Proposal Report: Solar Photovoltaic Panel Installation on a Residential House in Barrie, ON

APS 1032: Introduction to Energy Project Management

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Executive Summary

This project report details the specifications required for the development of a 7.125 kW solar PV system under the Ontario microFIT program in Barrie, Ontario. Twenty-five panels are proposed to be installed spanning an area of 48 m^2 of the 49.36 m^2 of available south facing roof space at 156 Cheltenham Road, Barrie, ON. The panels to be installed are CS6X-285P Max Power model with 285 kW output rating and 15% efficiency, purchased from Canadian Solar. Panels will be mounted with adjustable solar mounts for enhanced performance, with optimal tilt angles adjust twice yearly at 20.7° and 58.5° in the summer and winter, respectively. Installation of the project will be subcontracted to EthoEnergy, a Barrie solar based company. The duration time to complete this project is 84 days. The predicted annual power output obtained from the 7.125 kW system is 11538.293 kW, producing an annual microFIT savings of $3323. Financing the solar project at a debt ratio of 70%, total annual costs including maintenance and debt payments for the 7.125 kW PV system is $32,439. Cost-benefit analysis revealed a payback period of 10.7 years for the solar project.

1. Introduction

Due to the undeniable adverse effects of climate change, countries around the world are taking steps to reduce their carbon emissions and contributions to climate change. Ontario has taken significant steps to reduce its carbon footprint; they successfully phased out coal-fired electricity plants, and the Ontario government recently announced the Climate Change Action Plan (CCAP), which aims to further reduce carbon emissions. Item 5.1 in the "Update the Building Code" of the CCAP states, "The government intends to update the Building Code with long-term energy efficiency targets for new net zero carbon emission small buildings that will come into effect by 2030 at the latest…". [1] For buildings to have net zero carbon emissions, they need to generate and consume electricity produced through renewable energy. Solar collectors have become one of the most utilized methods for renewable energy generation in Ontario, as homeowners want to do their part in reducing their carbon footprint, while earning credit from the government through programs such as feed in tariffs and net metering. Solar collectors can be utilized for hot water generation and electricity generation. Solar thermal collectors generate hot water, while solar photovoltaic panels generate electricity. There are several advantages with solar collectors: they provide sustainable energy consumption with an infinite, renewable energy source. They are also relatively durable and require very little maintenance. Finally, as mentioned earlier, the government provides generous credits and payments to homeowners and businesses that generate solar powered electricity. These credits only apply to electricity generation, so homes that only have solar thermal systems will not be eligible for government credits. There are two main methods the government uses to incentivize the installation of solar collectors in Ontario: the Net Metering and MicroFIT programs. With Net Metering, the homeowner can export excess electricity generated back to the utility distribution system and in return, the homeowner receives a credit towards their electricity costs. MicroFIT is a feed-in tariff program, where the government pays the homeowner a certain amount (cents/kWh produced) for electricity generated and exported to the electrical grid. These programs will be compared in greater detail in later sections. Our project team has been tasked with installing a solar collector system for a home in Barrie, Ontario, with the goal of renewable electricity generation and payback in the form of credits from Net Metering, or income from the MicroFIT program. We will provide a cost/benefit analysis for solar collector installation, identify adequate solar subcontractors and develop execution flow charts with project timelines, activities and cost.

2. Objectives

The general objective of this proposal is to develop a project management infrastructure for the installation of solar panels on the roof of a residential house located in Barrie, Ontario. By examining available solar PV technologies, the following will be determined:

1. The owner's potential to reduce utility bill costs
2. Government initiatives available for electricity sale back to the grid
3. Optimal solar panel infrastructure size and output to meet the owners goal
4. Cost benefit analysis, along with estimated time and maintenance required.

3. Location Assessment

3.1. Property Evaluation

The site under investigation for PV installation is shown in Figure 1a. An estimated roof size of 191 m^2 was recorded with 49.36 m^2 of available south facing roof space (Figure 1b). The age of the house is recorded at 17 years of age, with roof replacement occurring in the last year. During the prefeasibility study an assessment of the roof will determine the roofs ability to support the weight of the PV panels, mounting hardware and expected worst case loads from snow and wind. If any roof repairs are required, as identified by the site inspector, repairs will be arranged and completed prior to panel installation.

A thorough analysis of the power generation potential of the regional solar radiation supply was carried out using data obtained from NASA satellite data and local ground measurements collected by Environment Canada for Barrie, Ontario. [2] The results are summarized in Table 1 showing a comparison between horizontal, tilted fixed, and tilted one-axis daily solar radiation. Figure 2. shows the proximity of the climate data site to the site location.

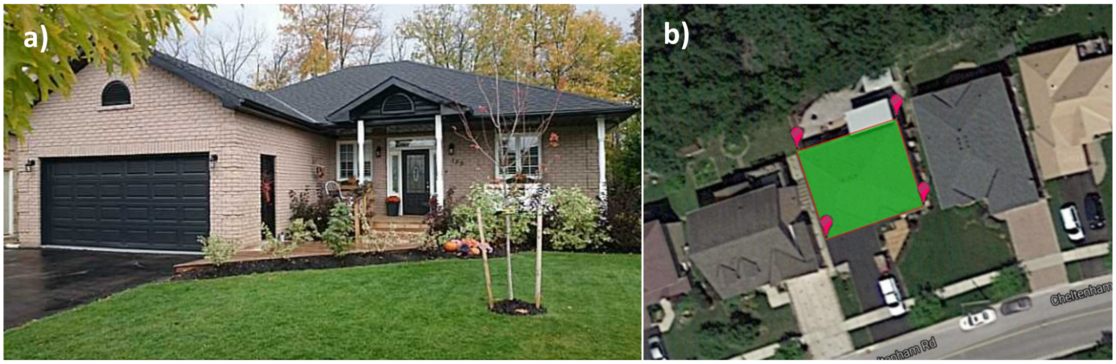

Figure 1. a) Assessment site: 156 Cheltenham Road, Barrie, ON, L4M 6S5. b) Roof sizing rough estimate.

