

Assessing the cost feasibility of solar projects in Canada using the RETScreen Expert software

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## ABSTRACT

The climate emergency is melting glaciers, destroying forests and increasing sea water levels worldwide. The burning of fossil fuels, current urbanization and transportation patterns, careless industrialization all release harmful greenhouse (GHG) gases to the atmosphere leading to the biggest issue faced by humanity: climate change. Countries around the world are addressing GHG emissions by transitioning to renewable energy sources. Energy experts calculate that offsetting 50% of all future demand growth in thermal electricity generation by solar photovoltaics (PVs) would reduce annual global carbon dioxide emissions by 10% in 20 years and 32% in 50 years. Installing more renewable energy projects worldwide to reduce GHG emissions is a way forward to avert the climate emergency. Countries like China, India and Germany on the one hand are the top greenhouse gas emitting countries in the world and on the other are becoming world leaders in installing solar projects, thereby reducing global installation costs and making solar power more financially and technically viable. By investing in research, development, and deployment those three countries are making solar PV systems better and extremely cost-effective for every other country. Empirical data clearly shows that today solar PV is now the cheapest source of electricity in the world and has reached grid parity in comparison to fossil fuel sources. Canada is amongst the top 10 countries in the world in terms of generating the most greenhouse gas emissions. In 2019, Canada emitted more than 1,982 MTCO<sub>2</sub> emissions on this earth and is ranked eighth in the world in terms of emissions. As per the Paris Agreement, 2015, Canada had committed to reduce its GHG emissions by 30 per cent from 2005 levels by 2030. To achieve that ambitious goal, Canada needs to focus on policies and processes that would help reduce GHG emissions in the long run. But is Canada making sufficient efforts to reach their target and to change the policies that favor more renewable energy installations, especially solar energy? This study reveals that Canada has a history of scraping decisions and policies that were made to promote and benefit the solar industry. No incentive systems are active at present, and the government is not rolling out plans for subsidies to solar projects that would have helped the sector achieve low-cost projects and hence acted as a motivation for more installations. By analyzing an actual quote given by a company for a 10-kW solar project in Ontario and assessing the costs using the RETScreen Expert software, this study concludes that a solar project is not feasible in Ontario if there are no incentives or subsidies provided to offset the high costs. This is further backed up by Canada's ranking at the international level as compared to the other countries in terms of total installed solar capacities and the cost of solar installations which shows that Canada has not been focusing on increasing solar installations that would have brought down the costs and made the projects feasible, and hence would fail to achieve the 2030 targets as it is not creating positive a policy environment with yearly targets and aim to reduce the GHG emissions.

## FOREWORD

Climate change is real, and it needs to be tackled by the present generation. Governments all over the world should focus on reducing greenhouse gas emissions, implementing ambitious regulations and incentive measures, setting science-based goals, and bringing investment and governance reforms, by promoting renewable energy and diversifying their energy portfolios.

This research focuses on the challenges to deploying solar PV systems within a Canadian context. My background of working in the solar industry in India, has given me an edge to understand some technical and financial scenarios that are applicable to solar systems across the world. Although a lot of factors change with geography there are also many commonalities in different parts of the world. In the past, I have worked closely with government officials in formulating and amending solar policies in India. In those professional experiences, I learnt that energy sector policies vary across countries and that policies favoring renewable technologies must evolve with national energy targets. Canada has a weaker policy ecosystem as compared to India, when it comes to supporting renewable technologies (especially solar PV), as the Canadian government has defined no federal yearly targets and has consistently cancelled incentive schemes in the past. Nevertheless, people passionate about deploying solar PV systems in Canada are working at their own end to make things happen and try hard to install systems using weak policies (e.g., net-metering regulations).

My research goals at York U were to learn more about the solar industry across the world and compare experiences with the Canadian scenario (e.g., by contrasting performance data and development figures). My graduate research has allowed me to learn more about solar system components and the importance of cultural factors as well as the difference technological approaches used in the western world. Since system costs and project feasibility are key drivers of investment around the world, focusing on assessing costs and project feasibility made sense to me. This focus further allowed me to dwell into government policies and analyze market barriers that are hindering the growth of the renewables industry.

My research has been guided by my plan of study, specifically understanding the renewable industry in Canada, and finding possible energy-efficient solutions that are feasible. Over the course of my graduation, I learnt the business aspect of sustainability and how energy-efficient solutions can be cost-effective for companies. By incorporating these practices, organizations can achieve their ESG (environment, society, and governance) goals and can become more sustainable.

Working with a professor at York University that is deeply connected with the Canadian solar industry, who is also my supervisor (i.e. Dr. Jose Etcheverry), we landed the opportunity of working on a real solar PV project at the Wheelbarrow Farm (located in Uxbridge, Ontario). This permaculture farm is also the proud owner of Canada's first electric tractor (which is charged using a 10-kW solar array).

During the summer of 2021, I learnt how to use RETScreen Expert software, which is a clean energy management simulation software, and a very powerful tool to assess and analyze the feasibility of renewable energy systems. For this report, I worked on a system analysis assessment, by comparing the actual costs of the solar PV system installed at the Wheelbarrow farm with average solar system costs in Canada being fed as inputs for simulation in the RETScreen Expert software. As part of this research, I have also closely analyzed the incentive schemes that are/were applicable in Canada for small rural and agricultural solar PV projects (like the ones implemented at Wheelbarrow Farm) and have explored new options to increase the use of solar PV in rural Canada. My research results led to proposing a portable solution of "Solar on a container" with battery systems, that can help meet energy needs locally. This new system is designed to be easily deployable and can be used for multiple purposes.

My research, therefore, concludes with a new eco-friendly renewable energy product, based on solar PV technology and energy storage systems that can be commercialized throughout Canada. That commercial focus aims at satisfying my requirements for the Business and Sustainability Diploma and provides me with a new product to help expand my professional practice as a solar expert after graduation from my master's degree.

## ACKNOWLEDGEMENTS

This paper is an outcome of the learnings of my master's at York University with the Faculty of Environmental and Urban Change. There was one person throughout this journey of mine from day one, who is my Advisor as well as Supervisor, Professor Jose Etcheverry. I would like to personally thank him for guiding me at each step, making things happen, motivating me for experiential learning and for always being there for me. My fellow master's colleague, Alice Olaluwoye, has been a constant support for me and helped me brainstorm new ideas about my graduate research. I also want to thank Tony Neale, the head farmer of the Wheelbarrow Farm for giving us an opportunity to work with him on his solar project at the farm. I learnt many new softwares during my studies at York U that have helped me analyze the data that I have presented in the report. Lastly, constant faculty support of EUC has helped me achieve this and produce this research paper that I enjoyed writing.

*Apeksha*

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## LIST OF ABBREVIATIONS

AC	Alternating Current
CanSIA	Canadian Solar Industries Association
CDM	Clean Development Mechanism
CERC	Central Electricity Regulatory Commission
CSA	Community Supported Agriculture
CUF	Capacity Utilization Factor
DC	Direct Current
EIA	U.S. Energy Information Administration
ESG	Environment, society, and governance
FIT	Feed in Tariff
GBES	Green Building Education Services
GBI	Generation based Incentive
GDP	Gross Domestic Product
GHG	Greenhouse gas
IBC	Insurance Bureau of Canada
IEA	International Energy Agency
IESO	Independent Electricity System Operator
IPCC	Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
LEED	Leadership in Energy and Environmental Design
MPPT	Maximum Power Point Tracking
NEB	National Energy Board
NREL	National Renewable Energy Laboratory
NSM	National Solar Mission
OPA	Ontario Power Authority
PPA	Power Purchase Agreement
REC	Renewable energy certificates
REL	Renewable Energy Law
REN	Renewables Now
RESOP	Renewable Energy Standard Offer Program
T&D	Transmission and Distribution
UN - SDG	United Nations' Sustainable Development Goals
USGBC	US Green Building Council
VGF	Viability gap funding

## Section 1 | Introduction

This report summarizes graduate-level work conducted to develop my understanding of the Canadian renewable energy sector. I designed the report as a guide for my professional development as a renewable energy practitioner and to ensure that I can continue exploring key research questions beyond completion of my master's degree. Becoming a renewable energy is a long journey and this report represent an important step to guide my professional development.

Solar energy is said to be the future energy source to power the world. It becomes essential to understand its worth to generate electricity as well as to tackle climate change issues. Countries all over the world have been undertaking and implementing the United Nations' Sustainable Development Goals – UN SDGs, as per their priorities and preferences of issues. Various studies and conferences on climate change have emphasized on the fact that renewable energy is required to diversify the energy portfolio of any country and that countries should make efforts to eventually phase out generation from high emission fossil fuels such as coal and gas. *Drennen et.al., 1996* in their paper have said that “offsetting 50% of all future growth in thermal electricity generation by photovoltaics (PVs) would reduce annual global carbon dioxide emission from projected increased levels by 10% in 20 years and 32% in 50 years.”

There are climatic differences in countries, but enough sunshine is available in most of the countries across the world, all the year round. Hence, deploying solar projects and increasing installations should be focused on in the policies formulated by all the governments at all levels. Due to difference in climatic conditions, trade policies and already established electricity networks, cost of renewable projects is different in every country, thereby affecting the feasibility and overall deployment.

This research study aims to find out feasibility of solar projects, especially in Canada based on international data available, and on the basis of a case study analysis of a farm in Ontario by assessing the cost feasibility of an installed solar project on the farm through the RETScreen Expert software.

## **Section 2 | Research Context**

This section aims at providing readers with a brief summary of the overall context of my research

### **Research Questions guiding my MES Report**

My graduate research is based on the assumption that renewable technologies have developed to the point that are a viable commercial proposition to address local energy security and a key solution to address the climate emergency. In short, renewable energy can fulfil all current and future energy demand while reducing greenhouse-gas emissions as a solution to climate change. To contextualize my work, the following research questions were used:

1. Is solar PV really a cost-effective solution as compared to the conventional fossil-fuel based energy systems?
2. What are the technical or policy barriers identified in the solar industrial growth?
3. Would major policy changes fuel up this growth?
4. Is the cost of solar systems feasible in Canada?
5. Do RE projects still need fiscal support and federal incentives to reduce the costs?
6. Should Canada come up with a yearly plan with realistic goals and achievable targets, to diversify its energy portfolio by increasing the share of renewables in the portfolio?
7. What is the future of solar PV industry in Canada?

### **Research Objectives**

1. To research about global solar scenario, solar PV system components, system advantages and major industry growth and drivers
2. To assess the barriers to solar industrial growth and suggest policy changes by reviewing policies of top countries with solar installations.
3. To determine the cost of solar components in Canada
4. To assess the feasibility of solar projects in Canada based on a comparison with the world data of other countries.
5. To assess an actual company quote for a solar PV system in Canada
6. To do a RETScreen analysis of a 10kW solar system based on average solar component costs in Canada, and then compare it with actual costs of the 10kW solar array on the Wheelbarrow farm located in Uxbridge, Ontario.

7. To propose a practical farm solution based on solar PV technology which is portable, accessible, customer-centric, multi-purpose as well as eco-friendly.

