Net-zero energy implementation at Humber College J Building

CIVIL 352 ONB

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Abstract:

This report presents an evaluation of the feasibility of installing a solar PV system on Humber College's J building, which has remained relatively unchanged since its construction in the 1950s. Installing a solar PV system would be a significant step towards achieving the building's sustainability goals and the college's broader sustainability objectives. The proposed solar PV system has a rated capacity of 184,716 kWh annually with an efficiency rate of 42%, but actual energy production is estimated to be 161,700 kWh due to losses from shading and system inefficiencies. The total cost of installation, which includes panels, inverters, auxiliary costs, and labor charges, is estimated at $464,184.48. The system generates revenue by offsetting the cost of electricity, which is $55,414 annually for the J building. The solar PV system generates $20,374 in annual revenue, with an average monthly revenue of $1,697.85. Monthly energy production from the solar PV system peaks in June and July, with 23,687.6 kWh and 24,201.8 kWh generated, respectively. However, production declines in colder months, with only 2,154.8 kWh generated in December. The system experiences losses of approximately 28.4% due to shading and system inefficiencies.

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1.0 INTRODUCTION:

The following report outlines a comprehensive analysis of net-zero energy building for the Humber college J wing. Humber College is considered the most prominent educational institution, with a firm commitment to sustainability. With the successful implementation of net zero technology at the Humber college NX building, the J building would be a steppingstone for its continuous commitment to sustainability. The Humber J building is a two-story, 31,530-square-foot facility on Humber college's north campus. It relies on traditional sources of energy. According to Humber's "energy conservation demand management plan" in 2012, the total electricity cost for the entire college was 1.6 million dollars, which in 2014 experienced a sharp growth of 3.8 million dollars, an almost 140% increase. Humber college's north campus is comprised of 24 buildings, therefor on average one building consumed 160,000 thousand dollars worth of energy, making the need for sustainable buildings a priority.(Humber IEMP plan, 2017)

The project includes a detailed analysis of the proposed Net zero energy building project, the design and construction process, the implementation of energy-efficient technologies and systems, and the anticipated performance of the building after its completion. The project addresses the issues regarding energy consumption and greenhouse gas emissions. To achieve these objectives energy efficient technologies and systems, such as solar photovoltaic cells, geothermal energy, high-performance windows, wall sealings, wall insulations, efficient lighting, efficient HVAC system, and high-efficiency appliances will be used to optimize energy usage.

2.0 Background:

2.1 What is net zero energy building?

A building generates as much energy from renewable sources as it consumes over the span of one year. In other words, the energy consumption of the NZEB is zero. These goals are achieved through the combination of on-site energy generation and energy efficiency measures, such as solar panels, wind turbines, geothermal heating and cooling system, efficient lighting fixtures, and insulations. The goal of Net zero energy building is to reduce the impact of greenhouse gases emission on the environment. Net zero energy building is becoming popular to combat climate crises and meet energy efficiency standards.

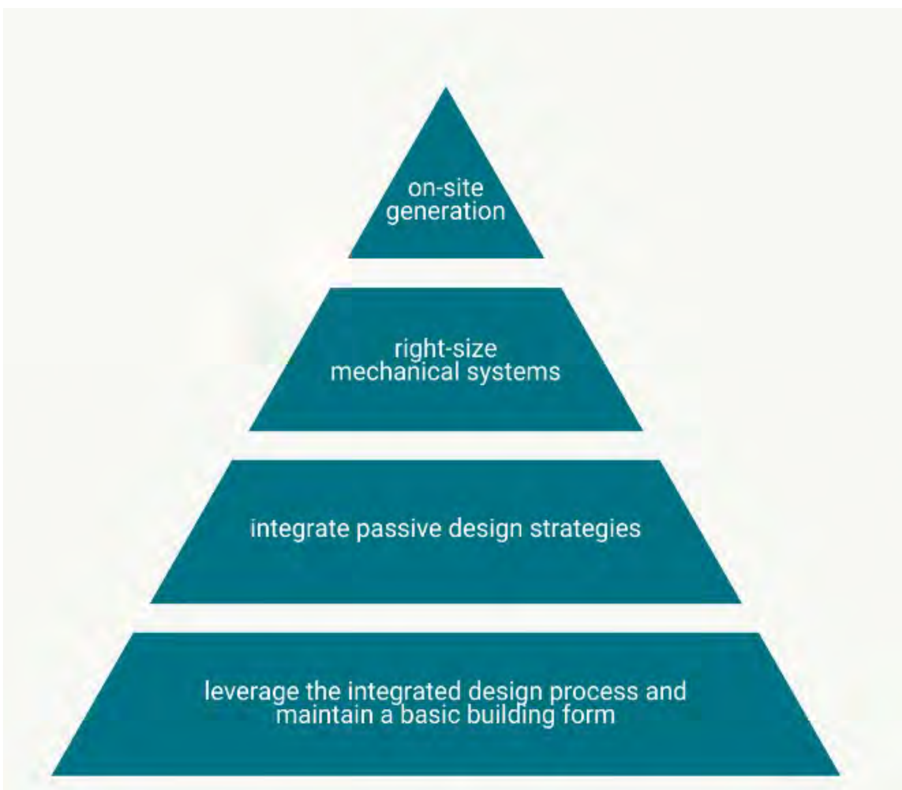


Figure 1: structure of net zero energy building

Canada is investing a lot of time and energy in reverting from its old traditional coal-fired electricity to a cleaner way of producing energy. In Canada, 80 percent of its electricity is produced by non-emitting sources like hydro, nuclear, wind, and solar. And by 2030 90 percent of its electricity will be produced by non-emitting sources, which will not only drive the clean energy sector but will create jobs.

According to the government of Canada's environmental and natural resources branch, in Canada, 12 percent of the national emission is produced by space and water heating and if electricity is added indirectly the share goes up to 17 percent, there for it is crucial to make buildings more energy efficient and use clean electricity.

2.2 Application of net zero energy concept to Humber college:

Humber College has made sustainability one of its core values and has incorporated it in all aspects of the institution, including it in both operation and curriculum. Humber college has developed 20- years integrated energy master plan (IEMP) to enhance further its sustainability, which aims to address any weak points in the colleges' sustainability efforts, such as building NX and making meaningful improvements.

2.3 College overview and outlook:

According to Humber's (IEMP) plan in 2014, the college spent 5.4 million dollars on utilities, of which 3.9 million dollars was for electricity and 1 million dollars for gas and water balance. The carbon footprint in 2014 was 8510 metric tons, which is equivalent to emissions from 2000 cars. the north campus is comprised of 49 buildings, which cover an area of 150,000 square meters. The building's age ranges from 1968 to 2014(Humber IEMP plan,2017).

In 2014 college educated 33,000 students and the number is expected to grow by 31 percent over the period covered by the IEMP plan (2014 – 2034). in which, the north campus is expected to grow by 29,400 students. To accommodate the growth another 90,000 square meters are expected to be added to the north campus.

2.4 Building’s energy use:

The college's 49 existing buildings are modelled using both generalized and individual models to estimate their energy use for heating, cooling, fans, pumps, lightning, interior equipment and service hot water in total cost, and energy use intensity (EUI). EUI is the energy use per floor area in kilowatt–hour per square meter (KWh/m2), which is a useful indicator of energy efficiency and facilitates benchmarking with other buildings and campuses (Humber IEMP plan,2017).

2.5 Collage framing goals:

In the IEMP plan challenging Goals were established for energy, water efficiency, greenhouse gas reduction, and economic returns. The following Goals were established, and the plan was made to meet these goals by 2034.

- Energy efficiency will increase by 50 percent.
- Water efficiency will increase by 50 percent.
- Carbon footprint will reduce by 30 percent.
- Investment returns will be at least 7 percent (Humber IEMP plan, 2017).

2.6 Utility Supply:

The college is supplied with electricity and natural gas from local distribution companies. The electricity is supplied from a medium grid operated by Toronto hydro electric system limited with the commodity procedure on the Ontario spot market.