Table 1. Regional solar radiation supply for Barrie, Ontario [2]

Climate Zone: Cold-Humid

Month	Air Temperature °C	Daily Solar Radiation – Horizontal $kWh/m^2/day$	Daily Solar Radiation – Tilted (Fixed) $kWh/m^2/day$	Daily Solar Radiation – Tilted (One- axis) $kWh/m^2/day$
January	-7.9	1.36	2.29	2.74
February	-7.0	2.18	3.22	3.88
March	-2.3	3.13	3.84	4.71
April	5.3	4.35	4.63	5.89
May	11.7	5.30	5.15	6.55
June	16.6	5.94	5.54	7.47
July	19.3	5.87	5.58	7.23
August	18.4	5.08	5.22	6.80
September	14.0	3.91	4.55	5.66
October	7.8	2.50	3.40	4.03
November	2.1	1.42	2.16	2.51
December	-4.3	1.13	1.90	2.15
Annual	6.2	3.52	3.96	4.97

Figure 2. Climate data site reference assessment

3.2. Building Permits

According to Ontario Building Code Act, a building permit is required for the construction or installation of a new structure, or for the construction of an addition or alteration of any structure that results in a building area of over 10 square meters (107 sq ft). [3] For this project the required roof area for solar panel installation is 48 m^2, therefore, obtaining building permits should be considered.

4. Proposal

4.1. Government Initiatives

The Ontario government promotes the use of solar energy for residential consumers through initiatives such as net metering, for projects less than 500 kW, and micro Feed-in Tariffs (microFIT) for generation projects less than 10 kW. Participants of microFIT program get paid with a guaranteed price for 20-year period for all the electricity they generate and deliver to the grid. The advantage of microFIT is that the set price is guaranteed following contract is executed. [4, 5] In contrast, net metering allows participants use what they generate from their own solar panels and send excess electricity to the grid to offset the hydro bills. [6] The advantage of net metering is that you get credits for what you generate back to the grid and you can use them until you need to. Both these programs do not require any licenses. [4, 6] People interested in participating in the microFIT program require a separate generator account while there is no need for this in Net Metering. The option for conversion from microFIT to net metering is available once specific requirements are met. [4, 5]

Due to current electricity time of use prices in Ontario being lower than the credit offered by the microFIT program it is highly recommended that the sponsor pursues the microFIT program. The microFIT program has the potential to offer a faster rate of return while contributing to a cleaner environment.

4.2. Project Infrastructure

4.2.1. Solar Thermal Overview

Working with solar energy, Solar thermal energy (STE) is a kind of technology to produce thermal energy or electrical energy for use in industrial, residential and commercial sectors. Basically, it has two types including Thermosiphon systems and Pumped or split systems [7]. Some typical data and characteristics about it is listed below [8]:

Storage Capacity	Typical four-person: 300–360L tank
Space	Four square metres of solar collector area(two panels)
Efficiency	Solar Energy Factor: 2-3 Solar Fraction: 0.5–0.75.
Installation Cost	$2000-7000
Annual Operating Cost	Some typical data [for three people]: With a gas auxiliary tank system: $149.83 With an electric auxiliary tank system:$175.64

Solar thermal systems can substantially reduce the amount of fuel you need to heat water and require minimal maintenance. However, it requires some form of supplementary heat (gas, electricity, wood, etc.) to meet all your hot water needs, particular in the winter [8] [9]. A downfall to solar thermal systems is the lack of government incentives. Currently, the government provides generous credits and payments to homeowners and businesses that generate solar powered electricity, however, these credits only apply to electricity generation making homes with solar thermal systems in eligible for government credits. At this point, we choose solar panels systems for our customers.

4.2.2. Solar PV Components

The typical components of a solar photovoltaic (PV) system (Figure 3) are noted below.

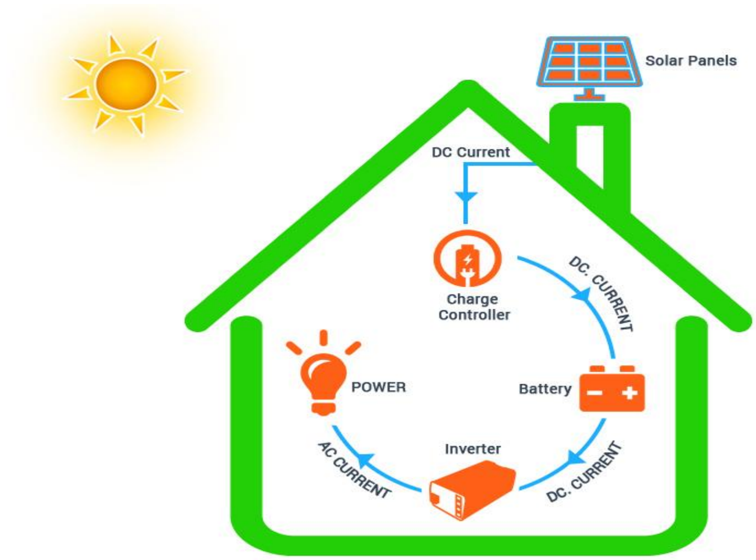

Figure 3. Components of Solar Photovoltaic (PV) Power Production. [9]

<u>Solar PV Panels</u>

The solar panel consists of three layers. The N-type layer is a semiconductor that consists of silicon material mixed with phosphorous [10]. This layer contains excess electrons. The P-type layer, also a semiconductor, contains silicon material mixed with boron [10]. This layer has a lack of electrons and is positively charged. The P/N junction exists between the N and P-layers and contains pure silicon [10]. At this junction, excess electrons move from the n-layer to fill holes in the p-layer. With adequate electrical wiring and resistance loads, the movement of electrons through the P/N junction produces the electrical current necessary to provide power [10]. This movement does not occur spontaneously, however. Electrons in the n-layer absorb energy from the photons contained in the incident sunlight. The electron energy must be greater than the band gap energy of the semiconductor to facilitate electron movement to the P-type layer and subsequent current production [10]. There are several types and models of solar PV panels, all with different efficiencies and power outputs. These will be discussed in the next section.