### **Scope of the study**

This research analyzes facts and figures of the energy sector and the electricity industry in the world, focusing on the renewable energy landscape, with special emphasis on Canada, and further down to the province of Ontario. The research identifies the role of renewable energy, especially solar energy, in combating climate change issues and the importance of a diverse energy portfolio for countries, in order to reduce the global greenhouse gas emissions. Understanding solar photovoltaic systems, their advantages and limitations is necessary to analyze the potential behind this renewable energy source, which relies on a fuel source that is available worldwide for free (sunshine) and that can provide electricity locally in almost any part of the world.

By analyzing the solar industry policy scenario in Canada, my study reveals major barriers and a lack of fiscal incentive schemes that create serious roadblocks for the industry to grow. In short, unlike many Asian and European countries, Canada currently lacks a proper renewable energy support system. That conclusion is supported by evidence of a current overall downward trend on solar installations in Canada, particularly in Ontario, and by the cost differential of solar projects as well the system components in Canada compared to other industrialized countries such as Germany.

More specifically, this study relies on a case analysis of a 10-kW solar project installed in the Wheelbarrow Farm in Ontario, that is evaluated using RETScreen Expert software, which assesses the project's financial feasibility when compared with the actual project costs and the costs used by the Virtual Energy Analyzer feature of the software. Furthermore, the study also suggests an innovative container based solar installation system for the farm, that can be an off-grid project with batteries to store the electricity generated thereby, supporting the farm's energy needs. Although the study results should not be used to generalize about the feasibility of developing solar PV systems in Canada, they nevertheless indicate that, at least in Ontario, current market structure is not favourable for widespread PV deployment.

## **Limitations of the study**

The COVID-19 pandemic has created all types of challenges and is also affecting researchers. More specifically, due to the province wide lockdown rules in Ontario in the past 20 months, the initial aim of this project (which was to re-install the 10k W solar system at the Wheelbarrow farm and add an additional capacity of 10kW), was not achieved. However, an innovative solution has been developed to be presented and recommended in this report.

Due to COVID restrictions, limited information could be accessed at the farm about the degradation of the original Wheelbarrow solar project and hence software simulations with RETScreen Expert, were done with the limited inputs that are available using project performance data and software simulations. When site visits are possible, it will be important to analyze the degradation of the Wheelbarrow PV systems and how they have been affected by storms and other weather-related phenomena. Since this research relies mostly on software simulations and a very small project sample, research results cannot yield the type of prescriptive conclusions or broad generalizations that can stem from a more comprehensive and statistically significant research. Nevertheless, the research presented here provides some indications of the problems faced by solar PV project developers in Ontario and can inform the design of larger studies of the sector.

## Section 3 | Literature Review

### Global Climate Change concern

Climate change has been identified as this century's key social concern, and a detrimental problem that can affect every living being on this planet. Climate emergency declarations have been made in 1,480 jurisdictions spanning 28 countries, and many solutions-oriented policies are in line with integrating renewable energy development into the forefront of decision-making. Among the most media-covered and recent events, in 2019, several strikes and climate protests involving millions of people across 150 countries proved that the concern about the issue is at the societal level and that the issue is no longer a political one.

Most of the global carbon emissions arise from cities. Heavy urbanization including constant construction as well as vehicular emissions account for three-quarters of global CO<sub>2</sub> emissions and two-thirds of final energy use. (*Renewables Now [REN 21],2020, Pg. 31*).

A few countries and regions are at the forefront of the climate emergency by implementing practical initiatives to help reduce greenhouse gas (GHG) emissions. For example, Darebin Council in Australia, in 2016, was the first government in the world to declare a climate emergency and work towards developing a plan to tackle this climate emergency by recognizing the contribution and the important role of renewable energy sources to reduce emissions in the long run. As a country, the United Kingdom was the first nation to declare a climate emergency in 2019 and has committed to take measures to reduce its GHG emissions by 2050 and reach net zero by employing more renewable energy technologies (*REN 21,2020, Pg. 26*) At the global level, 77 countries, 10 regions and more than 100 cities have now announced their commitment to net zero carbon emissions by 2050. Additionally, the European Commission has made a European Green Deal roadmap until 2050, with the intent of creating the first carbon-neutral continent by. (*Kosolapova,2019*)

While the majority of energy generation across the world is still contributed by fossil fuels, according to the data by *REN 21, 2020* report, renewable energy has grown three times faster than fossil fuels and nuclear over the past five-years span, but still accounts for less than a third of the increase in the energy demand across the world. Wind and solar energy can now be relied on as mainstream electricity sources in some countries and are getting increasingly cost-competitive as compared to fossil fuel power plants.

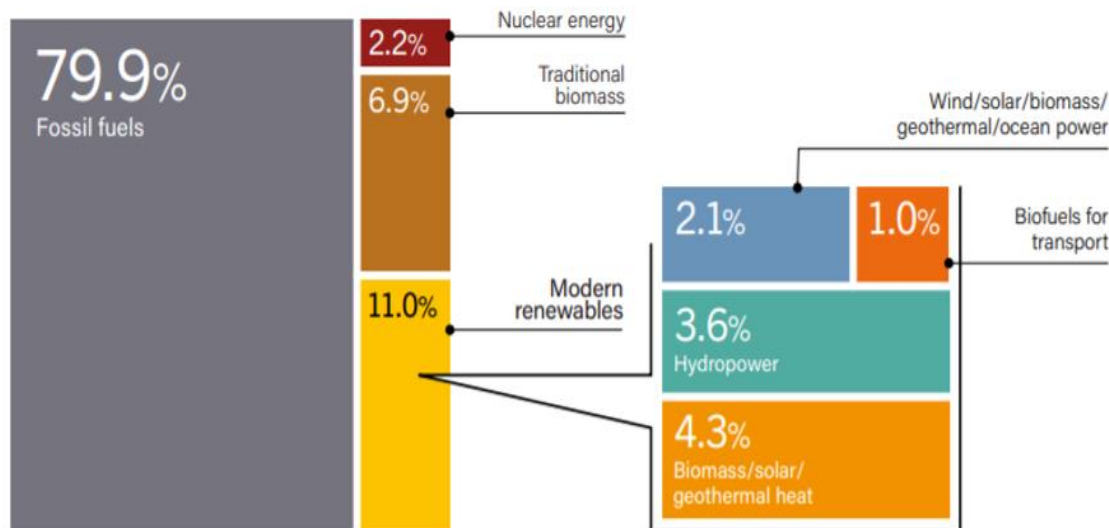


Figure 1: World Energy mix (*REN 21, 2020*)

Producing electricity from renewables has become cheaper and cost-effective almost everywhere in the world due to the high capital cost of setting up new coal-based power plants. (*Bloomberg New Energy Finance [NEF], 2020*). This cost-effectiveness as well as the public appeal of renewables has attracted major oil and gas companies to shift from traditional energy sources to investing in renewable energy technologies as well as electric vehicles. (*Willuhan, 2019*).

On December 12, 2015, Canada along with 194 other countries became signatories to the Paris Agreement which was a balanced and an ambitious global agreement to fight climate change. The agreement aimed to strengthen efforts that would limit the average global temperature rise to below 2 Celsius (C) and maintain average global temperature so that the projected increase is not more than 1.5 C. Canada committed to reducing its greenhouse gas emissions by 30% by the end of 2030 and also to achieving a target of 80% reduction in GHGs by 2050. As part of its commitment process, Canada has formulated a long-term strategy to reduce its GHG emissions. In its mid-century long-term strategy, which was submitted in response to its national commitment under the Paris Agreement, Canada

identifies decarbonization of the electricity sector as the most essential sector for GHG mitigation. (*National Energy Board [NEB], Canada, 2016*).

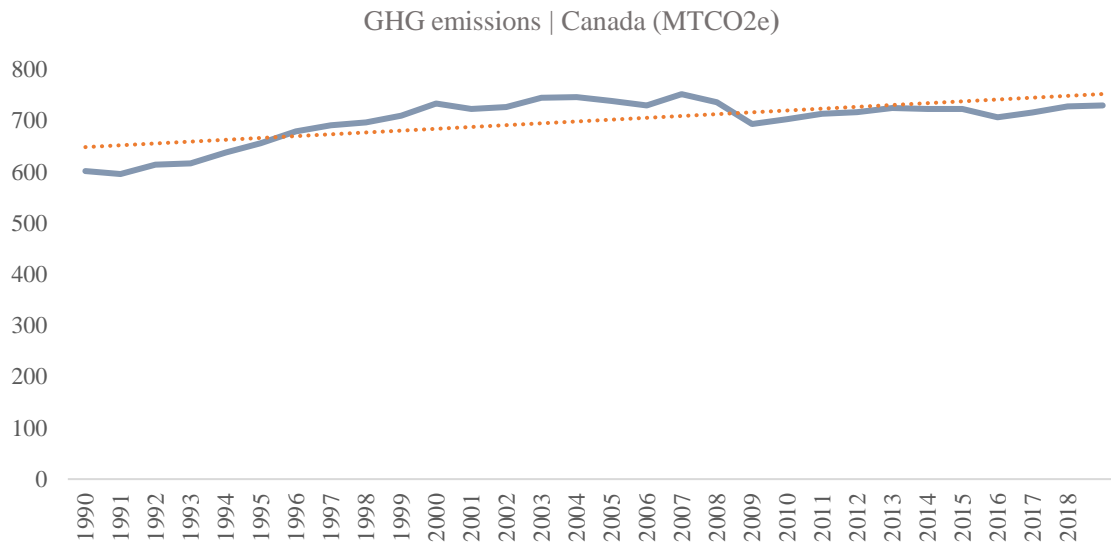


Figure 2: Yearly GHG Emissions trend for Canada (NRCan,2019)

Canada’s GHG emissions have been on a rising trajectory, and the federal government has plans to add more nuclear capacity as it terms it as a non-emitting source. Canada’s target is to generate 80% energy from non-emitting sources including a majority from nuclear energy. But the fact is that nuclear energy is not a “cheap” or “free” source of energy unlike solar and wind power (which do harness sources of fuel that are free of charge). Nuclear power is also a source of toxic waste and creates dangerous social scenarios (e.g., terrorism, nuclear accidents). The focus of this report is not on nuclear analysis, but the brief comments included above are here to highlight that a focus on nuclear investment in Canada is creating a lack of focus on renewable energy development. Canada has a huge potential of solar energy which is even more than Germany (which is today a world leader in solar development). Furthermore, Canadian cities such as Regina, Calgary and Winnipeg have solar potential which is above the average of most German cities. Therefore, Canada should tap into its enormous renewable energy potential and move its energy sectors towards cleaner fuels such as solar and wind.

**United Nations – Sustainable Development Goals (UN SDGs)**

In 2015, the United Nations laid out 17 sustainable development goals, that were adopted by UN Member States and that were part of a 15-year plan until the year 2030. Today, just 9 years are left for achieving all the UNSDGs goals and a UN World Summit in 2019 defined 2020-

2030 as the “Decade of Action”. The core goals of the 2020-2030 decade includes 17 interlinked goals (please see figure 3 below) that are all focused on:

1. the need for action to tackle growing poverty,
2. empowering women and girls, and
3. addressing the climate emergency.