Natural gas is supplied from the natural gas distribution network operated by Enbridge Gas Distribution, with the commodity contract being with Shell energy north America Inc. the pressure is at least 5 PSI/340 bar.

3.0 LITERATURE REVIEW:

Buildings are responsible for a significant amount of annual energy consumption and greenhouse gas emissions globally. Humber College's retrofitted NX building has achieved the Zero Carbon Building - Design Certification by the Canada Green Building Council, making it the first retrofit in Canada to achieve this certification. This literature review explores the importance of zero-carbon buildings and the significance of Humber College's achievement in retrofitting the NX building.

Zero-carbon buildings are highly energy-efficient and have the capability of offsetting annual carbon emissions using clean, renewable energy. Buildings are responsible for a significant amount of annual energy consumption and greenhouse gas emissions globally. Therefore, the construction of zero-carbon buildings is of great significance in reducing the carbon footprint of buildings and contributing positively to the fight against climate change. The energy-efficient design of zero-carbon buildings results in reduced energy consumption, lower greenhouse gas emissions, and cost savings on energy bills. Furthermore, zero-carbon buildings have been shown to improve the indoor air quality of buildings, resulting in healthier and more productive occupants.

Humber College's retrofitted NX building achieved the Zero Carbon Building - Design Certification by the Canada Green Building Council, making it the first retrofit in Canada to achieve this certification. The retrofit involved a complete envelope retrofit that is highly insulated and airtight, including new triple-pane windows. Additionally, energy-efficient upgrades were made to the lighting, heating, and cooling systems, and a new 25kW Solar PV system was installed. The retrofitted NX building uses 70% less energy than before, making it Humber College's most energy-efficient building and one of the most energy-efficient in North America. Humber College's achievement is significant as it demonstrates that Canada has the expertise and technology required for buildings to reach zero carbon and contribute positively to global climate change efforts.

The retrofit of Humber College's NX building was designed by B+H architects and constructed by BIRD Construction. The design of the retrofit involved careful integration across architectural design, energy modelling, envelope design, and mechanical and electrical design. This integration was guided by Humber's Integrated Energy Master Plan vision, which aimed to demonstrate to the Canadian design and construction industries how a deep energy retrofit can contribute positively to Canada's climate. The retrofit involved a complete envelope retrofit, including the installation of new triple-pane windows, and energy-efficient upgrades to the lighting, heating, and cooling systems. The installation of a new 25kW Solar PV system further reduced the building's carbon footprint.

In conclusion, Humber College's retrofitted NX building achievement of the Zero Carbon Building - Design Certification by the Canada Green Building Council is significant as it demonstrates the importance of zero-carbon buildings in reducing greenhouse gas emissions and contributing positively to the fight against climate change. The retrofit involved careful integration across architectural design, energy modelling, envelope design, and mechanical and electrical design. Humber College's achievement serves as an example to the Canadian design and construction industries of how deep energy retrofitting can contribute positively to Canada's climate. The installation of a new 25kW Solar PV system and energy-efficient upgrades to the lighting, heating, and cooling systems resulted in the retrofitted NX building using 70% less energy than before, making it Humber College's most energy-efficient building and one of the most energy-efficient in North America. (Construction line Network,2019)

4.0 Methodology:

The report analyzes the feasibility of the net-zero-energy building for the Humber college J building. The report explains the various steps taken to achieve the goal of a building that produces as much energy as it consumes, it also outlines the different technologies and techniques used in the building design. The Humber college J building was selected as an ideal site because the building is old and is in need to be retrofitted, as Humber long commitment to go zero energy by 2034. The report includes the following major objectives. (Humber IEMP plan,2017)

- Energy evaluation: Humber college gives access to its IEMP plan to the public. An energy evaluation was conducted to determine the building's current energy performance and identify areas where energy-saving measures could be implemented. The evaluation involved analyzing the building's historical energy consumption from the IEMP plan and Humber energy management plan.

- Renewable energy system: To achieve the goal of a Net Zero Energy Building, renewable energy sources were incorporated into the design. Solar panels were installed on the building's rooftop to generate electricity, and a geothermal system was installed to provide heating and cooling.

- Cost analysis: The cost analysis involved a detailed calculation of the building's energy consumption and generation, with data obtained from the Humber College Integrated Energy Master Plan. The building was designed to generate at least as much energy as it consumes on an annual basis, resulting in net-zero energy consumption. The initial investment for energy-efficient technologies and renewable energy systems is estimated to be $7,200,000 million. Overall, the Net Zero Energy Building is an innovative and sustainable solution for reducing energy consumption and greenhouse gas emissions in the built environment.

5.0 Data collection:

5.1 Average energy usage:

	Usage	Demand	Energy Cost
Electricity	21,877,100 kWh	46,632 kW	$1,629,368
Natural Gas	2,266,009 m^3	n/a	$343,023
Water	29,701,515 gal	n/a	$342,594

Energy Use and Cost for 2012

	Usage	Demand	Energy Cost
Electricity	21,325,773 kWh	48,677kW	$1,555,254
Natural Gas	2,384,724 m^3	n/a	$435,990
Water	29,730,100 gal	n/a	$299,101

Energy Use and Cost for 2011

	Usage	Demand	Energy Cost
Electricity	21,709,462 kWh	49,670 kW	$1,637,868
Natural Gas	2,403,752 m^3	n/a	$473,200
Water	29,132,906 gal	n/a	$271,321

Energy Use and Cost for 2010

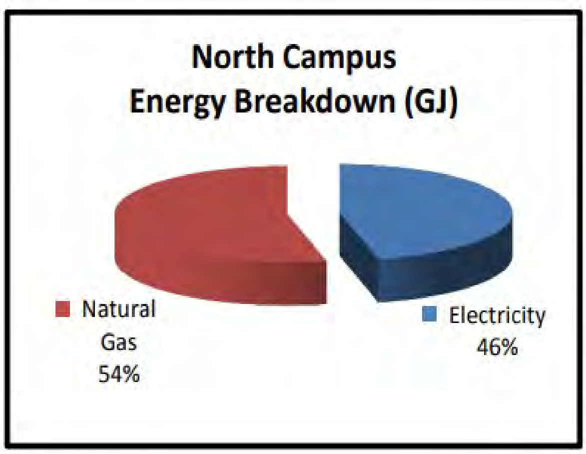
Figure 2: Average energy use in fiscal year of 2010,2011,2012

The figure demonstrates that the consumption of all three utilities, including electricity, has remained relatively stable over the period of 2010 to 2012, with minimal yearly variations of less than 5 percent. The energy cost for electricity remained constant with negligible yearly variations of less than 1 percent. Conversely, the cost of water increased progressively from 0.9 cents per gallon to 1.15 cents per gallon in 2012, and the trend was expected to continue.

The figure highlights that the principal focus of Humber College was to minimize electricity usage, as indicated in the provided figure. The report suggests that the consumption of electricity remained stable during this period, except for 2011 when it was around 400,000 kWh less than the other years. This decline in consumption could be attributed to several factors, such as the college's sustainability efforts, reduced occupancy in that year, or the college working on new projects. (Humber water and energy conservation plan,2012)

5.2 Energy Breakdown by utility:

The report presents a detailed breakdown of electricity and natural gas consumption by total annual energy in gigajoules and total annual cost in dollars, based on data averaged over the period of 2010 to 2012. Figure 1 illustrates that the consumption of both sources is relatively similar, with natural gas accounting for slightly over half of the total annual energy consumption. On the other hand, Figure 2 presents a breakdown of the two sources by energy cost. It reveals that the majority (80%) of the energy cost is attributed to electricity, in stark contrast to consumption. The report highlights that electricity costs are currently approximately four times greater than natural gas costs. (Humber water and energy conservation plan,2012)