Mount Stands

These are required in order to place solar panels on the roof safely and there are different types of mounts, corresponding to panel placement; rooftop, ground or building facades. For this project, we will be exploring rooftop panel mounts. There are three main types, which will be discussed later; fixed mount, adjustable mount and tracking mounts [11].

Controller

The controller regulates the voltage and current that comes from the solar panels and goes to the battery. Most panels put out more current than the batteries can take, so this is an important tool, as it prevents the potential of overcharging the batteries [9].

Inverter

Solar panels generate direct current (DC) electricity, which is also the same type that is stored in batteries. However, alternating current (AC) is the suitable form of electricity used in homes. The inverter converts DC to AC current using a series of switches that flip the DC current backwards and forwards multiple times, to create AC current [9].

Battery/Storage System

When solar power systems produce more electricity than is needed by the homeowner, a battery/storage system is necessary to store the excess energy. This energy can then be used when the panels are producing little to no energy, for example nighttime or less sunny days. Additionally, the battery/storage system can help further reduce the homeowner's bills due to the fact that electricity is more expensive during peak hours, at night. For this project, the homeowner desires to sell electricity back to the grid, so a battery/storage system will not be necessary.

Distributor

The distributor transports the AC power generated by the inverter. Current generated by inverter goes to a breaker in the home's electrical panel, and through the home, while excess electricity flows backwards and into the grid [9]. Credit will be paid to the homeowner, by the utility company. If the panel is not generating enough electricity, the deficit will be made up by utility company.

4.2.3. Solar Panel Options

Monocrystalline Silicon

This is the most effective type of solar panel, with an average efficiency of 15% [12]. This panel type has a number of advantages. They produce more energy than the other types of panels, so they require less space. They last longer than the other cells and also perform better under low light [12]. This panel does not come without disadvantages, however. The biggest disadvantage is the price; since it is cut from a single monocrystalline crystal, it is more expensive than the other panel types [12]. Therefore, monocrystalline is usually not the first option for homeowners. Additionally, the production of monocrystalline panels is a very wasteful process. Finally, the panels are highly affected by dirt or shade as the dirt particles can break the circuit [12].

Polycrystalline Silicon

This panel is less expensive than monocrystalline and with an average efficiency of 13%, it is the more economic option for homeowners [12]. In this case, multiple silicon crystals are melted together and then recrystallized to form polycrystalline, which is a less expensive and less wasteful process than monocrystalline [12]. In addition, the overall performance of these panels are very similar to the monocrystalline panel performance. The main disadvantage is that more panels will be needed to produce energy at the same rate as monocrystalline, due to the lower average efficiency of the polycrystalline panel. Therefore, more rooftop area will be needed. In addition, higher heats can reduce the overall lifespan of the panels [12].

Amorphous/Thin Film

These are the least efficient panels, at 7%, but are also the cheapest option on the market [12]. The main advantage of this panel is the price; it can be mass produced at a much cheaper cost than any other type of solar panel. In addition, these panels work well in low light, as opposed to the monocrystalline option and they can even generate some electricity from moonlight [12]. The main disadvantage is the efficiency. With such a low energy conversion efficiency, more panels will be required in order to generate the same amount of energy as the other panels. As a result, these panels are only feasible in areas where space is not a big issue. Therefore, they are generally not used for residential purposes. Finally, the cells within this panel degrade at a much quicker rate than the crystalline panels, so it has a much lower life span [12].

Hybrid Silicon

These are the most efficient solar panels, at 18% efficiency [12]. They are made from a mix of amorphous and crystalline cells. These types of panels are still in the research and development stage, so they are currently the most expensive option. Once the technology becomes commercialized and scaled up, hybrid panels should become the best option on the market.

4.2.4. Solar PV Models Comparison

We considered several PV models for installation. The following tables summarize operating parameters for a few panel types. The panels under consideration are manufactured by Canadian Solar [13].

Type: CS69P
Cell Specifications: Polycrystalline. 6 inch. 60 Cells (6*10)
Module Weight: 18kg. Dimensions: 1638*982*40(mm). Module Area: 1.60 m^2

Model	Module Power (Watts)	Module Efficiency (%)	Operating Voltage (V)
260P	260	16.2	30.4
265P	265	16.5	30.6
270P	270	16.8	30.8

Type: CS6K/CS6X
Cell Specifications: Polycrystalline. 6 inch. 60 Cells (6*10).
Module Weight: 18.2 kg. Dimensions: 1650*992*40(mm). Module Area: 1.64m^2

Model	Module Power (Watts)	Module Efficiency (%)	Operating Voltage (V)
260P	260	15.9	30.4
265P	265	16.2	30.6
270P	270	16.5	30.8
275P	275	16.8	31
285P	285	14.9	35.8

Type: CS6K
Cell Specifications: Monocrystalline. 6 inch. 60 Cells (6*10).
Module Weight: 18.2 kg. Dimensions: 1650*992*40(mm). Module Area: 1.64m^2

Model	Module Power (Watts)	Module Efficiency (%)	Operating Voltage (V)
275M	275	16.8	31.3
280M	280	17.1	31.5
285M	285	17.4	31.7

These were just comparisons of a few panels Canadian Solar has to offer. There were many more types to compare and in order to make a decision on which panel type/model to use, we considered the efficiencies, size and power output of each panel. After careful consideration, we chose the CS6X-285P Max Power model. It has efficiency of 15%, which is relatively low compared to the panels compared in the above tables. However, this model contains polycrystalline cells and has a high output rating at 285 kW, so it is a more economic option for the homeowner.