Addressing Climate emergency has been on the top of all UN discussion meetings and plans to tackle this issue with renewable energy is being emphasized. Alongside, the Intergovernmental Panel on Climate Change (IPCC), with its Paris Agreement in 2015, strengthens the global response to the threat of climate change by “keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels”. This global target is achievable only when all the countries do their part in reducing their emissions and work towards formulating plans to set yearly goals and targets for the same. The Agreement lays down technology frameworks to enhance the capacity building frameworks with adequate and appropriate financial flows for the countries.



*Figure 3: UN-SDGs (United Nations,2015)*

### ***Elaborating on UN SDG Goal 13: Climate Action***

As the United Nations notes, 2019 had been the warmest year in the history that was ever recorded in the past decade. (*United Nations,2020*). Also, carbon dioxide levels as well as emissions from other greenhouse gases in the atmosphere had reached by 2019 the highest level since industrialization started two centuries ago. Climate change is already affecting lives, economies and the entire planet. As one of the top-most climate positive actions, the UN lists Green transitions saying that investments must accelerate decarbonization of all the economies (*UN-SDGs,2020*).

### ***Harnessing UN SDG Goal 7: Affordable and Clean Energy***

Transitioning the world towards clean energy that is also affordable is defined by the following targets of this goal:

1. By 2030, ensure universal access to affordable, reliable and modern energy services,
2. By 2030, increase substantially the share of renewable energy in the global energy mix.
3. By 2030, double the global rate of improvement in energy efficiency.

Countries like China, India and the European Union have laid down strong policies to transition to renewable energy sources and have set examples in making this renewable energy accessible as well affordable. Other countries having high emission rates, should follow the same path.

### **Global renewable energy landscape**

The world's energy landscape is seeing a transition and is shifting power generation from fossil fuels to renewable energy sources. This transition justifies global efforts to reach carbon neutrality. According to *International Energy Agency [IEA], 2020*, solar and wind energy have been the two top renewable energy sources that have been growing at the fastest rate in the last two decades, with solar installed capacity outnumbering the wind projects in the last 5 years. As per the yearly data by *International Renewable Energy Agency [IRENA],2019*, on an average, renewable energy capacity additions have been growing at a rate of 9 per cent. These

capacity additions are predicted to grow even further in the coming years with technology improvements.

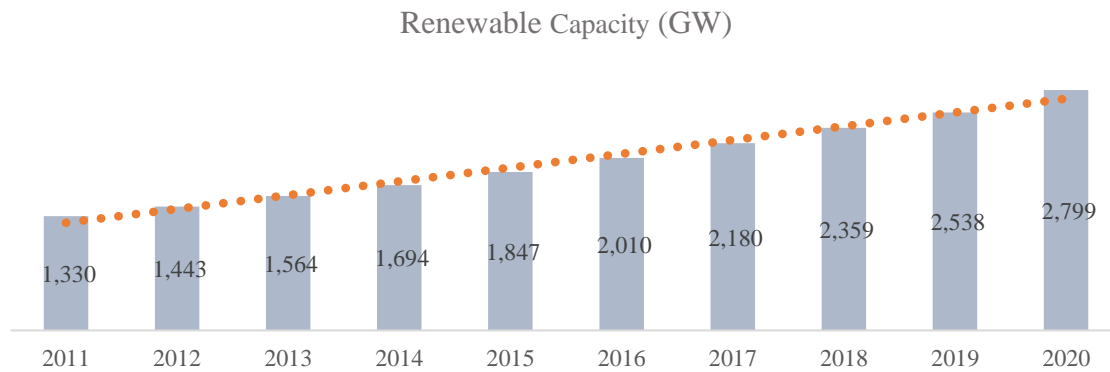


Figure 4: World Renewable energy growth trend (IRENA.2019)

In 2020, the renewable electricity sector worldwide grew by 45 per cent to reach a figure of 280 GW from 2019 which was the largest increase since 1999.

Out of this total, most of the installed renewable energy capacity worldwide was solar PV, which was followed by wind project installations. One of the countries that stands out in the renewable energy landscape, is China. It has become the center for global renewable energy supply and has been growing its total renewable capacity at a rate of 40 per cent per year for the past several years. According to *REN 21,2020*, there are lots of factors responsible for this enormous growth in renewable energy development. Lower interest rates, fluctuating oil and gas prices, better future long-term investor perspectives, promising technological revolutions along with the support of incentives and policies have all led to fast growth. Investments in the renewable energy sector in 2020 increased 2% from the previous year accumulating to USD 303.5 billion.

AVERAGE	8.6%	28.8%	14.4%	22.5%	21.9%			
Year	World (MW)	% World growth	Solar (MW)	% Solar growth	Wind (MW)	% Wind growth	Solar as % of World	Wind as % of World
2011	13,29,886		73,745		2,20,019		5.5%	16.5%
2012	14,42,763	8.5%	1,04,015	41.0%	2,66,908	21.3%	7.2%	18.5%
2013	15,64,390	8.4%	1,39,523	34.1%	2,99,919	12.4%	8.9%	19.2%
2014	16,94,061	8.3%	1,76,089	26.2%	3,49,300	16.5%	10.4%	20.6%
2015	18,47,258	9.0%	2,22,213	26.2%	4,16,248	19.2%	12.0%	22.5%
2016	20,10,005	8.8%	2,96,155	33.3%	4,66,864	12.2%	14.7%	23.2%
2017	21,80,389	8.5%	3,89,411	31.5%	5,14,374	10.2%	17.9%	23.6%
2018	23,58,749	8.2%	4,88,739	25.5%	5,63,830	9.6%	20.7%	23.9%
2019	25,38,441	7.6%	5,87,134	20.1%	6,22,249	10.4%	23.1%	24.5%
2020	27,99,094	10.3%	7,13,970	21.6%	7,33,276	17.8%	25.5%	26.2%

Table 1: World average renewable growth for solar and wind (IRENA,2020)

On average, solar energy installed capacity has been growing at a rate of 29% in the past 10 years. Wind on the other hand has seen lower growth (at an average annual rate of 14%). These two renewable energy sources contribute to a significant proportion of the world’s installed renewable energy capacity at a combined average rate of 22% every year to the overall energy mix. Since, wind and solar constitute the major renewable energy sources, which is approximately 50%, countries should focus on more deployment of these renewable energy as these technologies are becoming more cost-efficient.

### Global Solar scenario

Empirical data worldwide shows that wind and solar PV technologies are becoming the fastest growing forms of energy generation. Huge investments by big industrial players are being done in the sectors that have led to significant decrease in costs and bringing renewable energy to grid parity. Solar energy is one of the best options to meet future energy demand as it is better in terms of “availability, cost effectiveness, accessibility, capacity, and efficiency compared to other renewable energy sources.” (Kannan & Vakeesan,2016).

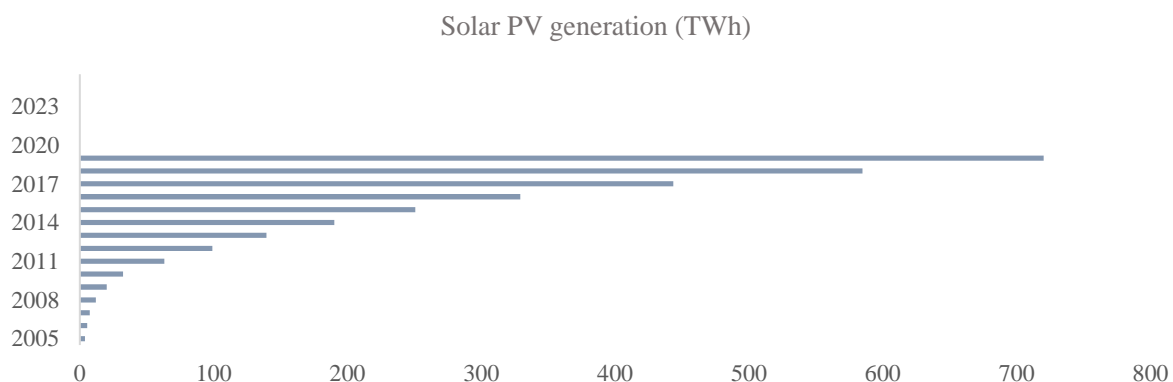


Figure 5: World Solar PV Generation (IEA,2020)

Although, only certain nations in the world are focusing in developing and installing solar plants, solar growth in the coming future seems strong and promising. Solar PV power generation has increased by 22 per cent in 2019 accounting to a total of a 720 TWh and it has increased by 131 TWh in 2019. (IEA,2020). Also, as per the future and current estimates, the International Energy Agency (IEA) states that solar PV is on track to reach the goal of 3300 TWh by 2030 (averaging an annual growth rate of 15%).

The top leading countries for cumulative solar PV capacity installations in 2020 continued to be China, the United States, Japan, Germany and India whereas the top five markets responsible

for 66% of new capacity additions have been— China, the United States, Vietnam, Japan and Germany (*REN21,2020*)

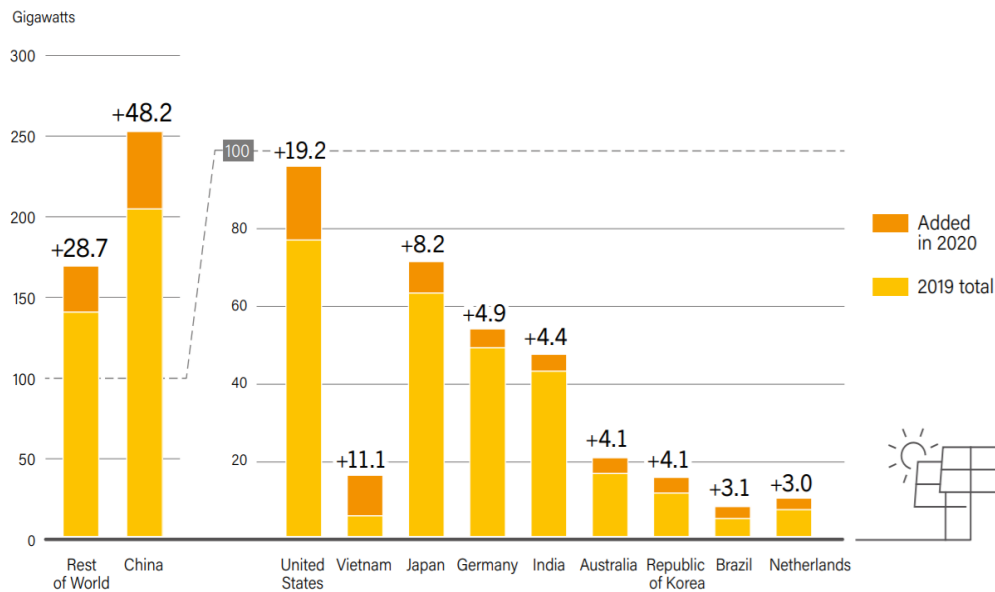


Figure 6: Countries leading in Solar PV capacity installations (*REN 21,2020*)

## Cost of Solar Projects

### Installation costs

Based on International Renewable Energy Agency (IRENA) projections and cost estimates, solar PV installation costs are bound to continue to drastically decline in the coming three decades until 2050. Those costs would be averaging in the range of USD 340 per kW to USD 834 per kW by 2030 and USD 165 to 481 per kW by 2050, compared to the average of USD 1210 per kW in 2018. While cost reductions are declining, the range of cost reductions have been quite different in a range of countries. For example, Germany and France have witnessed a reduction of 71%, while other countries such as China and Italy have witnessed reductions of 77% and 78% respectively. India is estimated to have experienced the greatest cost reduction, estimated at 80% (*IRENA, 2019*). At present, India is the world leader in solar with the lowest solar installation costs worldwide, mostly due to the falling tariffs discovered in the country’s reverse bidding mechanisms, and lower interest rates due to foreign investments. Rapid declines in installed costs and increased capacity factors have significantly improved the economic competitiveness of solar PV around the world (*IRENA, 2019*).