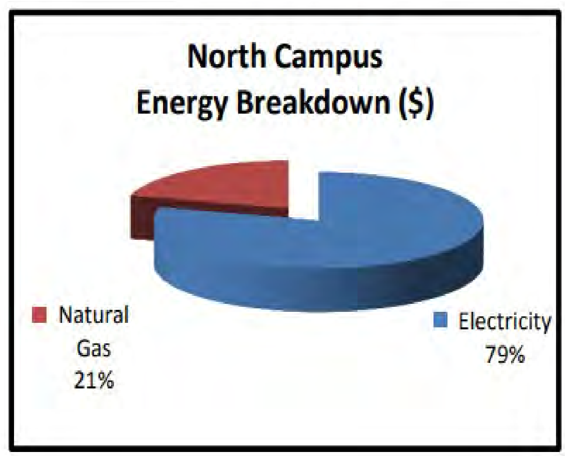


Figure 3: Energy Breakdown in Giga Joules

Figure 4: Energy breakdown structure in CAD

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5.3 Utility consumption profile as per HDD and CDD:

The presented graph provides an in-depth analysis of Humber College North campus' annual utility trends based on the average Heating Degree Days (HDD) and Cooling Degree Days (CDD) for calendar year 2010, 2011, and 2012. The electricity consumption in each month was recorded and plotted as the blue line, enabling the identification of energy usage patterns and trends throughout the year. The baseload, depicted as the black line, represents the minimum utility consumed during periods of low occupancy, such as weekends and holidays. By tracking the baseload, opportunities for reducing energy waste during low occupancy periods can be identified, improving overall energy efficiency.

Heating Degree Days (HDD) are represented by the red line, indicating the number of days in each month where the temperature falls below 18 degrees Celsius, typically associated with the heating load. Conversely, the green line represents Cooling Degree Days (CDD), indicating the number of days in each month where the temperature rises above 18 degrees Celsius, typically associated with the cooling load. By monitoring these values, energy efficiency strategies can be developed to optimize the heating and cooling performance of the building, reducing energy consumption.

Notably, the electricity profile of a college campus differs from typical commercial or residential buildings, as it experiences a decline in occupancy and usage during summer months. As a result, the North campus' electricity profile shows peaks in energy consumption during fall, March, and summer months, as opposed to summer months, which typically experience peak energy consumption in commercial or residential settings. The consistent high baseload throughout the year highlights the need for effective energy-efficient strategies to reduce energy consumption and achieve net-zero energy use. (Humber water and energy conservation plan,2012)

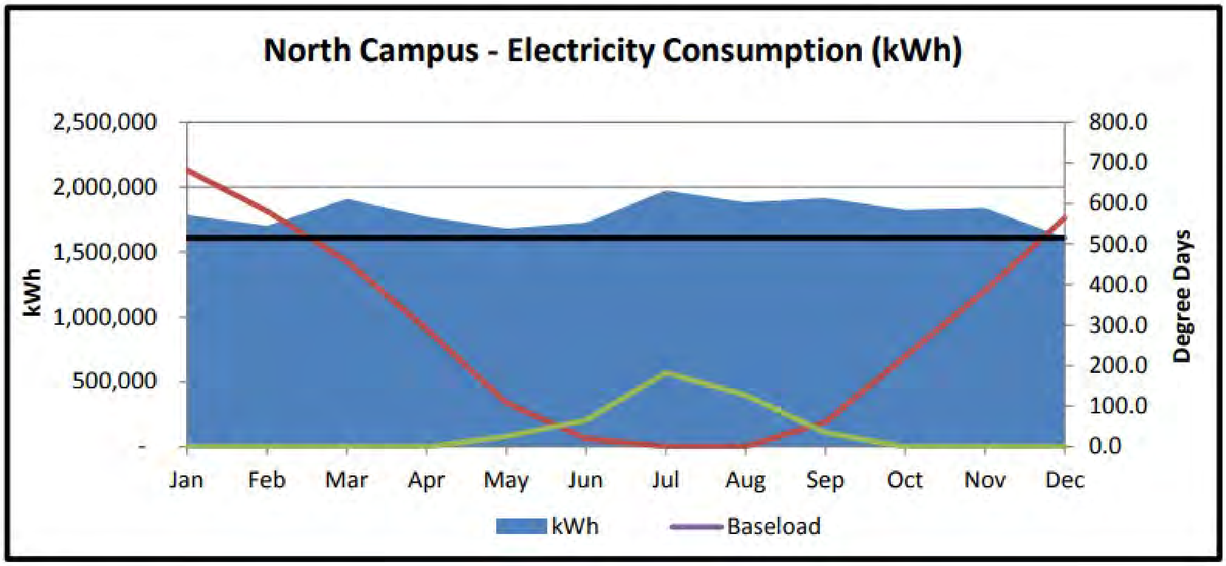


Figure 5: North Campus Electricity Consumption

In the context of energy usage, a typical commercial or residential annual electricity profile usually experiences a peak in the summer months, which corresponds to the cooling load. However, in the case of a college campus, the electricity profile tends to be at its lowest during the summer months, owing to a decline in occupancy and usage of the campus buildings. Specifically, the North campus' electricity profile shows peaks in energy usage during the summer, fall, and March months, along with a high baseload throughout the year. The dips in December and February coincide with periods of decreased occupancy, such as Christmas break and Reading Week. The baseload consumption represents energy usage associated with end uses, including lighting, plug loads, and ventilation. It is noteworthy that the baseload does not decrease in the summer months, as would be expected with reduced occupancy levels, indicating that these systems, including lighting, plug loads, and ventilation, are not scaled back during the summer due to some summer classes and office occupancy. This information reveals opportunities for optimizing energy usage during periods of low occupancy and suggests the need for implementing energy efficiency strategies to reduce energy consumption and achieve net zero energy use. (Humber water and energy conservation plan,2012)

5.4 Current baseline summery for 2014:

Baseline 2014C North Campus	Cost	Cost increase	Unit cost	Unit Cost Increase	Usage of Water	End Energy use	Source Energy use
Item	M$/yr	2010 - 2014	$/kWh	2010 - 2014	m³	MWh/yr	MWh/yr
Electricity	2.72	16%	0.126	14%		21,550	53,900
Natural Gas	0.77	34%	0.029	22%		26,610	27,900
			$/m³				
Water	0.37	36%	3.766	50%	98,000		
Total	***3.85***					***48,160***	***81,800***

Figure 6: Electricity consumption for the fiscal year 2014

The college's recent baseline summary has revealed some interesting insights about its energy usage and utility expenditures during the fiscal year 2014. According to the report, the college spent a total of 3.85 million dollars on utilities in 2014, which is significantly more than the previous years. This increase can largely be attributed to the construction of new buildings such as the Learning Resource Center (LRC) and Barrett Center of Technology, and also the fact that campus started enrolling and housing new students.(Humber IEMP plan,2017)

In terms of energy consumption, the college used a total of 82 GWh, that is about 81800000 Kwh of energy in 2014. This represents a substantial increase compared to the previous year, likely due to the added energy demands of the new buildings. Additionally, the report notes that the unit cost of electricity increased by about 14% between 2010 and 2014, as shown in Figure X.

The total electricity used by the college in the fiscal year 2014 was 21550 Mwh or 21550000 Kwh, according to the figure the unit cost of electricity for the year was 0.126 $/Kwh, so the college spent around 2.72 million dollars just on electricity.

$$cost\ of\ energy \in dollars = (21550\ Mwh \times 1000\ Kwh) * 0.126\ \frac{\$}{Kwh}$$

$$¿ 2{,}715{,}300\ \$$$

(Note: for the design purpose the 2014 fiscal year was considered as it is the most recent.)

