas Randall, Black & McDonald (Sales and Business Development)
- Erica Brabon, Black & McDonald (Manager, Energy and Sustainability)
- Angelo Suntres, Black & McDonald (Chief Estimator ICI Mechanical)
- Masih Alavy, HGS Software and Consulting
- Kelsey Saunders, Sustainable.TO Architecture+Building

Christie Refugee Welcome Centre

- Sam Chaise, Executive Director
- John Neil, Facilities Manager
- Michelle Dekoning, Communications & Public Engagement Manager
- Alison Witt, Administrative Staff

7.2 Letter of Support from CECA

Canadian Electrical Contractors Association
Association canadienne des entrepreneurs électriciens

April 30, 2018

Northern Lights Solutions - Green Energy Challenge 2018
University of Toronto CECA/NECA Student Chapter
Room GB 314, Galbraith Building
Department of Civil & Mineral Engineering, University of Toronto
35 St. George Street, Toronto, ON M5S 1A4

Attention: Northern Lights Solutions Team

Re: ELECTRI Green Energy Challenge, Energy Retrofit of Christie Refugee Welcome Centre

Thank you for your recent meeting with my colleagues at the Canadian Electrical Contractors Association, Garry Fitzpatrick (Treasurer, CECA) and Gregg Whitty (Operations Manager, CECA). I learned that you are working on another exciting proposal for the 2018 Green Energy Challenge. Your client, the Christie Refugee Welcome Centre, is very deserving of this type of assistance to support the community services they provide for newcomers to Canada. Your proposal for a net-zero energy retrofit is timely, as there are many incentives to improve the sustainability and carbon footprint of our buildings in Ontario.

Your continued efforts as NECA's first international student chapter are nothing short of remarkable. The depth of this proposal and its numerous energy conservation measures far exceed what is required for the Green Energy Challenge. Particularly the upgrades to the envelope, mechanical system, and water conservation measures testify to your commitment to design the most efficient and livable building for your client. You have demonstrated impressive hard work and innovation in these retrofits to create a client-centred proposal. We are proud to be associated with a group of young people that are certain to be among the future leaders of our industry.

The outreach component of your proposal has also continued to strengthen CECA's local presence. NLS volunteering at the CRWC's Children's Programs in literacy, fitness, and others proved excellent opportunities to teach young newcomers to Canada about the importance of energy conservation. We were happy to follow your regular blog updates about these activities throughout the project. We look forward to seeing a summary presentation of your work at our Annual Board Meeting in June. Additionally, we are excited to connect several members of NLS with electrical contractors across the country by sending out a portfolio of their resumes.

On behalf of CECA we wish Northern Lights Solutions great success in the 2018 Electri Green Energy Challenge competition.

Yours truly,

David Mason
President - CECA

Dave Mason, President, Canadian Electrical Contractors Association
41 Maple Street, Uxbridge, Ontario L8P 1C8
Tel: 416-491-2414 Fax: 416-795-0009 www.ceca.org