### ***Levelized cost of electricity***

In terms of global costs in the past decade, the levelized cost of electricity (LCOE) of utility-scale solar PV fell by more than 80% between 2010 and 2020 i.e., from USD 0.381 per kWh to USD 0.057 per kWh. This makes solar energy competitive with the other electricity generation sources and paves way to reach grid parity.

### ***Operations and Maintenance (O&M) costs***

US benchmark costs (without inverter replacement) have been reported at \$11.5/kW/year for residential, \$12.0/kW/year for commercial, \$9.1/kW/year for utility-scale, fixed-tilt, and \$10.4/kW/year for utility-scale, with tracking (*Fu et.al.,2019*)

### ***Reasons for Future cost declines***

Current cost declines were due to falling PV module prices and reductions in balance-of-system costs. Also, technological advancements and research has led to improvements in module efficiencies, thereby helping to scale-up manufacturing and hence helping to achieve economies of scales. Additionally, increased capacity factors along with seasonally adjustable trackers, have led to improved generation and hence improved the competitiveness of solar PV around the world (*IRENA, 2019*).

### **Solar PV Advantages**

Solar energy is derived from sun and sun is available for free on the earth. It is believed that theoretically, solar energy when harnessed to its full potential, is adequately enough to provide electricity for the entire world and can fulfil all energy demands. (*Kabir et.al.,2018*) Approximately, four million exajoules ( $1 \text{ EJ} = 10^{18}\text{J}$ ) of solar energy reaches the earth annually, out of which  $5 \times 10^4 \text{ EJ}$  is said to be easily harvestable. (IEA, 2012). With such immense potential, investments in technological advancements and appropriate research and development on solar cells to enhance their efficiency, can prove to be a miraculous and a milestone achievement in the history of humankind as well as the energy sector.

A solar PV project today can be expected to last 25 years (as guaranteed by most reputable manufacturers of PV modules). In short, most solar projects involve a one-time investment that lasts for a long period using a “fuel” that is free and readily available in many places around the world (i.e. incoming solar radiation). Moreover, installing solar projects is relatively easy, modular, and often does not require any heavy machinery and, overall, take significant less

time (i.e. months or one year, as compared to fossil fuel or nuclear power plants, which can take almost a decade to build). Solar power plants are also easier to permit and maintain. Operations and maintenance of solar projects basically requires mere cleaning of the panels to wipe off dust or snow and replacing inverters (usually every five years) or any other faulty electrical connections. This reality makes solar operations and maintenance (O&M) the cheapest among all other power plants. In short, regular and quite simple maintenance is sufficient for solar projects. Preventive and corrective maintenance can be done on “as needed” basis. Robot-based cleaning methods for cleaning the panels are becoming popular (particularly in large solar arrangements that can have thousands of solar modules spanning over large areas) and are being promoted to increase efficiency and to reduce manual labor requirements. Many solar companies are also investing heavily on water-less cleaning methods for solar panels (to reduce the ecological impact of maintenance and to lower costs in sunny water constrained installations).

### **Barriers to growth**

While solar power technology growth has definitely been promoted in the last five years across the globe, and the cost of solar electricity has reached parity (and in some locations below parity) with new fossil-fuel based energy sources, solar power still cannot replace all heritage coal-based power plants that were built in the past to last decades. Furthermore, since the main “fuel” source is dependent on solar irradiation, that source can vary greatly across geographies and times of the day. Solar energy can only be a round-the clock energy source with storage backup systems (e.g., batteries) a solution that is technologically possible but that still requires cost-reductions and policies to foster their growth. In addition, to basic unavoidable natural barriers, solar energy technologies face many “technological, financial and institutional” barriers, which are summarized below (*National Renewable Energy Laboratory [NREL], 2018*)

#### ***Technological barriers***

The major technological barrier for solar growth is the conversion efficiency of solar panels. The performance of solar power plants is defined by the Capacity Utilization Factor (CUF), which is the ratio of the actual electricity output from the plant to the maximum possible output during the year. As compared to nuclear and thermal energy plants, solar without storage backup can fall behind in terms of capacity factors which is due to the energy conversion. In other words, silicon based solar panels only convert ~25% of the energy from

the fuel (i.e., from ‘sunrays to electrons’).

0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

*Figure 7: Average Capacity Utilization Factors of various energy sources (EIA,2020)*

Another technical barrier that requires attention is grid feasibility or ‘transmission accommodation’ of new solar installations due to adaptability changes. Existing power grids were designed for a different era of power generation (which was characterized by megawatt and gigawatt centralized generators located, due to their toxic emissions in remote areas far from populated areas) instead of the modular installations that characterize distributed renewable energy generators ,such as solar PV, which can be placed where the electricity is needed (e.g. building roofs, parking lots, and nearby where people live).

Inadequate skilled workforce:

Solar being a fairly new technology requires basic but specialized electrical knowledge that is not yet readily available everywhere. Due to that reality, availability of a skilled workforce with sector-specific experience requires new training efforts worldwide.

Difficulty overcoming established energy systems:

For decades, the electricity sector has been dominated by big thermal players and the market is controlled by established fossil and nuclear generators. The electricity grids have been designed for centralized thermal based power plants including transmission lines. Changing the entire system or even altering part of it requires a mindset change apart from the obvious heavy financial investments, (*Margolis & Zuboy, 2006*)

### ***Policy barriers***

Key barriers here include lack of adequate electrical and building codes, standards, and interconnection and renewable energy-friendly guidelines.

The solar sector is trying to fit quickly into the existing giant thermal-based electricity industry that developed over the centuries since the First Industrial Revolution started. Diligent research needs to be done by governments and market regulators to lay down solar specific codes and standards which can only be achieved by employing people with great sector specific knowledge and practical renewable energy experience to be able to lay down new rules and guidelines for new players entering into the new renewable energy markets.

### **Trade policies**

Trade policy has a big impact on the production, exchange, and development of renewable energy products, as well as renewable energy demand levels within specific countries. (REN 21). For example, solar modules are not manufactured in every country of the world. A major part of the manufacturing of solar modules is done in South-East Asia where countries such as China, Taiwan, India, Korea, and Malaysia lead the world market. China manufactures 71% of total solar modules in the world. (*Statista.com,2021*). Hence, in order to place an order and source solar modules today, a country needs to have healthy trade policies with these manufacturing countries and their suppliers. If a country wants to develop its own manufacturing capabilities, it needs to create renewable energy targets and timelines, invest accordingly, and also implement a supportive local policy framework that enables it to harness local markets for electricity and energy generation plus invest to develop its own skilled workforce.

### **Absence of Canadian Federal government targets and support**

As stated above, new industries need strong government backing and, in the case of Canada, a robust Federal policy would help grow local businesses. If the Federal government comes out with five-year plans and yearly solar installation targets, market players will get a boost as they are dependent on government policies and these targets assure the governments' commitment to support industrial development and elimination of national barriers. Lack of support and targets is another major barrier that is being faced by solar developers in Canada.

Countries that are as different as China and Germany have, nevertheless, in common huge solar PV installation targets (i.e. China has a target of 110 GW by 2020 and Germany of 98 GW by

2030, respectively), whereas Canada and the United States have not stated any country-wide solar targets so far. (*REN 21,2021, Pg.219*)

### ***Financial barriers***

Financial barriers arise primarily due to institutional and government barriers. Most financial investors will invest in profitable projects with a secured payment fund and a constant revenue stream. In the case of solar energy, energy generation varies and hence do the revenues. Also, changing government policies and unstable regulatory frameworks in the sector, have been driving investors away from solar projects. Solar projects are quite cost intensive and require significant borrowings from banks and financial institutions. According to ADB's 2018 discussion paper series, many Asian banks are reluctant to fund and provide loans to renewable projects primarily due to two significant reasons which are: high risks and a low rate of return on invested capital as compared to fossil-energy projects. (*Peimani,2018*).

### **Fossil fuel subsidies**

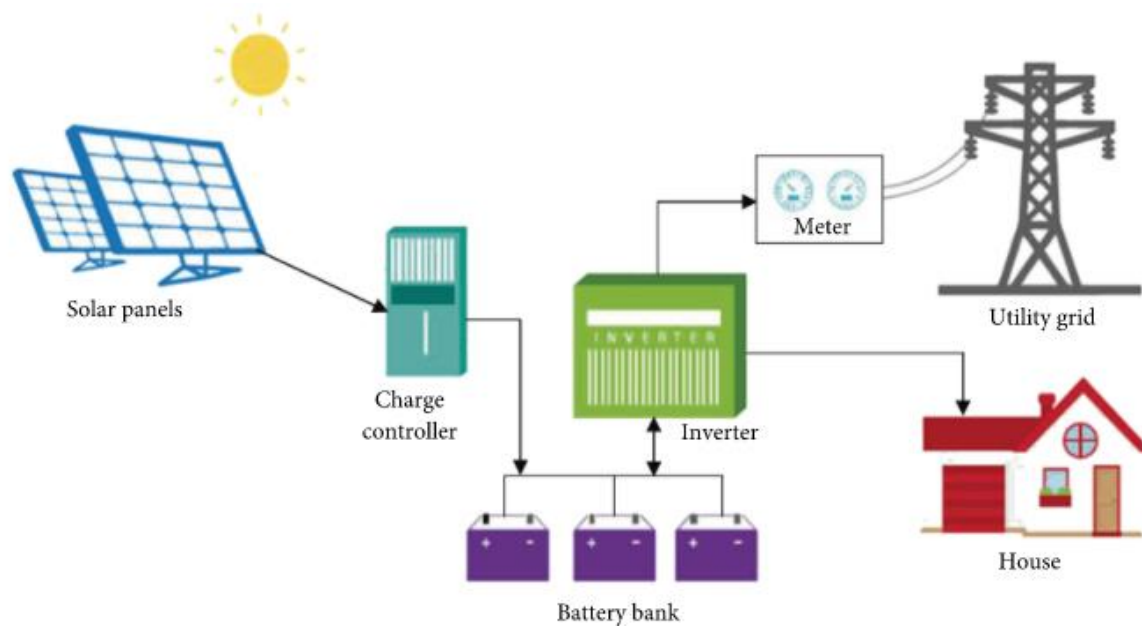
The industry demands subsidies for solar installations to cover a portion of cost of solar installation, whereas governments are still spending huge sums of money instead on fossil-fuel subsidies. (*Victor,2009*). As per a more recent report on Canadian fossil fuel subsidies, "Renewable subsidies are generally significantly lower in most countries than fossil fuel subsidies." (*Corkal et.al.,2020*). Fossil fuel subsidies at a global level are approximately around USD \$372 billion whereby renewable subsidies are comparatively lower and are around USD \$100 million. (*Bridle et al., 2019*). Instead of providing more incentives and financial support policies for renewable installations, steps like subsidizing fossil fuels often reveal the priorities of the government and their intentions to not ever reduce greenhouse gas emissions.