6.0 Renewable energy:

6.1 Design of solar PV Modules:

The major factor affecting the design of the solar PV system is the available roof area, as it directly relates to the efficiency of the system. The average Roof area of the J building is 2173.5 m2, according to the available roof area the installation factor for the solar PV system is 1589.3 m2. The orientation of the solar panel is also one of the main factors in in how efficient the system is, panels pointed south, south-east, or South-West are the most efficient they are also required to be on an angle. Solar panel require what is called the full sun to generate energy. The amount of solar radiation received by a solar panel is an important factor in its energy production. When sunlight strikes the panel, it must have sufficient energy to dislodge an electron from its bonds. If the sun strikes the panel at an angle that is not ideal, it may not provide enough energy. A theoretical estimate of the duration for which the sun will be in an ideal position to strike the panel can be obtained using a metric known as “full sun”. Full sun is the amount of time for which the sun is in an optimal position to provide the panel with maximum energy. In Toronto, the average full sun in the summer is approximately 3.98 hours per day, while in winter it is around 2.13 hours per day. This metric is used to estimate the energy production of a solar panel system based on the amount of solar radiation it will receive over a given period. (Peak sun hour Calculator,2022)

The optimal amount of the solar panels is designed based on the monthly consumption of the building, also the system is designed so that the building would experience 42% reduction in its electricity bill, without changing the utilities. As mentioned in the base case of 2014 the annual consumption of electricity for the entire college was 21550 Mwh (21550000 Kwh)

6.2 Calculations:

Table 1 Calculation for number of Solar panels

Annual consumption for the entire college: 21550000 Kwh
Humber college north consist of 49 buildings including residence, there for on an average one building consume: 21550000 Kwh/49 = 439795.91 Kwh
Monthly consumption of the J Building: 439795.91 Kwh / 12 Months = 36649.66 Kwh
42% Efficiency monthly consumption: 36649.6 Kwh * 0.42 = 15393.00 Kwh
Per day utilization: 36649.66 Kwh / 30.5 Days = 1201.64 Kwh
Per day utilization for 42% efficiency: 0.42 * 1201.64 = 504.69 Kwh
Panel capacity: 915 Watts
Panel area: =1.94*1.04 = 2.0176 m2
J wing roof area: 2173.5 m2
Installation area: 2173.5m2 / 2.0176 m2 = 1077 m2
Per Day average Generation: 1300/366 = 3.55 Kwh
System capacity: per day utilization 42% / per day average = 504.69 Kwh / 3.55 Kwh = 142.09 Kw
Number of panels: System Capacity / Panel Capacity = 142.09Kw / (915w/1000) = 155 panels

The design of the solar PV system is based on the monthly consumption of the J Building, with a goal of achieving a 42% reduction in its electricity bill without changing utilities. The annual consumption of electricity for the entire college is 21550000 Kwh, and on average, one building consumes 439795.91 Kwh. The monthly consumption of the J Building is 36649.66 Kwh, and its

42% efficiency monthly consumption is 15393.00 Kwh. The per-day utilization for the J Building is 1201.64 Kwh, and for 42% efficiency, it is 504.69 Kwh.

The panel capacity is 915 Watts, and the panel area is 2.0176 m2. The installation area for the J Building is 1077 m2, and the per-day average generation of the solar PV system is 3.55 Kwh. The system capacity is calculated as 142.09 Kwh, and the number of panels required for the J Building is 155

Overall, the design of the solar PV system for the J Building is based on factors such as available roof area, panel orientation, solar radiation, and the building's monthly consumption. The goal is to achieve a 42% reduction in the building's electricity bill without changing utilities, and this is achieved by installing 155 panels with a total capacity of 142.09 Kwh.

6.3 System specification:

Table 2: Specification for the system

Module DC Nameplate	143.7 kW
Module	EO Solare, 156M216VC (915) (915W) Count 157
Panels Tilt	10 Degree
Azimuth	180 Degree
Orientation	South-East
Inverter AC Nameplate	280.0 kW Load Ratio: 0.51
Inverter	3TL-40 (Advanced Energy) 7 (280.0 kW)
Annual Production	161.7 MWh
Performance Ratio	74.2%
kWh/kWp	1,125.8
Weather Dataset	TMY, 0.04° Grid (43.73,-79.62), NREL (psm3)