4.2.5. Solar PV Mount Design: Fixed, Adjustable or Tracking System

Fixed Mount

Fixed mounts are completely stationary, with a fixed tilt angle. One of the advantages of such a rigid system is that fixed mounts can accommodate harsher environmental conditions [14]. They are also the least expensive option, considering their lower installation and maintenance costs. The disadvantage of this rigid system is that the panel tilt angle cannot be adjusted to account for the variability in the Sun's position, so therefore it would have a lower energy output over certain time periods.

Adjustable Mount

Adjustable solar panel mounts can be manually adjusted to maximize the power output of the panels. This is a huge advantage of the system, as panel output can be increased by up to 25% by adjusting the panel mount 2 or more times a year [11]. Typically, they will be adjusted in the winter to account for the sun's lower position, then adjusted again in the summer when the sun is at a higher position in the sky. Additionally, if the region gets regular snowfall in the winter, the steeper angle of the panels makes it easier to shed snow. So this would be very applicable for Barrie. The disadvantage of the adjustable mount comes with rooftop installation. Manual adjustment of the mount could be a stressful, or even dangerous task for the homeowner.

Solar Tracking Mount

Solar tracking mounts automatically move the solar panel system to track the movement of the sun across the sky, resulting in more direct incident sunlight and maximized panel output [14]. Main advantages include a larger amount of electricity generated, compared to the fixed and adjustable mounts. It is about a 10-25% increase in panel output, depending on the geographical location of the solar tracker [14]. They also generate more electricity with similar space requirements as fixed systems. This is great for optimizing land usage. The main disadvantages include price and complexity of the system. These mounts cost about $0.11-$0.13/Watt more than fixed mounts, depending on the size and location of the project [14]. Due to the complexity of the system, more site preparation and project deliverables will be required; project timeline is increased. In addition, more maintenance will be required for tracking system. Finally, tracking systems are designed to be used in warmer climates, so they will not be very applicable in Barrie's climate.

4.2.6. Solar Panel Layout

Panel Orientation

For maximum output, solar panels should face true South. This is the direction in which the most sunlight will be captured. Ideally, no trees or tall objects should be nearby, as they could block the sunlight, greatly impairing the system's ability to produce energy.

Optimum Tilt Angle

This is the best angle from the horizontal, at which the panel should be tilted for maximum production. The optimum tilt angle depends on latitude. The latitude for Barrie, Ontario is 44.89°N. There are rules of thumb to be utilized, depending on the type of mount being installed. For fixed mounts, the optimum tilt angle is equal to the latitude multiplied by 0.76, plus 3.1 [15]. For Barrie, this corresponds to an optimum tilt angle of 37.2°. For adjustable mounts, assuming they will be adjusted twice a year, the optimum summer tilt angle is equal to the latitude times 0.93, minus 21°, and the optimum winter angle is equal to the latitude times 0.875, plus 19.2° [15]. So, the optimum summer and winter tilt angles for Barrie would be 20.7° and 58.5°, respectively. For solar tracking mounts, there is no rule of thumb for optimum tilt angles, as the panel automatically adjusts the tilt.

4.3. Proposed Size

Based on customer provided utility data and roof availability, it was determined that optimal unit sizing is a 7 kW system. A comparison between solar output of a 5 kW system versus a 7 kW system was performed providing a maximum of 8302.389 and 11538.293 kWh annually, respectively. The expected electricity production based on a 7.125kW system for fixed axis and one-axis mounting are in Table 2 as follows, which were used for the cost-benefit analysis.

Table 2. Expected electricity production based on a 7.125kW system for fixed axis and one-axis mounting

Month	Daily Solar Radiation – Tilted (Fixed) $kWh/m^2/day$	Electricity Production (Fixed) kWh	Daily Solar Radiation – Tilted (One- axis) $kWh/m^2/day$	Electricity Production (One-axis) kWh
January	2.29	489.182	2.74	583.914
February	3.22	613.910	3.88	740.464
March	3.84	793.690	4.71	973.308
April	4.63	895.809	5.89	1138.927
May	5.15	1001.987	6.55	1274.652
June	5.54	1020.002	7.47	1376.003
July	5.58	1048.346	7.23	1358.779
August	5.22	984.079	6.80	1282.677
September	4.55	846.977	5.66	1052.967
October	3.40	675.827	4.03	802.584
November	2.16	429.66	2.51	500.437
December	1.90	400.536	2.15	435.581
Annual	3.96	9200.01	4.97	11538.293

4.4. Cost Benefit Analysis

The cost/benefit analysis was conducted using RETScreen [2], which is a clean energy software used for energy efficiency and renewable project feasibility. Using RETScreen it was determined that the required size for optimal output for the system was 7.125 kW. A resource assessment, comparing fixed axis and one-axis mounting, for the

7.125 kW system can be found in Table 3. Noteworthy increases in annual electricity production are evident between fixed and one-axis mounting systems when assessing poly-Si - CS6X-285P – MaxPower produced by Canadian Solar [2].