### **Understanding Solar PV System Components**

Although generating energy from a solar PV installation involves basic knowledge of electrical connections the entire process of design, implementation and maintenance still requires specialized skills. Solar projects involve:

"Designing, selecting and determining specifications depending on a variety of factors, such as geographical location, weather conditions, solar irradiance, and load consumption" (*Shukla et.al.,2016*)

Other factors that affect a PV module performance are: ambient temperatures, humidity, module efficiency, ideal tilt angle of the panels towards south, and most importantly, shadow-free space. As per *Dunlop and Halto (2005)* shading of a module can dramatically affect its power generation and can reduce the output from the whole array. Shading from buildings or trees or major obstructions should be avoided, to the south direction of the array (in the Northern Hemisphere).



*Figure 8: A basic Solar system design (Syahputra & Soesanti,2020)*

### **Solar cells**

Most of the solar technology that has been used across the world is photovoltaic (PV) based. PV is a field of science and technology that relies on the “transformation” of incoming sunlight into electrons. A solar cell is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect. The basic material used for production of the solar cells is silicon. Around 60-72 solar cells are combined to form a module, modules connected in series or parallel form panels and many panels for solar arrays.

A number of PV technologies are either commercially available (or under development) and are different in the way that they are manufactured, their costs and conversion efficiencies. PV systems can be grouped into three major categories (*IRENA,2013*):

- 1) wafer-based crystalline silicon (c-Si)
- 2) thin films (TF)
- 3) emerging and novel PV technologies, including concentrating PV, organic PV, advanced thin films, and other novel concepts.

Crystalline silicon cells vary in the way that they are cut from silicon ingots and are classified as mono or poly. Monocrystalline silicon is made using a process known as the Czochralski process wherein single-crystal wafer cells are cut from cylindrical ingots without any substantial wastage of refined silicon and hence are slightly more expensive. Polycrystalline silicon is made from cast square ingots wherein large blocks of molten silicon carefully cooled and solidified. Poly-Si cells are less expensive to produce than single crystal silicon cells but are less efficient in conversion. (Dobrzański et.al.,2013).

Today (i.e. 2021), in large scale ground-mount solar plants, mono-crystalline modules are now becoming the most commonly used due to their higher efficiency. Since solar modules are approximately 60% of the overall system cost, this component is important.

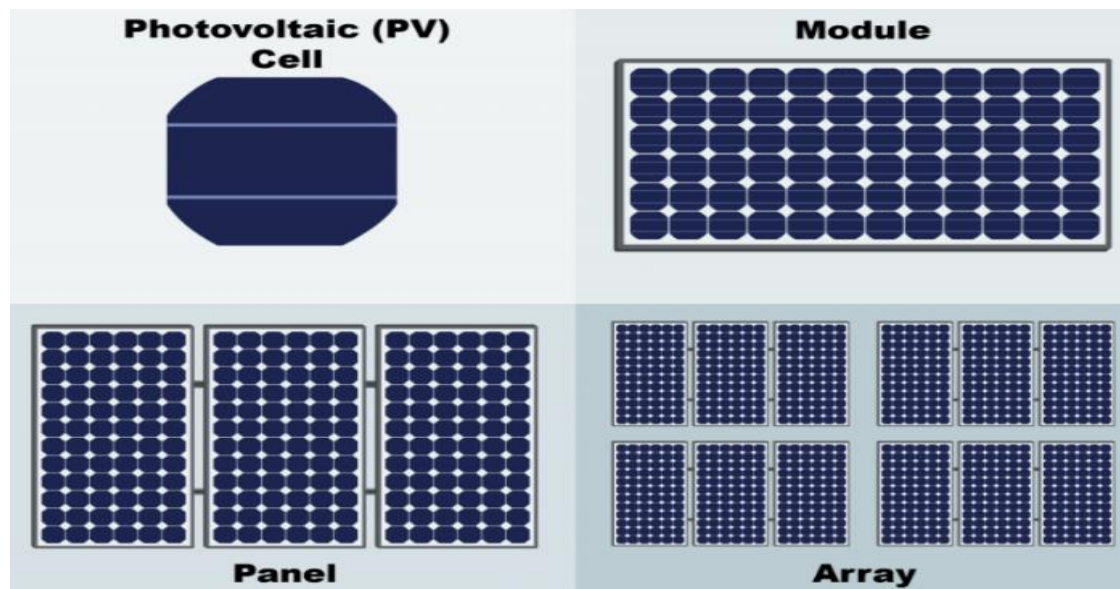


Figure 9: Basic Solar cell terms

In 2018, the efficiency of multi-crystalline PV reached 17%, while that of mono-crystalline reached 18%. Crystalline silicon (c-Si) cells have reached a record lab efficiency of around 25%. (IRENA,2013). The majority of c-Si modules used commercially have efficiencies in the range of 13-19% with now have a lifetime of more than a 25-years. While lab efficiencies of thin film modules are 21.7% (Britannica.com,2020), commercial thin-film modules are exhibiting lower efficiencies between 6 to 12%. Due to these major differences, 95% of the global solar PV market uses crystalline based solar modules.

### ***Inverters***

Solar panels convert the sunlight into direct current (DC). To be able to use the solar electricity produced, in both on-grid and off-grid solar panel installations, it needs to be converted to alternating current (AC) from direct current (DC). Solar inverters are used to make this DC to

AC conversion thereby transforming solar electricity in a usable form. Just like home inverters, these are safer to install, good for solar systems that encounter shade, and allow for future system expansion.

### ***String and Central inverters***

There are two types of solar inverters. A string inverter is used conventionally which is basically a big single central inverter to which the solar panels are connected in series as well as in parallel to form an array. String inverters are typically used for large solar installations particularly ground-mount projects requiring a high load inverter. But string inverters have a major disadvantage. Since many solar modules are connected to them, even if one panel fails to function, the entire connected array shows no output. In this case, the maximum output performance of the string is defined by the minimum (poorest) performing solar panel. (Snidvongs ,2020). This problem can affect the overall system performance and troubleshooting.

For smaller installations, including rooftops, micro-inverters are preferred (which is an individual inverter attached to each solar PV module, thereby supporting smaller outputs and lower nominal rating). Micro-inverters are easy to troubleshoot in case of any connection problem or output issues.

In the past, a big string inverter would be cheaper than many micro-inverters in larger installations (i.e. MWs versus kW) but the technology is evolving very rapidly and micro-inverters are now increasingly used in new MW-level installations.

### ***MPPT (Maximum Power Point Tracking)***

Another inverter linked device used in solar installations is a solar charge controller with MPPT, which is Maximum Power Point Tracking (MPPT). It is a technology that works on an algorithm to harvest the maximum amount of power available from the PV modules at any given point of time, and hence provides maximum energy output out of the system.

### **Future Solar Technologies**

Solar PV industry has been evolving rapidly in the last decade, with new innovations that are changing the industry rapidly. The primary driver of these innovations is the need for higher efficiency modules which is pushing researchers to work on new technologies and system approaches (Green,2019)

PERC (passivated emitter and rear cell/contact): PERC technology is being expanded rapidly in the Asian solar markets. This technology increases the performance of crystalline based cells and offers more efficient cells. Mono-PERC technology is becoming popular in Indian solar markets.

CPV (Concentrating Photovoltaics) is one of the most mature emerging solar technologies. In CPV systems, optical sun-tracking concentrators or the lens, that look like curved mirrors, focus the direct sunlight on highly efficient solar cells thereby reducing the need for costly active materials and helps off set the additional cost of the concentration system, to some extent.

Organic Solar Cells are based on active, organic layers that are also suitable for liquid processing. This technology is based on the use of very low-cost materials and manufacturing processes, with low energy input and easy upscaling. In case this technology picks up in the market, there is a possibility that it might be feasible to achieve very costs, even below USD 0.5 per Wp

Tandem/hybrid cells: Tandem solar cells are basically, stacks of individual cells, one on top of the other, that each selectively convert a specific band of light into electrical energy, leaving the remaining light to be absorbed and converted to electricity in the cell below.

Bifacial cells, as the name indicates, are capable of generating electricity not only from sunlight received on their front, but also from reflected sunlight received on the reverse side of the cell (bifacials are ideal for areas where snow is common as they can continue to generate electricity even if snow is on top of the module, and also can generate more electricity as sunlight bounces off high albedo surfaces)

### **Canada's Energy Landscape**

Canada's energy sector is huge, and it accounts for more than 10 per cent of nominal national Gross Domestic Product (GDP). The revenues to the government from the energy sector was approximately \$ 18 billion in 2018 (NRCan,2019)

Canada's energy sector contributes to 4 percent of the world's total electricity generation (as per 2018 figures) by generating 641 TWh of electricity, out of which 60 per cent was from hydro energy. Canada is still slow in adopting other renewable energy sources such as wind, solar and biomass, but these numbers surely show that a major proportion of Canada's

electricity mix already comes from renewables (hydroelectricity is a renewable energy source but it has a much higher ecological footprint than solar and wind). Another important fact about Canada is that it exports around 8 per cent of its electricity to the United States. In 2019, Canada imported 60.4 TWh of electricity to the United States. (NRCan,2020). As per the provincial generation numbers, Ontario and Quebec are the largest producers of electricity in Canada that generate an approximate 25 and 30 per cent of total Canadian electricity, respectively. *Canada Energy Regulator [CER],2016*

While Canada is still relying on hydroelectric, fossil fuel and nuclear as major power generators, Asian countries like China and India lead the world in solar generation and have ambitious solar targets. China has a target of 110 GW of Solar power generation by 2020 whereas India has a target of 100 GW by 2022. (REN 21, 2020, Pg.219). China and India have massive solar markets (i.e. local manufacturing as well as installation) that are helping to bring equipment costs down worldwide. In contrast, Canada, the second largest country in the planet, accounts for only 1% of the total solar generation in the world. (NRCan,2020)

**World capacity of solar PV – 627 GW (2019)**

Rank	Country	Percentage of Total
1	China	33%
2	United States	12%
3	Japan	10%
4	Germany	8%
5	India	7%
9	<b>Canada</b>	<b>1%</b>

*Figure 10: Canada’s solar capacity as % of world solar capacity in 2019 (NRCan,2019)*

### **Renewable Landscape: Canada**

At present, Canada has 16% of its total primary energy supply coming from renewable energy sources (wind and solar energy are proving to be growing fastest among all the electricity sources and are picking up in the market). While hydroelectricity constitutes the major proportion of the renewable energy sector in Canada, the wind power sector has been growing at a good pace in the past decade. Solar power is only 0.1% of Canada’s overall power generation sources. (NRCan,2020) According to the National Energy Board, Canada has a strong solar PV potential that is unexploited and it untapped. Regions like Regina, Calgary and Winnipeg have solar potentials that is above average. Overall, Canada’s solar energy potential

is higher than Germany which has been one of the leaders in renewable energy in the world for a long time. (NEB, 2016). Considering Canada’s climatic conditions and altitude, the potential for solar energy varies across different regions. Canadian cities have a huge potential of solar energy which is comparable to many international cities around the world, mainly in the central regions. According to NRCan: “about half of Canada’s residential electricity requirements could be met by installing solar panels on the roofs of residential buildings.”