6.4 Layout of the panels and Invertor:

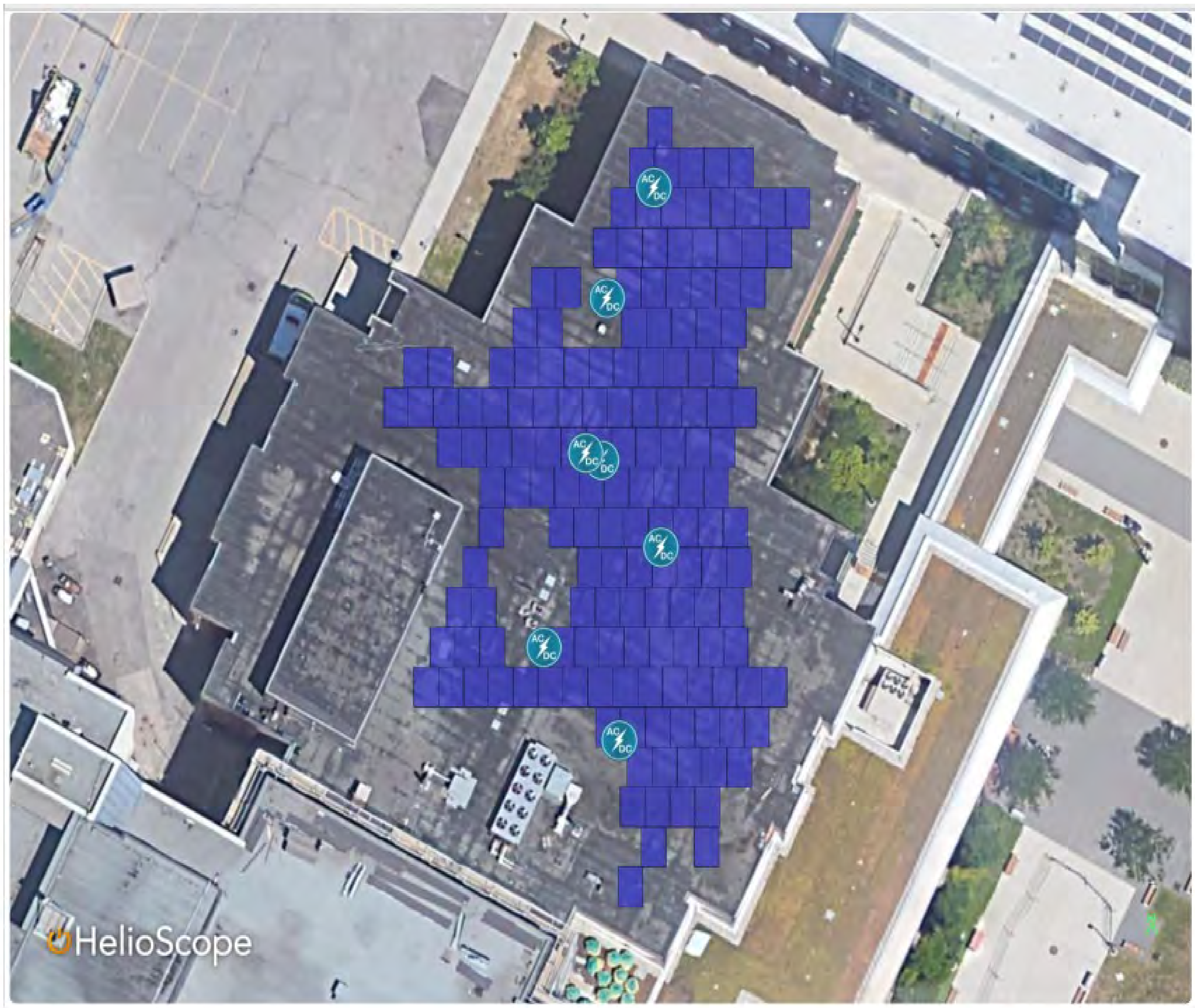


Figure 7 Layout for panels and invertors

6.5 Monthly production:

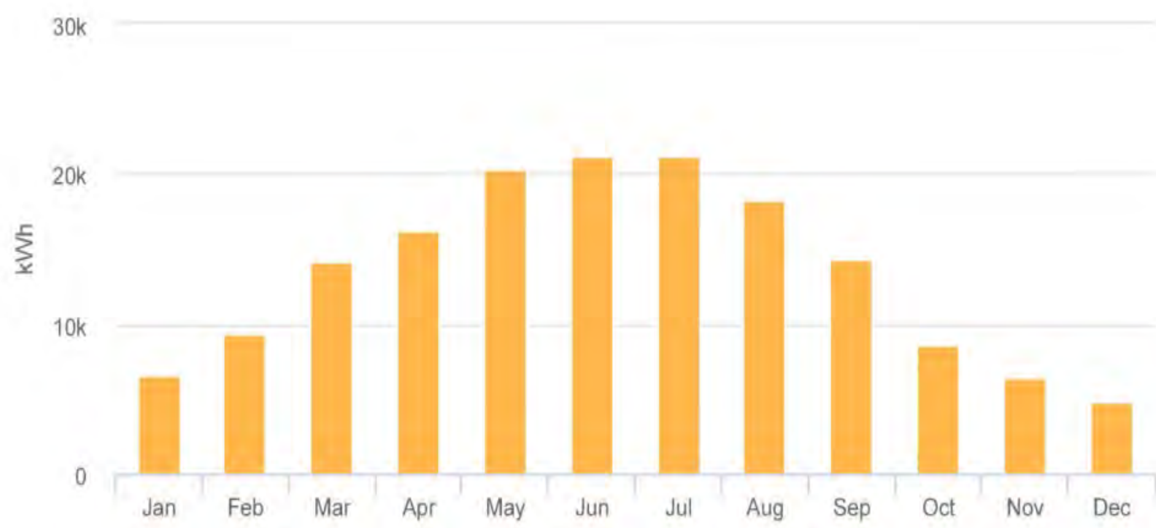


Figure 8: Monthly Production from Solar system

The presented graph illustrates the monthly production of solar energy from the installed solar system. The graph highlights that the system's highest electricity production occurred during the months of June and July, which is consistent with the clear weather conditions that prevail during this time of the year. However, this high energy production comes at a cost, as the irradiance, or the amount of solar energy received by the system, is also high during these months. For instance, the energy production during June and July was 23687.6 KWh and 24201.8 KWh, respectively, with an irradiance of 188.3 KWh/m2 and 191.8 KWh/m2.

Conversely, as the weather becomes colder, the production of solar energy begins to decline. Notably, during these months, the Global Horizontal Irradiance (GHI), which is the amount of solar energy received by a horizontal surface, is negligible. For example, in December, the GHI was measured at 36.4 KWh/m2. The same can be said for POA, and shaded irradiances.

Table 3 Detailed Monthly production form solar system.

Month	GHI (kWh/m^2)	POA (kWh/m^2)	Shaded (kWh/m^2)	Nameplate (kWh)	Grid (kWh)
January	48.2	60.1	48.5	6,501.9	6,530.0
February	72.6	86.2	69.5	9,372.5	9,332.6
March	118.2	132.3	106.4	14,414.1	14,123.4
April	141.2	150.4	125.0	17,006.5	16,184.3
May	175.1	180.4	163.7	22,279.6	20,368.8
June	188.3	191.0	173.8	23,687.6	21,203.5
July	191.8	195.6	177.6	24,201.8	21,235.8
August	171.9	181.3	154.1	20,959.4	18,311.7
September	134.0	147.7	118.6	16,075.1	14,352.2
October	73.7	85.4	69.4	9,348.7	8,700.7
November	50.5	61.3	50.3	6,748.0	6,508.0
December	36.4	45.2	36.7	4,915.2	4,874.9

The presented table provides detailed information on the irradiance and solar panel production. The table includes the following terms and their respective definitions:

- GHI (Global Horizontal Irradiance): The amount of solar radiation received by a horizontal surface.
- POA (Plane of Array Irradiance): The amount of solar radiation received by the solar panel after it has been adjusted for the angle and position of the panel.
- Nameplate: Refers to the rated capacity of a single solar panel, typically measured in watts.
- Grid: Refers to the electrical power that is fed into the power grid after being generated by the solar panels.

The table presents data on the daily average GHI and POA irradiance, as well as the daily solar panel production and nameplate capacity. The grid column indicates the daily average power fed into the grid by the solar system. Overall, the table provides a detailed breakdown of the solar system's daily performance, including its irradiance, solar panel production, and power generation.

6.6 System losses:

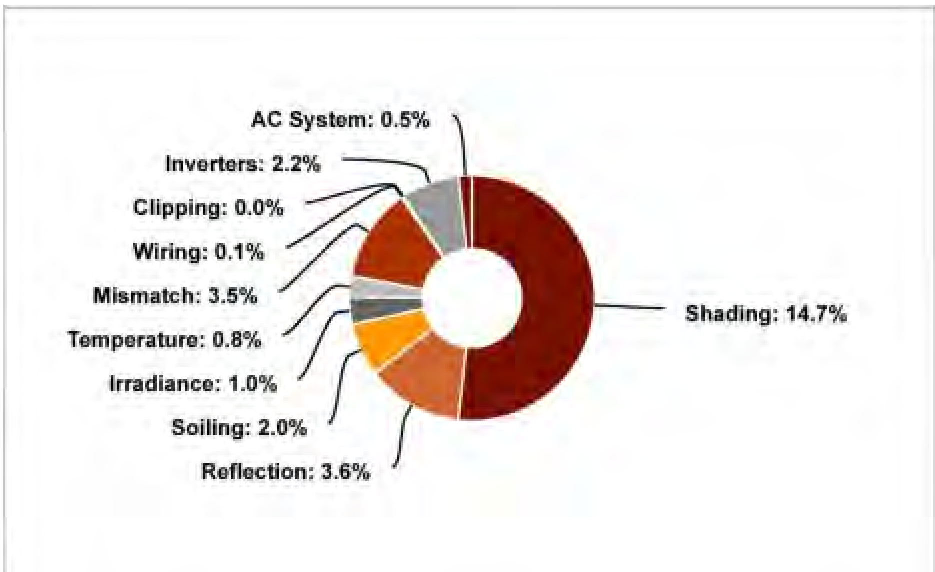


Figure 9: Energy losses from the system

Solar PV systems can experience energy losses due to various factors such as resistance, impedance, conversion efficiency, clipping, wiring, mismatch, temperature, irradiance, soiling, reflection, and shading. The losses in the AC system, inverter, and wiring are 0.5%, 2.2%, and 0.1%, respectively. Mismatch, temperature, irradiance, soiling, reflection, and shading losses are 3.5%, 0.8%, 1.0%, 2.0%, 3.6%, and 14.7%, respectively. The total energy losses in this system are around 28.4%. These losses should be considered to maximize the energy production and efficiency of solar PV systems. For more information, please refer to the appendix 2.

The system was supposed to generate 184,716 Kwh of energy annually at 42 % efficiency rate, but due to losses from shading and the losses mentioned above its only generating 161,700 Kwh of energy. Therefor it looses about 23,016 Kwh of energy Annually.

7.0 Cost analysis:

7.1 Solar PV System Breakdown:

Table 4: Cost structure of installing solar panels.

Items	Number of items	Price of one unit	Total cost
Penal	157	2010.67	312234.48
inverter	7	3850	269850
Auxiliary cost			100000
Labour charges			25000
Total system completion cost			464184.48

The table provides an estimated breakdown of the cost of installing a solar PV system, with auxiliary costs encompassing various expenses such as the cost of the frame, site survey fees, permitting charges, and insurance premiums. Notably, approximately half of the auxiliary costs are attributable to the frame cost, while the remaining expenses are divided among the site survey, permitting, and insurance costs. It is important to note that the specific allocation of costs may vary depending on the installation project and the associated expenses involved. The cost breakdown presented is a preliminary estimate and does not provide a comprehensive overview of all the expenses associated with installing a solar PV system. Other costs, such as transportation fees, sub-contractor expenses, insurance costs, connection charges, and system monitoring and maintenance fees, may also need to be factored into the overall cost. Therefore, it is important to consider the potential additional expenses that may arise during the installation process and incorporate them into the final project budget to ensure an accurate representation of the total cost.