Table 3. Resource Assessment for 7.125 kW system for fixed axis and one-axis mounting [2]

Resource Assessment	Solar tracking mode	Fixed	One-axis
	Slope	35	35
	Azimuth	0	0
	Type	poly-Si	poly-Si
	Power Capacity /kW	7.125	7.125
	Manufacturer	Canadian Solar	Canadian Solar
	Model	poly-Si - CS6X-285P - MaxPower	poly-Si - CS6X-285P - MaxPower
	# Units	25	25
	Efficiency	14.85	14.85
	Nominal Operating cell temperature	45	45
	Temperature coefficient	0.40%	0.40%
	Solar collector area	48	48
	Miscellaneous losses	5%	5%
Summary	Initial Costs $/kW	3300	4200
	$	23,513	29,925
	O&M cost $/kw-year	15	30
	$	106.88	214
Annual Electricity Production	kWh	9200.01	11538.293

It was determined that the overall cost for a fixed mount tracking mode would total approximately $23,513, where an adjustable one-axis mount would total that of $29,925. To further examine the benefits of a fixed versus an adjustable one-axis mount system a financial comparison was performed. A 10.7 and 12.2 year equity payback was determined for the one-axis and fixed mount systems, respectively. The model calculates the equity payback, which represents the length of time that it takes for the owner of a facility to recoup its own initial investment (equity) out of the project cash flows generated. The equity payback considers project cash flows from its inception as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. A benefit-cost ratio comparison also reveals a ratio greater than 1 for both proposed mount systems, indicative of a profitable project. Based on enhanced performance and an improved equity payback the one-axis mounting system was chosen for the system optimization. The results of the one-axis mounting system are presented below. Results for the fixed axis system can be found in the appendix.

An overview of initial cost, savings, and revenue provided are present in Table 4. The microFIT savings are calculated based on IESO version 4 microFIT price schedule, effective January 2017, and the estimated annual electricity production. The one-axis system had $673 increased yearly microFIT savings compared to that of the fixed mount. Factoring in financial parameters, assuming the solar system is to be financed at a debt ratio of 70%, total annual costs including maintenance and debt payments for the 7.125 kW PV system is $32,439. For details on the financial parameters please see appendix Table A.1.) An assessment of yearly cash flows (after tax) reveals a payback period, of 10.7 years as displayed in Figure 4. Please see Table A.2 for predicted yearly cash flows after tax.

Table 4. 7.125 kW system – one-axis		
[2]**Cost|Savings|Revenue**		
Initial Costs	100%	29,925
Annual cost and debt payment		
O&M costs	$	214
Debt payments - 15 yrs	$	2300
Total Annual Costs	$	32,439
Annual Savings		
microFIT savings	$	3323
Financial Viability		
Pre-tax IRR - equity		14.60%
Pre-tax IRR - assets		2.70%
After-tax IRR - equity		10.70%
After-tax IRR - assets		0.13%
Simple Payback	yr	9.60
Equity Payback	yr	10.70
NPV	$	1537
Annual life cycle savings	$/yr	168
Benefit -Cost (B-C) ratio		1.2
Debt service coverage		1.4

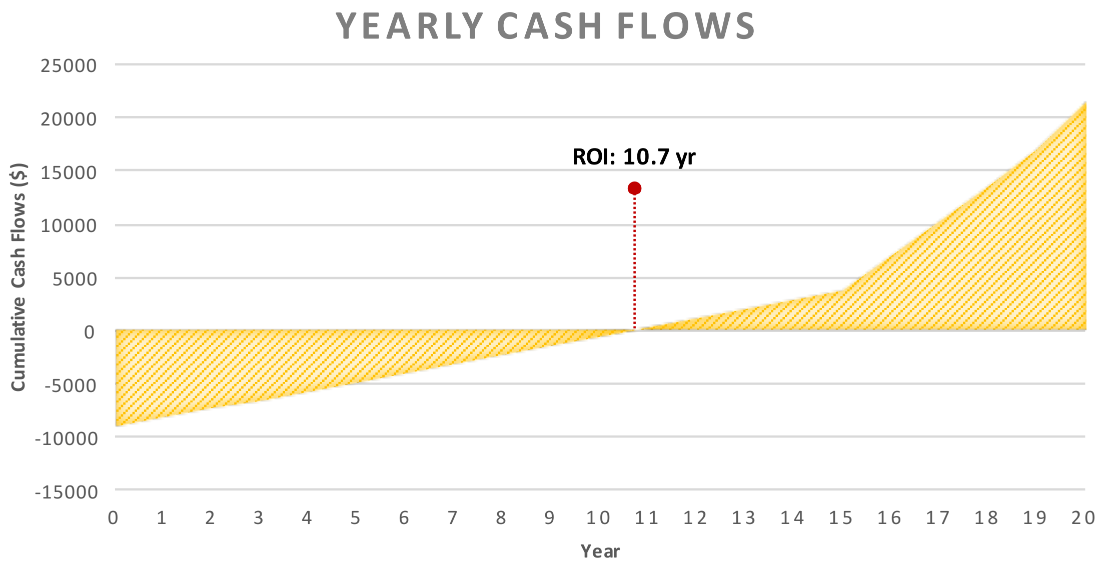

Figure 4. Predicted yearly cash flows (after-tax) for one-axis 7.125 kW solar system

Other economic considerations include maintenance fees and insurance coverage. Due to the nature of solar projects, little to no maintenance is required, totaling in at an annual fee of approximately $214. This annual fee includes the price for annual tilt adjustment as well as optional annual inspections. For a nominal fee, snow removal can also be performed. With regard to insurance, no specialty policy for solar system is required, and standard homeowner's insurance with liability coverage will suffice.

4.5. Proposed System Configuration

After factoring in the cost and advantages/disadvantages of each system, we decided to utilize the adjustable mount system, as it provides an option for seasonal tilt adjustment, therefore the maximum output of the solar panels can be realized. For a small operating and maintenance fee, the panels will be maintained and adjusted seasonally by our solar installation contractor. The proposed size of the solar panel system was calculated based on the output requirements, roof area and size of the individual solar modules. The required capacity of the solar panels was 7 kW. The roof area was estimated to be 191 m^2, with the area of the South-facing roof portion to be 50 m^2. Using the CS6X-285P Max Power solar panel, with a frame area of 1.91m^2, we determined that 25 panels would be required, producing 7.125 kW of electrical output, with an overall panel area of 48 m^2.