In terms of market growth and penetration, solar energy growth in Canada has been very slow although the growth trend has been increasing. The period 2008-2014 saw immense growth in the solar market and the installed capacity of solar photovoltaic power increased reached a record 1843 MW in 2014 with the period experiencing a compound growth of 13.8% since 2004. Continuing the trend, solar power has grown to 3040 MW in 2018 (166 MW was added in 2018) from a mere 16.5 MW in 2005.

In Canada, Ontario has the largest installed solar capacity. While Canada as a country has not specified any country-wide target for solar installation, Ontario’s solar target has been announced as 40 MW by 2024. (REN 21,2020, Pg 218)

**Solar installations trend: Canada**

As per IEA,2019 data, Solar installations in Canada have been categorized as off-grid and grid-connected (i.e. distributed and centralized). The installation trend in Canada has not been even and has not grown at a steady pace. The years 2009 and 2010 witnessed remarkable growth in solar installation numbers. The yearly installation figures from 1994 onwards have increased at an average rate of 43.2%. The overall trend however has been on the positive side. In Canada, Ontario seems to still be the largest solar market for installations and continues to be the market leader despite lack of provincial and federal government support in terms of fiscal incentives and rebates.

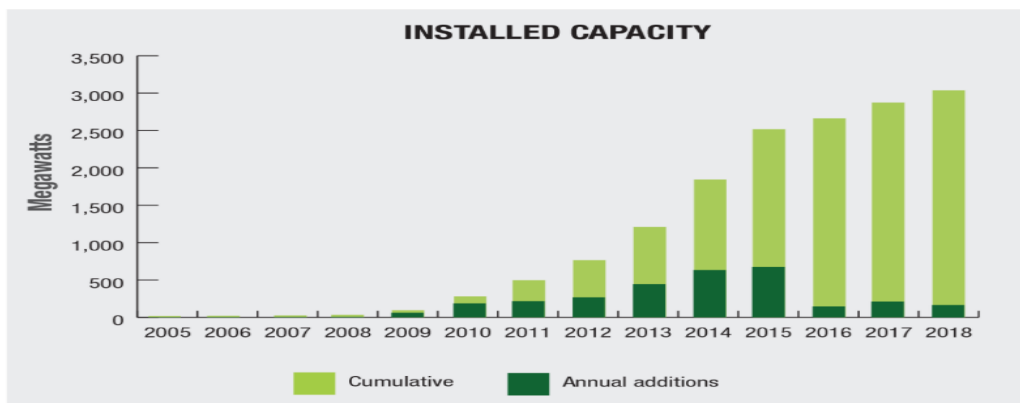


Figure 11: Canada’s Solar installed capacity trend (NRCan,2019)

Ontario was a leader in renewable energy during the previous three liberal governments (i.e. 2004-2018) that implemented: the Ontario coal phase-out, two progressive renewable energy programs (the Standard-Offer Contract Program and its successor the Ontario Feed-in Program) a pro-renewable energy law (the Ontario Green Energy and Green Economy Act) and a GHG Cap and Trade Program (that included Ontario-Quebec and California). All of those programs and initiatives were cancelled in 2018 by the Conservative Government that currently holds a majority in the Ontario Parliament until 2022.

Year	Off-grid [MW <sub>DC</sub> ]	Grid-connected distributed [MW <sub>DC</sub> ]	Grid-connected centralized [MW <sub>DC</sub> ]	Total [MW <sub>DC</sub> ]	% Change
1994	1.3	0.20	0.01	1.51	
1995	1.64	0.21	0.01	1.86	23.2%
1996	2.31	0.24	0.01	2.56	37.6%
1997	3.12	0.25	0.01	3.38	32.0%
1998	4.2	0.26	0.01	4.47	32.2%
1999	5.53	0.29	0.01	5.83	30.4%
2000	6.84	0.30	0.01	7.15	22.6%
2001	8.48	0.34	0.01	8.83	23.5%
2002	9.63	0.37	0.00	10.00	13.3%
2003	11.43	0.40	0.00	11.83	18.3%
2004	13.37	0.47	0.04	13.88	17.3%
2005	15.62	1.07	0.06	16.75	20.7%
2006	18.98	1.44	0.06	20.48	22.3%
2007	22.86	2.85	0.06	25.77	25.8%
2008	27.48	5.17	0.06	32.72	27.0%
2009	35.2	12.25	47.12	94.57	189.0%
2010	60.1	27.74	193.29	281.13	197.3%
2011	61.05	131.16	366.11	558.29	98.6%
2012	NA	218.68	547.29	765.97	37.2%
2013	NA	273.19	937.29	1210.48	58.0%
2014	NA	540.85	1 302.23	1843.08	52.3%
2015	NA	735.81	1 782.50	2518.31	36.6%
2016	NA	792.66	1 871.65	2664.31	5.8%
2017	NA	926.34	2 006.29	2932.63	10.1%
2018	NA	1088.01	2007.34	3095.35	5.5%

*Table 2: Canada's solar installed capacity break-up trend (IEA,2019)*

### **Cost of solar installations: Canada**

As per the 2020 solar economic data estimates by the Canada Energy Regulator, the following table represents the cost of installations in Canada, that are sub-divided into the residential, commercial, community and utility sectors. The figures also estimate the near future and low-cost future installation costs.

Type	Current Installation (\$/W)	Near Future Installation (\$/W)	% Change	Low-Cost Future Installation (\$/W)	% Change
Residential (5 kW)	3.20	\$2.595	18.9%	\$2.252	13.2%
Commercial (200 kW)	\$2.210	\$1.772	19.8%	\$1.529	13.7%
Community (200 kW)	\$2.210	\$1.772	19.8%	\$1.529	13.7%
Utility – Fixed Mount (50 MW)	\$1.458	\$1.001	31.3%	\$0.753	24.8%
Utility – Tracker Mount (50 MW)	\$1.557	\$1.067	31.5%	\$0.803	24.7%

*Table 3: Canada’s Cost of solar installation and future estimates (CER,2020)*

If the percent change in prices is calculated, a very high decline of 31 per cent can be seen in the Utility tracker mount 50 MW systems. The residential market, however, does not decline as per the same rate as the Utility system. This is due to the economies of scale that is achieved when the system sizes increase. Hence, for residential, rooftop small markets having installation sizes of 5kW to 10kW, should be backed by incentives from the government. The figures for commercial as well as community scaled installations have nearly the same decline rate for 200 kW systems, as the residential installations, despite their capacity being much larger than the residential systems, which is unexpected.

In terms of competing with the prices across big solar markets in the world, in Canada, the competitiveness of solar power (or the overall financial viability) depends on the local electricity prices in a province, rather than the capacity utilization factor (CUF) or the amount of sunlight received. (*NewsWire.ca,2018*). As per the latest study on economies of solar power done by National Energy Board (2020), solar installations are financially viable only in provinces where the rates of electricity are high. The break-even prices of solar PV are lesser than the provincial electricity prices. Provinces such as Ontario, Saskatchewan and Prince Edward Island have high electricity prices. Hence, solar installations still make sense in these provinces as solar can compete with the prices of other electricity sources (*CER,2020*). However, without ambitious target/timelines for renewable energy growth and supportive incentives and policy systems (such as those offered in other G7 countries such as Germany) the growth of the Canadian renewable energy sector will remain slow and small.

### ***Cost break-up of solar installations: Canada***

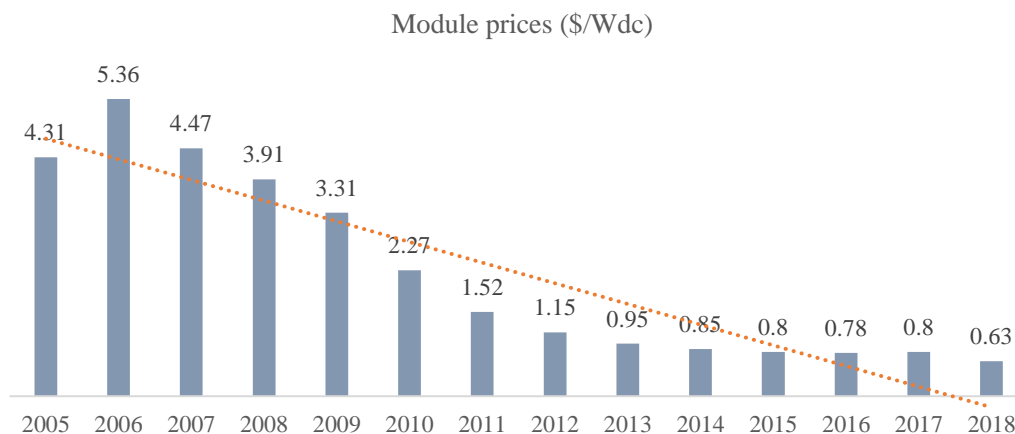
According to IEA’s 2019 data for the break-up of system components in Canada, the total average cost of a rooftop grid connected solar system with a capacity ranging from 5-10 kW is around \$2.95 per Watt. While the cost of major system components such as modules, inverters and other electronics cumulates to \$1.41 per Watt, the installation costs are higher at around \$ 1.51 per Watt. Installers and electricians charge a high price for solar installations. This is opposite in the South-East Asian countries where the system cost is much higher than the actual installation cost.

System components	\$/Wdc
Module	0.63
Inverter	0.45
Other electronics (mounting, cables, etc)	0.33
Installation	1.52
Total	2.93

*Table 4: Cost break-up of solar system components in Canada (IEA,2018)*

### ***Solar Module prices: Canada***

Module prices depend on the manufacturer as well as the type of the module whether it is a monocrystalline or a multi-crystalline or thin-film module type. China is the largest solar module manufacturing market in the world. As of August 2018, modules from China are on average 7.3 cents cheaper than Europe and the rest of Asia (IEA,2019). But the rapid declining trend of module prices, has been consistent in all the solar markets across the world.



*Figure 12: Canada’s Solar Module prices trend (IEA,2018)*

Canada has also seen a sharp exponential decline in the price of a typical standard crystalline silicon module. As compared to the module prices in 2005, where the prices were approximately at \$4.31 per Watts, the decline in 2018 has been by a whopping 85% in 2018 and the current module prices stand at 63 cents per Watts. This massive drop in module prices gives a ray of hope that Canadian solar installations can also compete in prices at the world level and other PV markets, provided a supportive policy atmosphere is available for the solar industry to thrive in Canada.