7.2 Return from the solar PV system:

Table 5: Annual and Monthly Revenue generation calculation

The annual consumption of electricity for J building: 439795.91 Kwh The unit cost of electricity: 0.126 cents (average of peak hours) The total annual cost for the electricity: 439795.91 KWh * 0.126 cents = $55,414 Monthly cost of electricity: $55,414 / 12 = $4617 Annual production from solar system: 161700 Kwh The annual amount of revenue generated form the solar system: 161700 Kwh *0.126 = $20374 There for monthly: 161700 Kwh / 12 = 13475 Kwh Total amount of revenue generated from solar system monthly: 13475 Kwh * 0.126 cents = $1697.85 (average monthly revenue, the graph below shows a detail revenue than can be potentially generated every month.)

The provided calculations offer insights into the annual and monthly profits generated by the solar system installed on the building. To better understand the benefits of the solar system, a comparison was made between the building's annual electricity consumption and the annual production of electricity from the solar system.

According to the calculations, the building's annual electricity consumption was 439795.91 KWh, which cost $55,414. On the other hand, the solar system produced 161700 KWh of electricity annually, generating $20,374 in revenue. This indicates that the solar system has saved the college $20,374 annually from its original electricity bill. To further explain, the savings generated by the solar system represent the difference between the cost of electricity consumed by the building and the revenue generated by the solar system. The cost of electricity consumed by the building was calculated by multiplying the annual consumption of 439795.91 KWh by the unit cost of electricity during peak hours, which was 0.126 cents. This resulted in a cost of $55,414. The revenue generated by the solar system was determined by multiplying the annual production of 161700 KWh by the unit cost of electricity during peak hours, which was also 0.126 cents. This resulted in a revenue of $20,374.

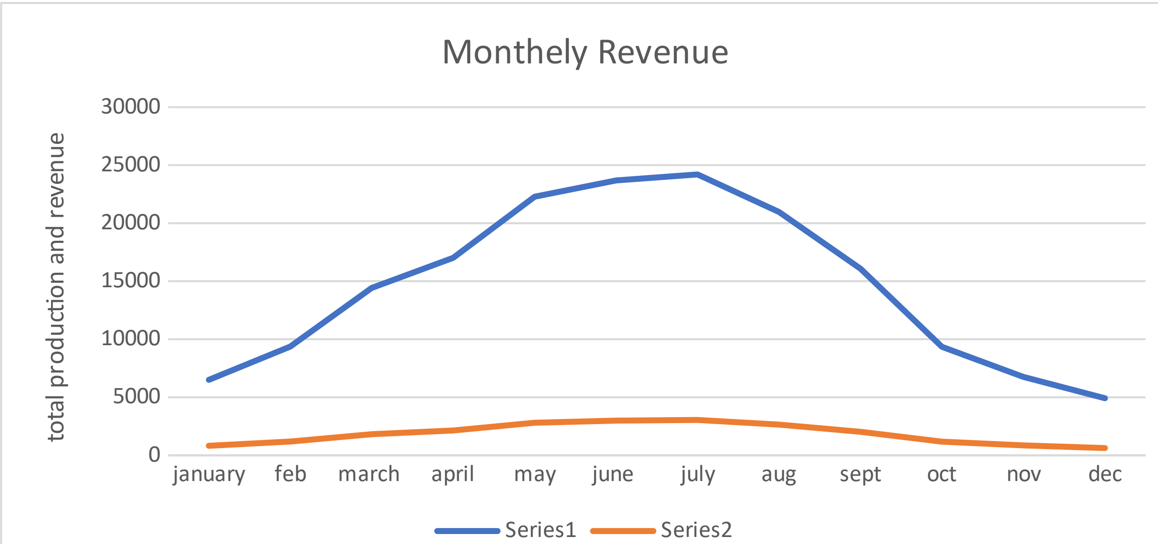


Figure 10: Monthly Revenue Generation graph

The presented graph depicts the relationship between the monthly solar energy production and the resulting revenue. The data shows that during the summer months, when solar panels operate at their maximum capacity, the energy production rate is higher. According to the provided table, the highest amount of revenue generated was observed in July, which amounted to $3049. And the lowest was in the month of December $619 as there is not enough solar energy available as the climate is mostly cloudy.

Table 6: Monthly revenue Generated.

Months	Monthly Production	Revenue Generation In CAD
JAN	6501.9	819
FEB	9372.5	1181
MAR	14414	1816
APR	17006	2143
MAY	22279	2807
JUNE	23687.6	2985
JULY	24201.8	3049
AUG	20959.4	2641
SEPT	16075.1	2025
OCT	9348.7	1178
NOV	6748	850
DEC	4915.2	619

9.0 Conclusion:

The primary goal of the project was to design a building that could generate as much energy as it consumed and a building that meets the college IEMP plan goals of reducing the energy cost by 50 percent. However, the project faced various limitations such as the available roof area, climatic changes, and system losses that constrained its scope.

One of the major limitations was the availability of roof area (2173.5m2), which made it necessary to install approximately 155 panels to produce 161.7 Mwh energy annually for the J building's consumption. This was further complicated by the impact of climate change on the building's energy consumption patterns, which varied based on the season and the building's orientation. Despite these challenges, the project was designed to cut the utility bill by 42 percent. The design achieved this by using renewable energy sources, such as solar panels, to offset the building's energy consumption. As a result, the project was able to cut the utility bill by $22,113 annually, representing a 42 percent reduction in energy costs. While this figure may not seem significant compared to the college's overall energy consumption of $55,414, it still represents a significant cost savings. The energy-efficient measures implemented in the project have the potential to reduce the building's carbon footprint, decrease energy consumption, and save costs in the long term.

8.0 Recommendations:

- To improve the energy generation from limited roof area, it is recommended to enhance the efficiency of the solar panels. The utilization of high-efficiency solar panels can increase the percentage of sunlight that is converted into electricity, thereby maximizing the energy output from the available roof space. To achieve this, it is suggested to consider using 1.5Kw solar panels that are currently available in the market. However, it should be noted that these high-efficiency solar panels may come at a higher cost for both purchase and maintenance. Additionally, to align with the college's framing goals of increasing energy efficiency by 50 percent by 2034, it is imperative to prioritize the use of efficient solar panels in the building's design and implementation.
- Energy efficient technologies: Energy efficient technologies like Geothermal heating and cooling system (HVAC system) and LED lightning can further improve the building efficiency and would potentially give a positive impact on the college commitment to sustainability.
- Implement building envelope improvements: Building envelope improvements such as insulation, air sealing, and high-performance windows can help reduce energy consumption by minimizing heat loss/gain through the building envelope.