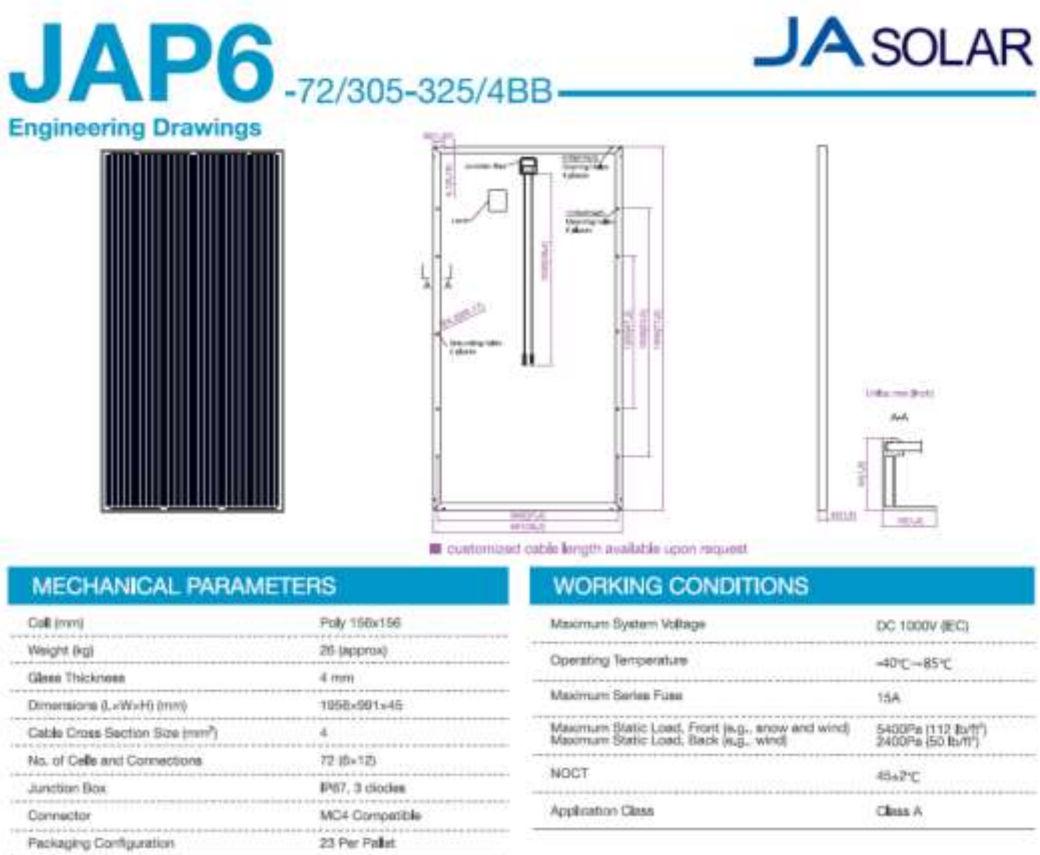
7.3 Solar Panel Decision Matrix

The following table compares different panel types to various categories. The numbers in the matrix above represented order of best to worst in each category. The category with the lowest score has outweighed all others.

Objective	Astronergy CHSM6612P-3 [19]	Canadian Solar CS6K-270P [20]	JA Solar–315W [21]	Solarland SLP190S-24 [22]	SolarWorld SWA 285 Plus Black Mono [23]
Cost/Watt	2	2	1	4	3
Efficiency	2	1	1	2	1
Warranty	3	2	1	3	1
Weight	2	2	3	2	2
Temperature	1	1	1	4	3
Type	2	2	2	1	1
Total	12	10	9	16	11

7.4 Panel and Inverter Specifications

The following are detailed specifications for the team's recommended panel and inverter.



JAP6 -72/305-325/4BB

JA SOLAR

Engineering Drawings

customized cable length available upon request

MECHANICAL PARAMETERS

Cell (mm)	Poly 156x156
Weight (kg)	26 (approx)
Glass Thickness	4 mm
Dimensions (L×W×H) (mm)	1956×991×45
Cable Cross Section Size (mm^2)	4
No. of Cells and Connections	72 (6×12)
Junction Box	IP67, 3 diodes
Connector	MC4 Compatible
Packaging Configuration	23 Per Pallet

WORKING CONDITIONS

Maximum System Voltage	DC 1000V (IEC)
Operating Temperature	-40℃~+85℃
Maximum Series Fuse	15A
Maximum Static Load, Front (e.g., snow and wind) Maximum Static Load, Back (e.g., wind)	5400Pa (112 lb/ft²) 2400Pa (50 lb/ft²)
NOCT	45±2℃
Application Class	Class A

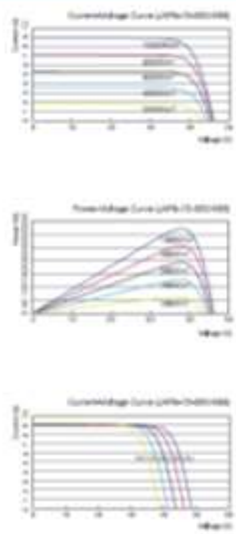
ELECTRICAL PARAMETERS

TYPE	JAP6-72-305/4BB	JAP6-72-310/4BB	JAP6-72-315/4BB	JAP6-72-320/4BB	JAP6-72-325/4BB
Rated Maximum Power at STC (W)	305	310	315	320	325
Open Circuit Voltage (Voc/V)	45,37	45,65	45,95	46,22	46,48
Maximum Power Voltage (Vmp/V)	36,88	36,99	37,19	37,38	37,49
Short Circuit Current (Isc/A)	8,81	8,89	8,98	9,06	9,14
Maximum Power Current (Imp/A)	8,27	8,38	8,47	8,56	8,67
Module Efficiency (%)	15,73	15,99	16,25	16,51	16,77
Power Tolerance (W)	-0~+5W				
Temperature Coefficient of Isc (αIsc)	+0,058%/℃				
Temperature Coefficient of Voc (βVoc)	-0,330%/℃				
Temperature Coefficient of Pmax (γPmp)	-0,410%/℃				
STC	Irradiance 1000W/m², Cell Temperature 25℃, Air Mass 1,5				

NOCT

TYPE	JAP6-72-305/4BB	JAP6-72-310/4BB	JAP6-72-315/4BB	JAP6-72-320/4BB	JAP6-72-325/4BB
Max Power (Pmax) [W]	221,43	225,06	228,69	232,32	235,95
Open Circuit Voltage (Voc) [V]	41,53	41,71	41,92	42,12	42,32
Max Power Voltage (Vmp) [V]	33,81	33,95	34,08	34,27	34,45
Short Circuit Current (Isc) [A]	6,95	7,01	7,06	7,12	7,18
Max Power Current (Imp) [A]	6,55	6,63	6,71	6,78	6,85
Condition	Under Normal Operating Cell Temperature, Irradiance of 800 W/m², spectrum AM 1.5, ambient temperature 20℃, wind speed 1 m/s				

I-V CURVE



Electrical data in this catalog do not refer to a single module and they are not part of the offer. They only serve for comparison among different module types.