### **Renewable and Solar Landscape: Ontario**

In Canada, Ontario leads in the energy sector specially in the electricity generation from renewable energy and nuclear power. In 2018, about 96% of the electricity in Ontario was produced from zero-carbon emitting sources i.e., 60% from nuclear, 26% from hydroelectricity, 7% from wind, and 2% from solar. Natural gas and biomass constituted the remainder of the electricity share. The southern region is generating the most electricity in Ontario. The province also leads in wind energy in Canada. A Capacity of 5061 MW of wind installations was added between the years 2005 to 2018. (*CER, Provincial profile, Ontario,2020*)

A major proportion of Ontario's renewable energy comes from hydro power. In the last decade, hydro was generating a fourth of Ontario's total energy generation. In terms of renewables, hydro is followed by wind, solar and then biomass. Excluding the electricity generation from hydro, the total renewable energy produced in Ontario is around 16.5 GWh which is the largest in any province in Canada. However, in 2018, more than a third of Ontario's total electricity generation was from renewable energy sources. In 2017, Ontario had the maximum capacity of installed solar power in Canada which was 2771 MW.

The period from 2010 to 2017, had seen an addition of a net 7152 MW of renewable energy from wind and solar. While wind energy was around 3688 MW, solar was lesser at around 2299 MW. In the coming nearby future, which is between the period from 2017 and 2023, Ontario's projection of new renewable capacity addition seems to be around 466 MW. This marks a very slow growth pace of renewable energy in Ontario as the numbers seem significantly low. Out of the above projected number, 235 MW is projected from solar installations. The growth in this period as compared to the period between 2010 and 2017 is surprisingly lower.

Year	Solar Capacity (MW)
2010	281
2017	2520
2018	2669
2020	2815 (projected)
2023	2815 (projected)

*Table 5: Solar capacity projection: Ontario (CER,2020)*

Studies of Canada Energy Regulator, project no growth in solar installed capacity from 2020 to 2023, although a mere 5.5% growth rate was projected from 2018 to 2020 and 5.9% before that, from 2017-2018. This does not seem to be a positive growth projection and the numbers show that Ontario has no significant future for the solar industry.

### **Canada: Carbon Pricing Mechanisms**

As per the Paris Agreement, 2015, Canada had committed to reduce its greenhouse gas (GHG) emissions by 30 per cent from 2005 levels, by 2030 and an over ambitious goal of 80 per cent reduction by 2050. This 2050 pledge will require both steep reductions in energy intensity and a radical transformation of the fuel mix. *(Cleland Michael, 2017)*

A price on carbon is necessary and it is one of the most efficient ways to reduce greenhouse gas emissions. This would lead to increase in investments in clean innovation technologies, and also create incentives for individuals, households, and businesses to choose cleaner options. *(Canada.ca,2021)*. Carbon pricing can be implemented using either a carbon tax or a cap-and-trade system.

Canada did not have any nationwide carbon pricing policy until 2016, although some provinces had been working to implement the same before that. Prime Minister Justin Trudeau announced a national carbon pricing plan for Canada in October,2016. This announcement was a ray of hope for all environment supporters and was a reaffirmation from the government, that Canada is committed to reduce its emissions by 2030. As part of the policy, provincial government had to implement one of the two carbon pricing programs in line with the federal price, i.e., either a cap-and-trade or a carbon tax, within two years, failing which, the federal government would then impose a carbon tax in that jurisdiction. *(Snoddon & VanNijnatten,2016)*.

Prior to 2016, only three provinces — British Columbia, Alberta and Quebec had implemented carbon pricing.

	Policy instrument	Carbon price (\$ per tonne of CO <sub>2</sub> equivalent)	2030 target	Emissions coverage	Design features
<i>Carbon pricing policies in place</i>					
British Columbia	Carbon tax	30	None <sup>1</sup>	70-75%	Introduced 2008; revenues used to reduce other taxes
Alberta	Carbon tax	20 in 2017 30 in 2018	50 mega-tonne reduction by 2030 <sup>2</sup>	78-90%	Introduced 2015; revenues recycled to tax cuts, industry/consumer support and investment
Quebec	Cap and trade	16.45 <sup>3</sup>	37.5% below 1990 (37.8% below 2005)	85%	Introduced 2013; linked with California 2014; revenues earmarked for Green Fund
<i>Carbon pricing policies in development</i>					
Ontario	Cap and trade	≈16.45 <sup>4</sup>	37% below 1990 (46% below 2005)	82%	Expected 2017; revenues used to fund green projects
Manitoba	Cap and trade	0	33% below 2005		Signed memorandum of understanding with Ontario and Quebec, December 2015
<i>No carbon pricing policies in place</i>					
Saskatchewan		0	n/a		
New Brunswick <sup>5</sup>		0	35-45% below 1990		
Nova Scotia <sup>5</sup>		0	35-45% below 1990		
Prince Edward Island <sup>5</sup>		0	35-45% below 1990		
Newfoundland and Labrador <sup>5</sup>		0	35-45% below 1990		
Yukon		0	n/a, 2020 goal to be carbon neutral		
Northwest Territories		0	Equal to 2005 levels		
Nunavut		0	n/a		

Figure 13: Various carbon pricing mechanisms in Canadian Provinces (Snoddon & VanNijnatten, 2016)

### Ontario's Cap-and-Trade pricing program

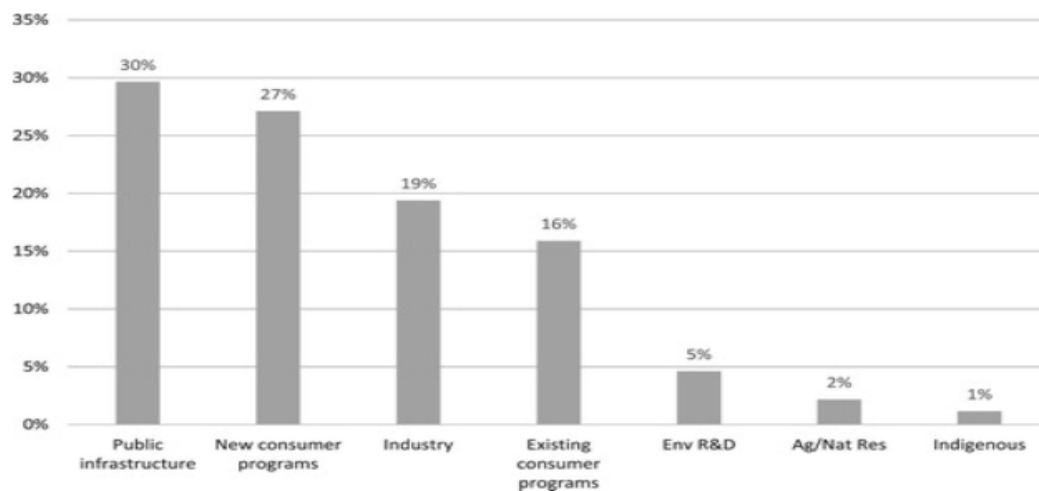


Figure 13: Ontario's Climate Change Action Plan, 2016-2020 (Raymond, 2020)

Initially, in 2015, Ontario had decided to pursue a cap-and-trade approach to carbon pricing and launched in 2016. With the intent of using its carbon pricing revenues to fund green projects, Ontario's carbon price was estimated at around \$18 in 2018, in line with Quebec and California. (*Sawyer et.al.,2016*). But soon, the policy was repealed and replaced with a weaker plan that rejected carbon pricing (*Raymond,2020*). As per the Province of Ontario, 2018, "Effective July 3, 2018, we cancelled the cap-and-trade regulation and prohibited all trading of emission allowances".

Several reasons have come to light that led to this historical repeal. According to some interviews, the major pitfall was lack of policy focus to consumer costs and widespread priorities ranging from diverse industrial and commercial groups to environmental NGOs and the obvious reality of the electricity sector's adjustment to a coal-free generation system and a fearing competition from US environmental firms. (*Raymond,2020*)

### **Ontario's history of Renewable Policies and Incentives**

Ontario laid the foundation of promoting its renewable energy in 2006. A Program named Renewable Energy Standard Offer Program (RESOP) was initiated that was basically intended to lay out a pricing mechanism for small renewable energy generating installations.

#### ***Renewable Energy Standard Offer Program (RESOP)***

It was also focused on disbursing incentives to support renewable energy production and to promote clean generation ranging from big industries and large manufacturers, community-based systems. At the backdrop, this would have helped the province to work on its goal to reach its target of doubling the generation of electricity from renewable energy resources by 2025. (*Gorrie,2009*).

Every government laid out program has certain pre-requisites to work and set a benchmark or a standard procedure and to ease the business functioning. The requisites under RESOP were to have an installed capacity of under 10 MW along with a legit connection to the nearby transmission line. These conditions were then bound by a Power Purchase Agreement (PPA) with the Ontario Power Authority (OPA) for a lock-in period of 20 years. The tariff was fixed at a 11 cents per kWh for all renewable energy production i.e., water, biomass, solar and wind, excepting solar PV. The tariff for solar PV installation was capped at 42 cents per kWh as per *OPA, 2007*. The promising and secured nature of contracts with the provincial authority, led to

signing of a total of 443 contracts by 2008 and surprisingly, 90% of the contracts were with wind and solar PV generation plants under construction, accounting to around 1420 MW. Problems started arising when projects started to enter the implementation stage. Transmission accessibility and grid connectivity issues in certain regions of Ontario and issues securing finances to prove project feasibility started springing up. (*Ontario.ca,2009*). All of this eventually paved way for the formation of a more wholesome Act, in the need of a robust policy framework that would streamline the system and therefore, the Green Energy and Green Economy Act came into existence.

### ***Green Energy and Green Economy Act (GEGEA)***

The primary aim of such an Act was to diversify Ontario's electricity portfolio and project Ontario as a market leader in the competitive renewable sector in the world. GEGEA focused on improving process efficiencies by reducing approvals, and keeping the communities motivated and engaged by providing sufficient incentives. Regarding the financial security aspect of renewable projects, GEGEA reduced the risk for investors and lenders thereby leading to a guaranteed revenue stream. (*Ontario.ca,2009*).

### ***Ontario's Feed-in-Tariff (FIT) program***

Since GEGEA was a problem solver and worked to eliminate issues at the grass-root level, it was time to introduce the Feed-in Tariff or FIT program. The FIT program was launched in 2009, and it was a way of procuring solar, wind, hydro, and biomass generating capacity in order to diversify the energy portfolio in Ontario and replace the province's coal-fired power plants. (*IEA,2019*)

This was divided into two levels, FIT for projects greater than 10kW of capacity, up to and including 500 kW; and microFIT for projects generating a capacity of less than 10 kW, that would provide tariffs for all renewable energy projects such as “wind, solar PC, hydro, biomass, biogas and landfill gas.”