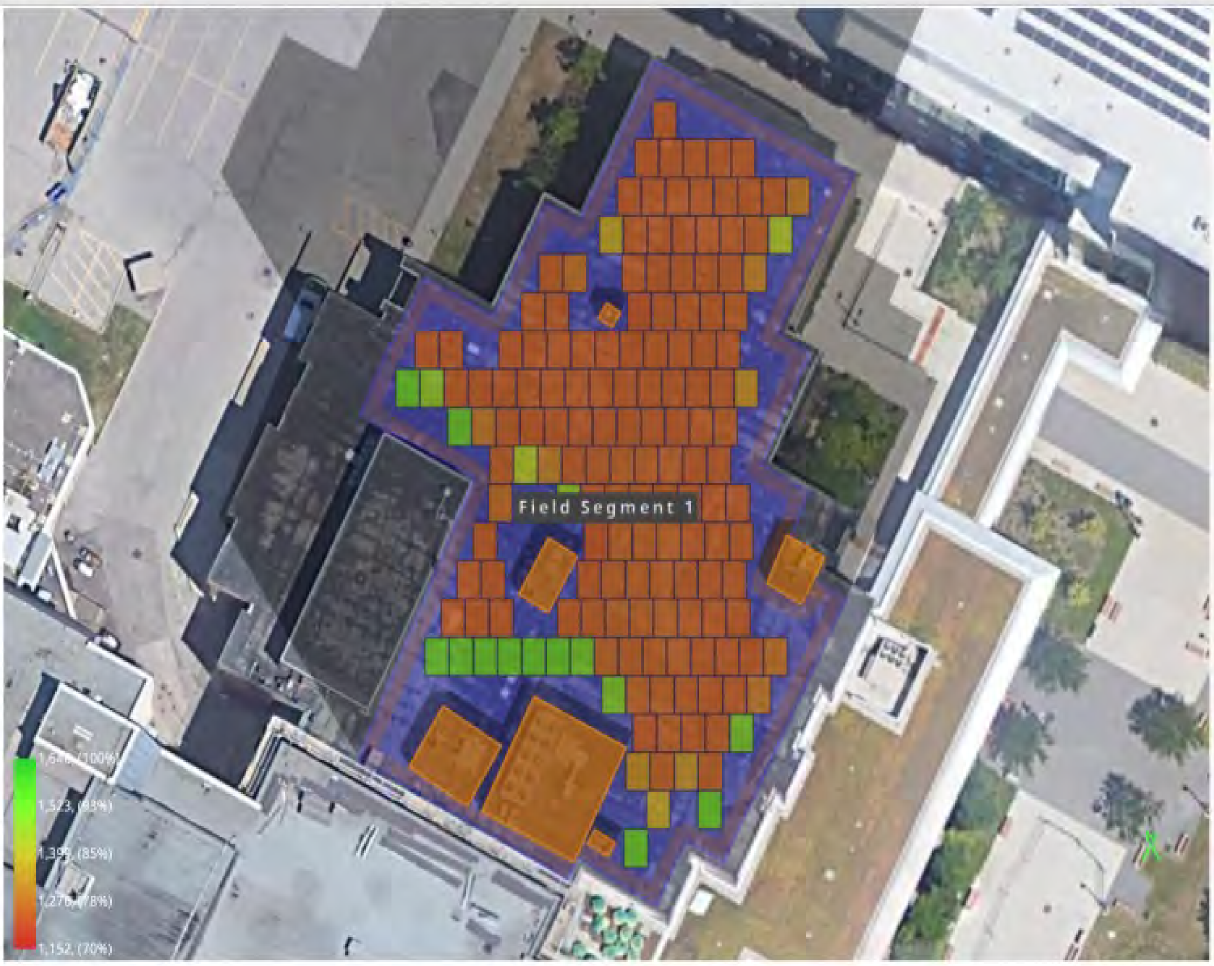
Implementing these improvements can help reduce energy consumption and associated costs. By implementing these energy-efficient technologies, the building can reduce its energy consumption and associated costs while also reducing its carbon footprint.

Appendix A:

Shading Summery from Helioscope software:

Design 1 Humber college J building, M9W5L7

Shading Heatmap



Shading by Field Segment

Description	Tilt	Azimuth	Modules	Nameplate	Shaded Irradiance	AC Energy	TOF[2]	Solar Access	Avg TSRF [2]
Field Segment 1	10.0°	180.0°	157	143.7 kWp	1,293.5kWh/m^2	161.7 MWh[1]	92.1%	85.3%	78.6%
Totals, weighted by kWp			157	143.7 kWp	1,293.5kWh/m^2	161.7 MWh	92.1%	85.3%	78.6%

[1] approximate, varies based on inverter performance
[2] based on location Optimal POA Irradiance of 1,646.2kWh/m^2 at 35.0° tilt and 183.7° azimuth

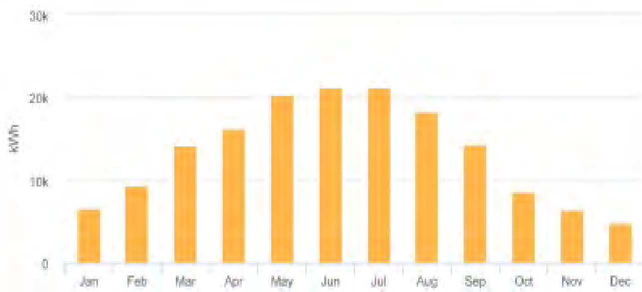
Solar Access by Month

Description	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Field Segment 1	81%	81%	80%	83%	91%	91%	91%	85%	80%	81%	82%	81%
Solar Access, weighted by kWp	80.8%	80.7%	80.4%	83.1%	90.7%	91.0%	90.8%	85.0%	80.3%	81.2%	82.0%	81.2%
AC Power (kWh)	6,530.0	9,332.6	14,123.4	16,184.3	20,368.8	21,203.5	21,235.8	18,311.7	14,352.2	8,700.7	6,508.0	4,874.9

HelioScope

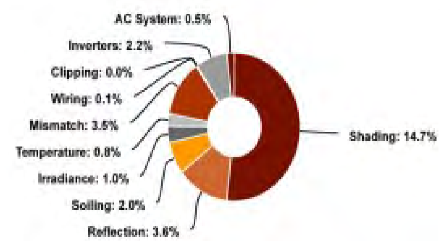
Shading Report produced by Huzaifah Bariwala

Monthly Production

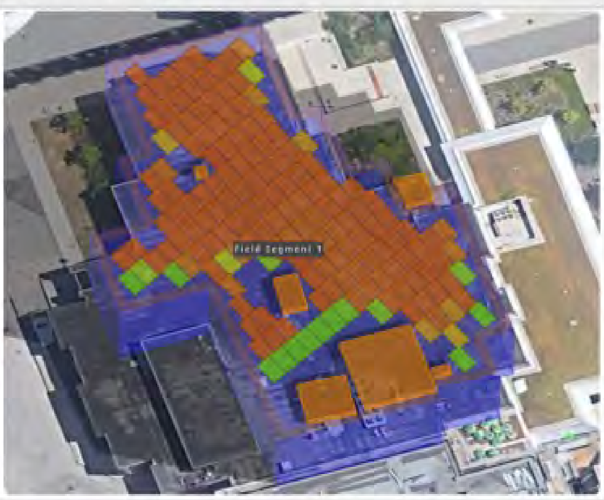


Month	GHI (kWh/m²)	POA (kWh/m²)	Shaded (kWh/m²)	Nameplate (kWh)	Grid (kWh)
January	48.2	60.1	48.5	6,501.9	6,530.0
February	72.6	86.2	69.5	9,372.5	9,332.6
March	118.2	132.3	106.4	14,414.1	14,123.4
April	141.2	150.4	125.0	17,006.5	16,184.3
May	175.1	180.4	163.7	22,279.6	20,368.8
June	188.3	191.0	173.8	23,687.6	21,203.5
July	191.8	195.6	177.6	24,201.8	21,235.8
August	171.9	181.3	154.1	20,959.4	18,311.7
September	134.0	147.7	118.6	16,075.1	14,352.2
October	73.7	85.4	69.4	9,348.7	8,700.7
November	50.5	61.3	50.3	6,748.0	6,508.0
December	36.4	45.2	36.7	4,915.2	4,874.9

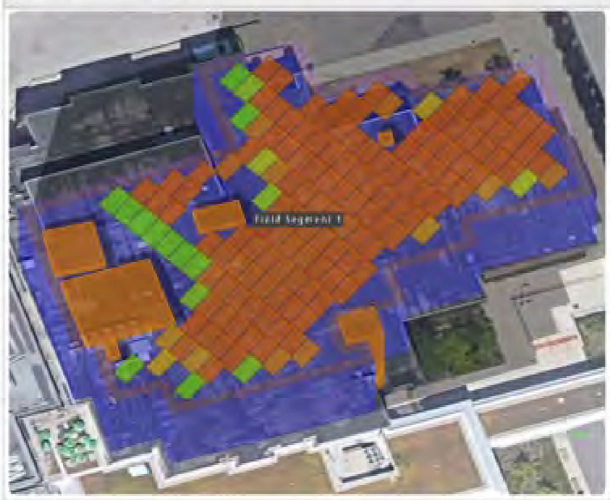
Sources of System Loss



Southwestern Angle



Southeastern Angle



Appendix B:

Design 1 Humber college J building, M9W5L7

Report

Project Name	Humber college J building
Project Address	M9W5L7
Prepared By	Huzaifah Bariwala bariwalasaad2@gmail.com

System Metrics

Design	Design 1
Module DC Nameplate	143.7 kW
Inverter AC Nameplate	280.0 kW Load Ratio: 0.51
Annual Production	161.7 MWh
Performance Ratio	74.2%
kWh/kWp	1,125.8
Weather Dataset	TMY, 0.04° Grid (43.73,-79.62), NREL (psm3)
Simulator Version	3be6805f30-2bd0b278bb-87e3d752bb-2174047595

Project Location

Monthly Production

Month	GHI (kWh/m²)	POA (kWh/m²)	Shaded (kWh/m²)	Nameplate (kWh)	Grid (kWh)
January	48.2	60.1	48.5	6,501.9	6,530.0
February	72.6	86.2	69.5	9,372.5	9,332.6
March	118.2	132.3	106.4	14,414.1	14,123.4
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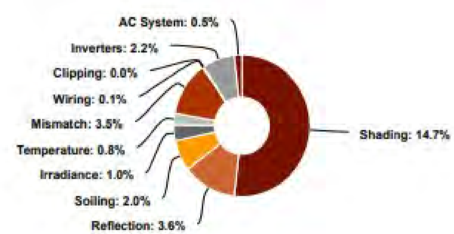
August	171.9	181.3	154.1	20,959.4	18,311.7
September	134.0	147.7	118.6	16,075.1	14,352.2
October	73.7	85.4	69.4	9,348.7	8,700.7
November	50.5	61.3	50.3	6,748.0	6,508.0
December	36.4	45.2	36.7	4,915.2	4,874.9

Sources of System Loss



HelioScope

Annual Production Report produced by Huzaifah Banwala

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,401.9	
	POA Irradiance	1,516.8	8.2%
	Shaded Irradiance	1,293.5	-14.7%
	Irradiance after Reflection	1,246.7	-3.6%
	Irradiance after Soiling	1,221.8	-2.0%
	Total Collector Irradiance	**1,222.0**	**0.0%**
Energy (kWh)	Nameplate	175,510.4	
	Output at Irradiance Levels	173,731.4	-1.0%
	Output at Cell Temperature Derate	172,374.1	-0.8%
	Output After Mismatch	166,315.2	-3.5%
	Optimal DC Output	166,195.0	-0.1%
	Constrained DC Output	166,194.8	0.0%
	Inverter Output	162,538.5	-2.2%
	Energy to Grid	**161,725.8**	**-0.5%**
Temperature Metrics			
	Avg. Operating Ambient Temp		11.2 °C
	Avg. Operating Cell Temp		18.2 °C
Simulation Metrics			
		Operating Hours	4350
		Solved Hours	4350

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 0.04° Grid (43.73,-79.62), NREL (psm3)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C
East-West	-3.56	-0.075	3°C
Carport	-3.56	-0.075	3°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
2	2	2	2	2	2	2	2	2	2	2	2

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	-2.5% to 2.5%
AC System Derate	0.50%

Module Characterizations

Module	Uploaded By	Characterization
156M216VC (915) (EOSolare)	HelioScope	Spec Sheet Characterization, PAN

Component Characterizations

Device	Uploaded By	Characterization
3TL-40 (Advanced Energy)	HelioScope	Spec Sheet Efficiency

Components

Component	Name	Count
Inverters	3TL-40 (Advanced Energy)	7 (280.0 kW)
Strings	10 AWG (Copper)	31 (1,563.6 ft)
Module	EOSolare, 156M216VC (915) (915W)	157 (143.7 kW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	3-6	Along Racking

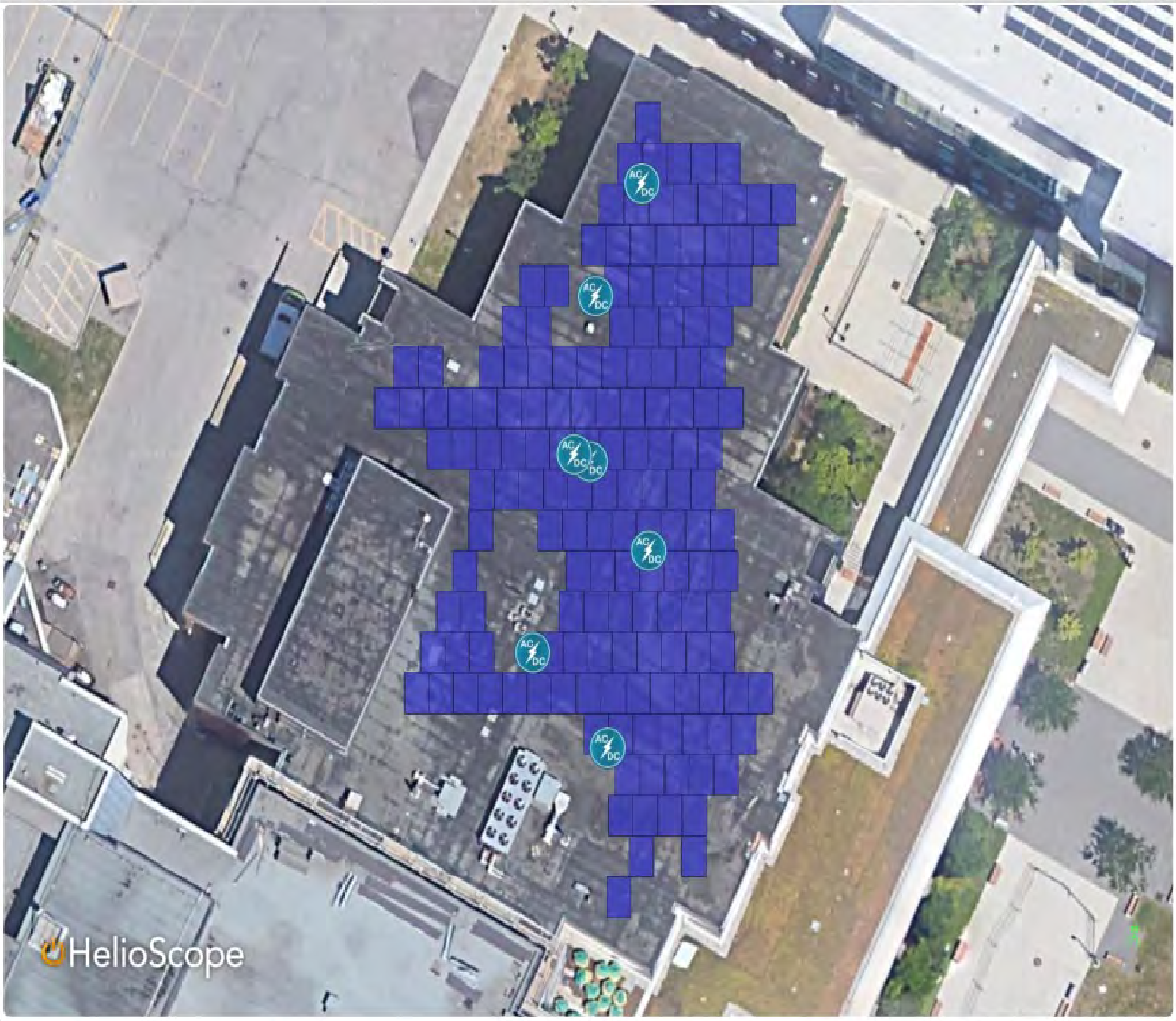
Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 1	Fixed Tilt	Portrait (Vertical)	10°	180°	0.0 ft	1x1	157	157	143.7 kW

HelioScope

Annual Production Report produced by Huzaifah Bariwala

Detailed Layout



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