5. Power Purchase Agreement (PPA)

The PPA offered through the microFIT program spans a 20-year term for the electricity produced and delivered to Ontario's electricity grid, by the eligible participant. The micoFIT PPA contract is provided by the Independent Electricity System Operator (IESO) and can be cancelled at anytime. [4, 5] Applications are currently being accepted for microFIT version 4 with the following price schedule effective January 1, 2017 [16]:

Renewable Fuel	Project Size Tranche	Price (¢/kWh)
Solar (PV) – Rooftop	> 6 kW≤ 10 kW	28.8
Solar (PV) – Non-Rooftop	≤ 10 kW	21.0

NOTE: microFIT Program registration and application will be completed by us (NRSol) for a nominal fee. All the terms and conditions in PPA agreement will be review with our in house consultant.

6. Proposed Timeline

The timeline of this project is developed based on the below chronological order.

1. Site assessment and evaluation
2. Required permit and contracts
3. Material procurement
4. Installation and construction
5. Final system testing
6. Commissioning, maintenance and training

6.1. Critical Chain Path Method (CPM)

The detailed of proposed timeline which is consist of duration of each activity, the sequence of activities, start and finishing time of each activity is shown in the Table 5. The CPM chart shows the shortest and the longest of each activity based on their dependencies on each other. In this project the required time for completion of each step is obtained by 3-estimated approach. The CPM chart which provides a visual representation of this project activities, is shown in Figure 5. In this chart, critical tasks-activities which has zero float- are shown by red colour. (See Figure A.2 in appendix for larger version)

Table 5. Solar project sequence of activities

Task	Task Description	Required Predecessor	Duration	Start day	Finish day
Task A	Site Evaluation	None	1	2/1/2016	2/2/2016
Task B	Feasibility Study	A	3	2/2/2016	2/5/2016
Task C	Proposal	B	5	2/5/2016	2/10/2016
Task D	microFIT Application	B	2	2/5/2016	2/7/2016
Task E	Building Permits (Barrie)	C	10	2/10/2016	2/20/2016
Task F	Request Offer to Connect from LDC	D	10	2/7/2016	2/17/2016
Task G	IESO Review Period & Approval	F	50	2/17/2016	4/7/2016
Task H	Order Materials	G,C	7	4/7/2016	4/14/2016
Task I	Mount installation	H	1	4/14/2016	4/15/2016
Task J	Panel Installation	I	1	4/15/2016	4/16/2016
Task K	Wiring	J	2	4/16/2016	4/18/2016
Task L	System Testing (After each installment)	K	1	4/18/2016	4/19/2016
Task M	Meter Installation	L	1	4/19/2016	4/20/2016
Task N	Parallel Meter Connection	M	1	4/20/2016	4/21/2016
Task O	ESA Project Inspection & Certification	N	2	4/21/2016	4/23/2016
Task P	PPA Contract	N	1	4/21/2016	4/22/2016
Task Q	Final Systems Testing and project completion	O,P	1	4/23/2016	4/24/2016
Task R	Follow-up Maintenance & Training	Q	1	4/24/2016	4/25/2016

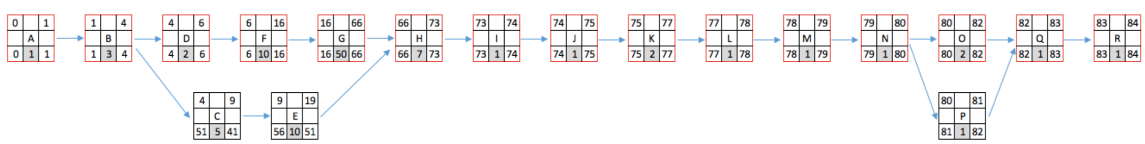

Figure 5. CPM chart for the proposed solar project

6.2. Gantt Chart

In the Gantt chart which is shown in Figure 6 the required time and the sequence of activities which is discussed in previous section is shown in Figure 5 in detail.

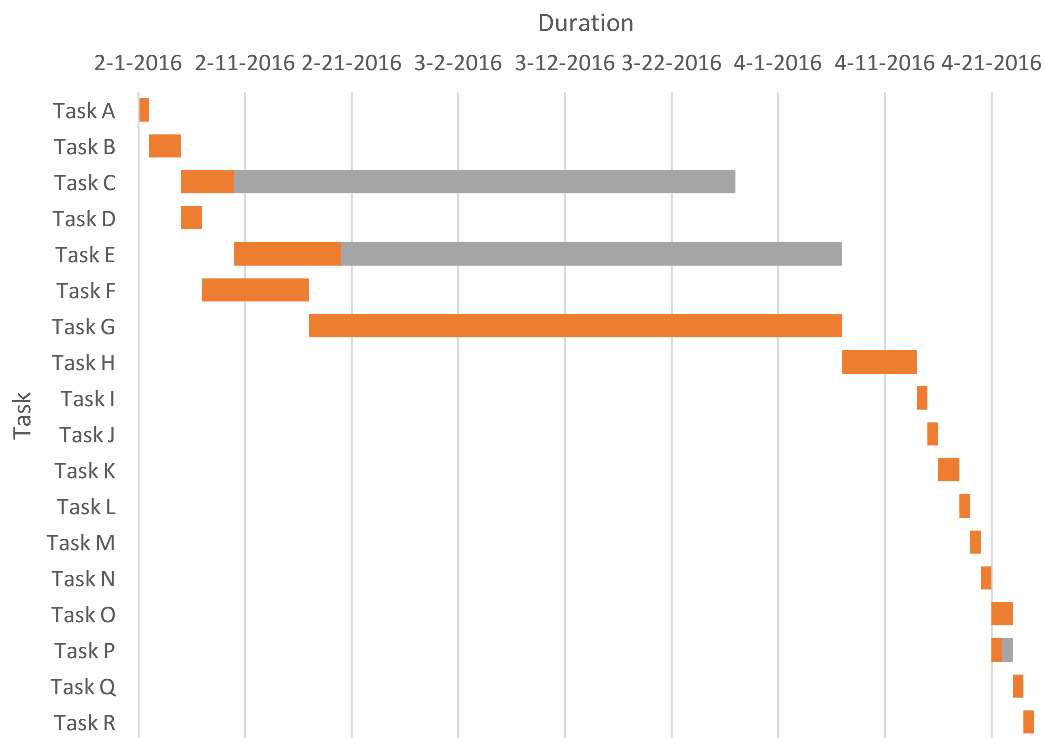

Figure 6. Gantt Chart

6.3. Resource Leveling

Resource leveling for this project is shown in Figure 7. This figure shows the number of employee which is required in each step of the project.