Enphase IQ 6 and IQ 6+ Microinverters

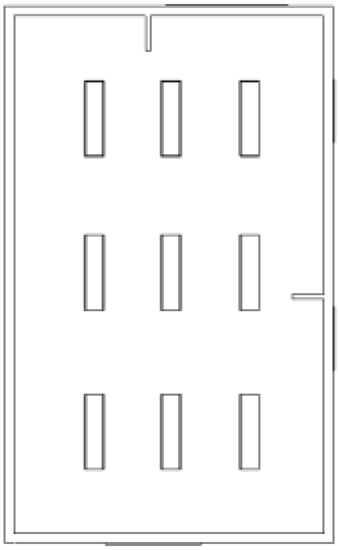
INPUT DATA (DC)	IQ6-60-2-US		IQ6PLUS-72-2-US	
Commonly used module pairings[1]	195 W - 330 W +		235 W - 400 W +	
Module compatibility	60-cell PV modules only		60-cell and 72-cell PV modules	
Maximum input DC voltage	48 V		62 V	
Peak power tracking voltage	27 V - 37 V		27 V - 45 V	
Operating range	16 V - 48 V		16 V - 62 V	
Min/Max start voltage	22 V / 48 V		22 V / 62 V	
Max DC short circuit current (module Isc)	15 A		15 A	
Overvoltage class DC port	II		II	
DC port backfeed under single fault	0 A		0 A	
PV array configuration	1 x 1 ungrounded array; No additional DC side protection required; AC side protection requires max 20A per branch circuit			
OUTPUT DATA (AC)	**IQ 6 Microinverter**		**IQ 6+ Microinverter**	
Peak output power	240 VA		290 VA	
Maximum continuous output power	230 VA		280 VA	
Nominal (L-L) voltage/range[2]	240 V / 211-264 V	208 V / 183-229 V	240 V / 211-264 V	208 V / 183-229 V
Maximum continuous output current	0.96 A	1.11 A	1.17 A	1.35 A
Nominal frequency	60 Hz		60 Hz	
Extended frequency range	47 - 68 Hz		47 - 68 Hz	
Power factor at rated power	1.0		1.0	
Maximum units per 20 A (L-L) branch circuit	16 (240 VAC) 14 (208 VAC)		13 (240 VAC) 11 (208 VAC)	
Overvoltage class AC port	III		III	
AC port backfeed under single fault	0 A		0 A	
Power factor (adjustable)	0.7 leading ... 0.7 lagging		0.7 leading ... 0.7 lagging	
EFFICIENCY	**@240 V**	**@208 V**	**@240 V**	**@208 V**
CEC weighted efficiency	97.0 %	97.0 %	97.0 %	97.0 %
MECHANICAL DATA				
Ambient temperature range	-40ºC to +65ºC			
Relative humidity range	4% to 100% (condensing)			
Connector type	MC4 locking type			
Dimensions (WxHxD)	219 mm x 191 mm x 37.9 mm (without bracket)			
Weight	1.29 kg (2.84 lbs)			
Cooling	Natural convection - No fans			
Approved for wet locations	Yes			
Pollution degree	PD3			
Enclosure	Class II double-insulated			
Environmental category / UV exposure rating	NEMA Type 6 / outdoor			
FEATURES				
Communication	Power line			
Monitoring	Enlighten Manager and MyEnlighten monitoring options Compatible with Enphase IQ Envoy			
Disconnecting means	The AC and DC connectors have been evaluated and approved by UL for use as the load-break disconnect required by NEC 690.			
Compliance	CA Rule 21 (UL 1741-SA) UL 62109-1, UL1741/IEEE1547, FCC Part 15 Class B, ICES-0003 Class B, CAN/CSA-C22.2 NO. 107.1-01 This product is UL Listed as PV Rapid Shut Down Equipment and conforms with NEC-2014 and NEC-2017 section 690.12 and C22.1-2015 Rule 64-218 Rapid Shutdown of PV Systems, for AC and DC conductors, when installed according manufacturer's instructions.			

1. No enforced DC/AC ratio. See the compatibility calculator at https://enphase.com/en-us/support/module-compatibility
2. Nominal voltage range can be extended beyond nominal if required by the utility.

To learn more about Enphase offerings, visit **enphase.com**

ENPHASE.

7.5 Rendering of dining facility at CRWC



7.6 Thermal image of building envelope