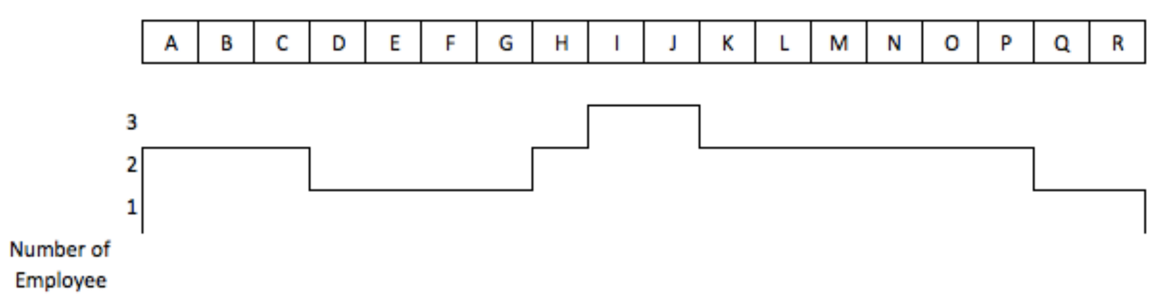

Figure 7. Resource leveling, number of employees required in each step of the project

6.4. Subcontractors

There are several solar PV contractors capable of undertaking a project like this, including companies such as Canadian Solar, Ontario Solar Installers and even local solar contractors such as EthoEnergy and SunFlow Solar. After careful consideration we decided to use two subcontractors. We will obtain the required solar panels from Canadian Solar. We chose them due to their extensive track record in Solar PV projects around the world, in addition to their wide range of solar PV panel models/types. We will contract out the installation and maintenance operations to EthoEnergy. They are a solar installation company based in Barrie, with over 1000 systems connected since 2009, 13,000kW of solar capacity developed, and 50,000+ solar panels installed in residential and business sectors [17]. Using a Barrie based subcontractor will result in quicker installation times.

7. Conclusion

We were tasked with developing a project management infrastructure for solar panel installation on the roof of a residential house in Barrie, Ontario. We identified how much the owner will reduce utility bill costs by taking advantage of government initiatives such as microFIT. We provided a cost benefit analysis, in addition to estimating the time and maintenance required. We conclude that this project is financially viable for the homeowner, with a 10.7 year payback and they will realize great savings of $ 3,323 annually, with this proposed solar panel system.

8. References

[1] Government of Ontario, "Ontario's Five Year Climate Action Plan 2016-2020," 2016. [Online]. Available: http://www.applications.ene.gov.on.ca/ccap/products/CCAP_ENGLISH.pdf . [Accessed 2016].

[2] Natural Resources Canada, *RETScreen Expert,* 2016.

[3] Government of Ontario, "Building Code Act, 1992, S.O. 1992, c. 23," 03 December 2015. [Online]. Available: https://www.ontario.ca/laws/statute/92b23.

[4] IESO, "microFIT Program Overview Version 4.0," 21 June 2016. [Online]. Available: http://microfit.powerauthority.on.ca/sites/default/files/microFIT-Program-Overview.pdf. [Accessed 2016].

[5] IESO, "microFIT program: Addressing Marketplace Issues," 8 November 2016. [Online]. Available:

http://microfit.powerauthority.on.ca/sites/default/files/microFIT-expectations-20161108.pdf. [Accessed 2016].

[6] Ontario Energy Board, "Information for Generators," 13 01 2016. [Online]. Available: http://www.ontarioenergyboard.ca/oeb/Industry/Rules%20and%20Requirements/Information%20for%20Generators/What%20Initiatives%20are%20Available.

[7] C. Barnes, " Saving for a sunny day," 28 August 2014. [Online]. Available: https://www.choice.com.au/home-improvement/energy-saving/solar/buying-guides/solar-hot-water-systems . [Accessed 2016].

[8] Energy Saver Inc., "Estimating the cost and energy efficiency of a solar water heater," [Online]. Available: http://energy.gov/energysaver/estimating-cost-and-energy-efficiency-solar-water-heater . [Accessed 2016].

[9] Solar Nation, "So what are the components of a solar power system?," 2015. [Online]. Available: http://www.solar-nation.org/so-what-are-the-components-of-a-solar-power-system.

[10] J. Wallace, "Photovoltaic Fundamentals," 2016. [Online]. Available: portal.utoronto.ca Directory: courses/Fall-2016-MIE515H1-F-LEC0101 Photovoltaic%20Fundamentals_rev%281%29.pdf.

[11] Peak Solar, "Types of Solar Array Mountings: Fixed, Adjustable and Tracking.," 12 August 2013. [Online]. Available: https://needsolarsystem.wordpress.com/2013/08/21/types-of-solar-panel-array-mountings-fixed-adjustable-tracking/.

[12] The Renewable Energy Hub, "What are the different types of solar photovoltaic cells?," 2016. [Online]. Available: https://www.renewableenergyhub.co.uk/solar-panels/what-are-the-different-types-of-solar-photovoltaic-cells.html.

[13] Canadian Solar, "Solar Modules," [Online]. Available: http://www.canadiansolar.com/na/solar-panels/dymond.html.

[14] Solar Power World, " Advantages and Disadvantages of a Solar Tracker System.," 09 May 2016. [Online]. Available: http://www.solarpowerworldonline.com/2016/05/advantages-disadvantages-solar-tracker-system/.

[15] C. R. Landau, "Optimum Tilt of Solar Panels," 11 November 2015. [Online]. Available: http://solarpaneltilt.com/#2season.

[16] IESO, "FIT Price Schedule," 2016. [Online]. Available:

http://fit.powerauthority.on.ca/sites/default/files/2017-FIT-Price-Schedule.pdf .

[17] EthoEnergy Inc., "A story of our future," 2016. [Online]. Available: http://www.ethoenergy.com/company/.

Appendix

Financial parameters for both the fixed and one-axis mounting system.

Table A.1. Financial parameters used for project feasibility analysis

Parameters	Unit	Fixed	One-axis
General			
Inflation Rate	%	2%	2%
Discount Rate	%	9	9
Project life	yr	20	20
Finance			
Debt ratio	%	70	70
Debt	$	16459	20948
Equity	$	7054	8978
Debt interest rate	%	7	7
Debt term	yr	15	15
Debt payments	$/yr	1807	2300
Income Tax analysis			
effective income tax rate	%	30	30
Loss carryforward?		No	No

Details regarding the predicted yearly cash flow for the one-axis 7.125 KW solar system can be seen as follows:

Table A.2. Predicted yearly cash flows for the one-axis 7.125 KW solar system

Year	Pre-tax	After-tax
0	-8978	-8978
1	872	809
2	935	813
3	1000	819
4	1066	824
5	1133	831
6	1202	838
7	1272	845
8	1343	852
9	1416	859
10	1490	866
11	1566	873
12	1643	879
13	1722	885
14	1803	890
15	1885	893
16	4268	3196
17	4354	3245
18	4441	3296
19	4530	3349
20	4620	4620

Table A.3. 7.125 kW system – Fixed axis		
Cost|Savings|Revenue		
Initial Costs	100%	23,512
Annual cost and debt payment		
O&M costs	$	100
Debt payments - 15 yrs	$	1807
Total Annual Costs		25,419
Annual Savings		
microFIT savings	$	2650

Financial Viability		
Pre-tax IRR - equity		13.20%
Pre-tax IRR - assets		2.00%
After-tax IRR - equity		9.60%
After-tax IRR - assets		-0.45%
Simple Payback	yr	10.10
Equity Payback		12.20

NPV	$	398
Annual life cycle savings	$/yr	43.55
Benefit -Cost (B-C) ratio		1.1
Debt service coverage		1.3

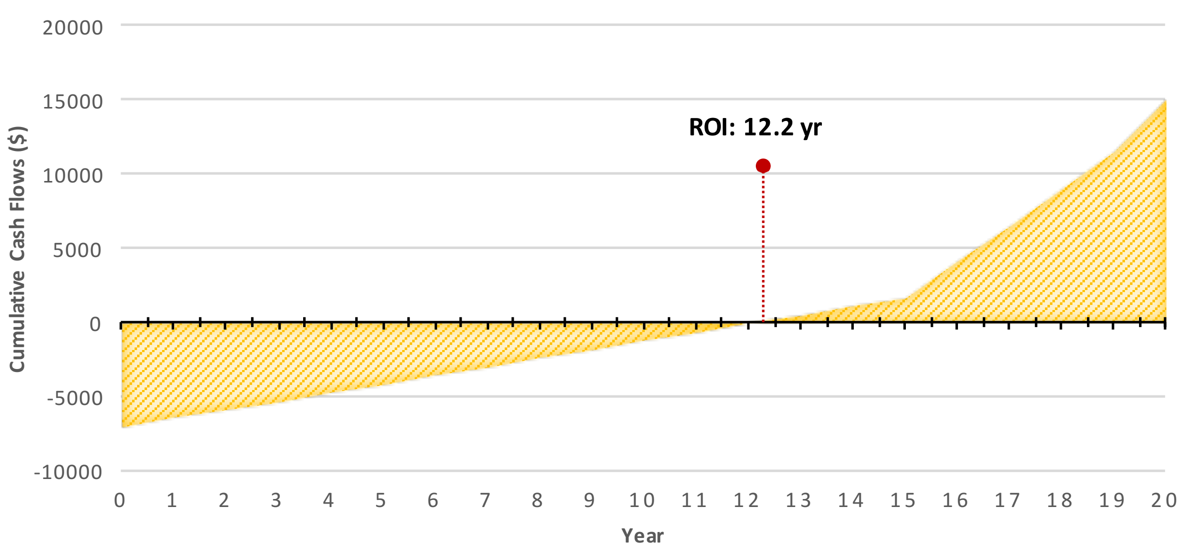

Figure A.1. Predicted yearly cash flows (after-tax) for fixed-axis 7.125 kW solar system

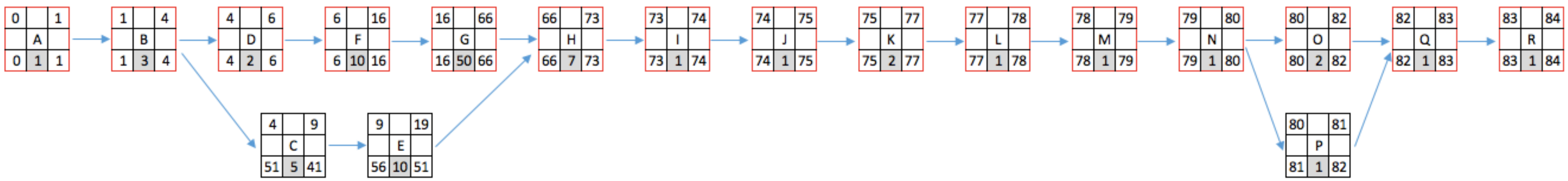

Figure A.2. CPM chart for the proposed solar project