According to (*Bringham,2009*), GEGEA encouraged many small-scale developments by farmers, communities, rural landowners and even the First Nations. These projects, especially Aboriginal and community projects are entitled to receive additional incentives on top of the regular incentives. This is due to the cost and project hurdles that they face in project implementation, that big commercial companies overcome due to experience and lesser project costs and knowledge of sourcing materials. An additional incentive of 0.4 to 1.5 cents per kWh

is provided to the Aboriginals and communities on top of the FIT rates, that highly depends on the energy source. Wind energy source receives the highest of 1.5 cents per kWh and other sources such as biogas, receive lesser incentives. (OPA 2011).

***FIT: Current status***

As per IESO, “Since the program launch in 2009, over 20,000 microFIT projects have been connected to the grid - 99 per cent of which are solar PV projects.” (Independent Electricity System Operator [IESO].ca,2017)

The FIT and microFIT programs have been discontinued and IESO has ceased any applications for the programs after 2017 for microFIT, and post 2016 for FIT, as per the directive of Minister of Energy. Documents for microFIT however are still available.

***The Large Renewable Procurement (LRP) programme***

LRP was launched in 2014 with the primary aim and intent of replacing the FIT program for solar projects that had a generating capacity which was exceeding 500 kW. The program was specifically designed for large-scale solar projects in order to ensure a better pricing mechanism for such projects and to have a control on the number of solar installed projects. The program’s first phase was successfully operated from the years 2014 until 2016. Just like other solar programs in Ontario, this program was cancelled in 2016 and its second phase that was supposed to be launched in 2016 had been suspended. (IEA,2018)

<b>Solar PV incentives in Ontario</b>				
Program		Aim	Start	End
<b>Financial Incentives</b>				
GreenON's rebates	Solar	<ul style="list-style-type: none"> <li>• Rebates for Solar PV and Energy Storage systems to help Ontario homeowners and businesses use renewable electricity and reduce their greenhouse gas emissions.</li> <li>• Providing homeowners \$1 per watt for residential solar panels, with a cap at 10kW (AC). Adding \$0.50 per watt for a total of \$1.50 when homeowners couple solar panels with an energy storage installation.</li> <li>• Those who wish to go completely off-grid get \$3 per watt for a solar panel plus energy storage installation.</li> <li>• Providing businesses \$0.75 per watt for commercial solar panel installations, with a cap at 500 kW (AC).</li> </ul>	2018	2018

FIT (Feed in Tariff) Program	<ul style="list-style-type: none"> <li>• The FIT Program was open to projects with a rated electricity generating capacity greater than 10 kilowatts (kW) and generally up to 500 kW.</li> <li>• Approved projects to receive a fixed price for the electricity produced over a 20-year contract period.</li> <li>• The program provided homeowners and other eligible participants with the opportunity to develop a small or "micro" renewable electricity generation project (10 kilowatts (kW) or less in size) on their property.</li> </ul>	2009	2016
Micro-FIT Program	<ul style="list-style-type: none"> <li>• Homeowners to be paid a guaranteed price over a 20-year term for all the electricity produced and delivered to the province's electricity grid.</li> </ul>	2009	2017
<b>Regulatory policies</b>			
Net-metering	<ul style="list-style-type: none"> <li>• Is for electricity consumers in Ontario who produce some of their own power from a renewable resource (systems that are 500 kW or less)</li> <li>• Net metering allows Ontarians to send excess electricity generated from renewable resources to the distribution system for a credit toward energy costs. In essence, it is a "trade" of electricity supplied against electricity consumed.</li> </ul>	2017	Present

*Table 6: Summary of Ontario's solar incentive schemes (Sunmetrix.com,2018)*

For any industry or sector to thrive, it is very important to have strong regulatory policies and government backing. It is very evident from the above summary that the Canadian Federal Government as well as the Provincial Government of Ontario has low to zero interest in promoting renewable energy establishments and installations. The history has been rocky and weak in terms of policies, acts and solid mandatory regulations. All the incentive programs, that could have boosted investments and bring down the capital costs in the long run, have been shut down or closed. Canadian target or commitment to reduce greenhouse gas emissions does not seem promising, considering the fact, that no major changes are being done in the system to curb emissions and make a path to change their energy mix.

So, in a nutshell, apart from the Net metering regime, Ontario has no other incentive scheme to offer to residential owners, rural landowners, permaculture farms, small communities, or off-grid establishments.

## **Solar Policies and Incentives**

Governments all over the world, in consultation with industry experts and crucial experienced market players have worked to formulate schemes and policies to help the sector grow. Various fiscal incentives, preferential interest rates, tax credits and exemptions, feed-in-tariff, subsidies, and rebates as part of government schemes have benefitted the industry and promoted immense growth in top solar producing countries including voluntary green power programs. Other policy initiatives such as net-metering, Renewable energy certificates (REC) and Clean Development Mechanism (CDM) suggested in the Kyoto Protocol, have been undertaken by countries in the past during the process of policy formulation. (*Timilsina et.al.,2012*)

## **Policies and incentives of top solar nations in the world**

### ***China***

China is one of the finest examples of having a success story in the renewable industry. It leads the world in both solar and wind installations and leaves a learning history for every other country. Hence, assessing China's renewable energy policy was a mandate for this study.

China's path to renewable growth and development started with the passing of a new law in 2005, named the Renewable Energy Law (REL). This was a demonstration of China's commitment to develop renewable energy and grow it to its peak. REL led to increased renewable installations within years of its inception and the country doubled its wind capacity installation every year beyond that for three years from 2006 to 2008. (*Wang et.al.,2010*)

Under this law, renewable energy was treated as a preferential area in energy development. Additionally, industrial growth of renewable energy through research and development is also listed as the "preferential area for hi-tech industrial development" in the country's national industrial program. According to REL, at the national level, the State Council has the responsibility for the management and implementation of renewable energy projects in order to facilitate smooth development and utilization of renewable energy sources. The Council is also responsible for setting short and long- term targets to increase the total volume of renewable energy installations and would work on preparing national plans for the implementation of these targets. Cooperation with local and regional governments to identify differences in targets is also one of the tasks assigned to the State Council. (*IEA,2021*)

The REL was amended in 2009 and over the years it has focused on key policies that include a national feed-in tariff or FIT system, and a mandatory connection and purchase policy. In

addition, the law lays out national renewable energy targets and makes arrangements for funding and sharing renewable energy incentives and their schemes. (*Schuman and Lin,2012*)

With the backing of such a strong law and policy support, China's solar PV manufacturing industry has grown ever since 2004 and at present, is the world leader producing over 70% of solar modules used in the solar industry across the globe. This was possible due to the streamlined incentivizing industrial policies provided by the government at the national level and also due to the overseas solar PV market demand that was simulated by governments of Germany and other countries of the European Union. (*Zhao et.al.,2016*)

The Chinese government identified major incentive strategies for the renewable industry to grow manifold. These following inter-connected incentives led to cost declines at each level:

- research and development incentives
- fiscal and tax incentives
- grid-connection and tariff incentives
- market development incentives

Additional policies that supported the overall ecosystem of renewable growth were identified as:

- financial subsidy policies
- technical support policies
- tax deduction and exemption policies
- Preferential feed-in tariff policies

As per the study done by *Zhao et.al., 2016* the results are a proof that the incentives have a very significant role to play when it comes to promotion and development of the renewable energy generation sector in China.

China manufactures the cheapest available solar panels in the world. This marked the most significant technological breakthrough to achieve in the solar PV market and the industry leaders, which was possible due to research and development incentives provided for the same. R&D done by relevant Chinese institutions have succeeded in developing the polysilicon used to manufacture the solar cell, using a low-cost method that now fills the gap in this manufacturing technology. (*Zhao, Zhang & Tian, 2012*)

As per the *Ministry of Finance of People's Republic of China, 2012*, the costs of construction of solar PV power projects have drastically come down from 30 Yuan per MW to 12 Yuan per MW and the cost of electricity generation from solar projects is now 1 Yuan per MW.

### ***India***

India is one of the top countries in the world with the maximum solar installations and an ever-growing renewable energy sector. As per the Paris Agreement, India is committed that by 2030, out of all the energy sources 40% of the installed energy would be from renewable and clean energy sources.

India's renewable history was started when the National Solar Mission first came into being in 2009. The NSM set nation's renewable energy target of 100 GW by 2022. Seeing the immense growth of both solar and wind industry and huge investments being undertaken by domestic as well as foreign investors, this target was pushed further to 175 GW which includes 100 GW from solar, 60 GW from wind and the rest from other clean sources. (*Sharma et.al., 2021*). Solar energy is by far the cheapest source of electricity in India and had reached grid parity years back.

The following incentive schemes were started in India with the National Solar Mission:

Viability gap funding (VGF): This is a government funded incentive scheme that allowed for significant solar tariff reductions in initial years to fill in the gap to achieve the financial viability. A certain portion of the cost that contributed to the tariff quoted in the solar bidding projects included the VGF incentive.

Accelerated Depreciation (AD): It is an asset depreciation method that allows for allows greater deductions in the earlier years of the life of an asset than the traditional straight-line method. This saves money from huge corporate taxes by writing of asset values in initial years of the project. In the year 2010–2011, when the National Solar Mission (NSM) was first announced, the levelized tariff for solar as issued by the central authority (CERC) stood at Rs. 17.91/kWh without AD and Rs. 14.95/kWh with AD for 25 years and it decreased by 68% to Rs. 5.68/kWh without AD and by 66% to Rs. 5.08/kWh with AD in 2016–2017. (*Sharma et.al., 2021*).

Generation based Incentive (GBI): For every unit of electricity generated, an additional incentive was provided which was termed generation-based incentive. This was mostly applicable in earlier stages specially in wind power projects. This led to new installations and motivated the generators to generate more units to be fed to the grid.

Tax holiday: A tax holiday or tax rebate for 10 years was given to solar project installers which led to witnessing a significant growth in projects due to the savings in huge corporate and commercial taxes. Several small and medium businesses benefitted from the scheme.

Subsidies for rooftop solar projects: After seeing a successful era and large amounts of ground-mount solar installations all over the country, it was time to focus on the rooftop sector. These incentives were divided into three categories i.e., up to 25 kW, 25 kW to 100 kW and 100kW to 500kW. In addition to that, incentive schemes for residential solar system such as the government subsidies of 30% capital cost was a huge success. All such incentive schemes led to increased residential and commercial installations.

Tender/Reverse auctions: The energy sector in India is long run with the tradition of open tenders and electricity tariffs been determined by reverse auction mechanisms in a competitive bidding process wherein a government or any private company can participate based on the eligibility conditions. State/provincial governments come up with open tenders based on their yearly targets and then conduct tender submissions and subsequent auctions of the tender capacities. Companies quoting the lowest tariffs are the winners until the bid capacity is exhausted. In December 2020, India witnessed a record low solar tariff of INR 1.99/kWh which is US\$0.0269/kWh in a ground-mount 500 MW auction. (*PV-tech.org,2020*).

With this, India is on a mission to reduce its greenhouse gas emissions as per the commitment in the Paris Agreement by fulfilling its yearly renewable and solar power installation targets.

## Section 4 | Research Methods

So far, we have seen the energy landscape scenario in the world and how certain countries are ahead of others in terms of commitments and actions to reduce the GHG emissions. Canada is among the top 10 countries producing the most emissions and is one of the signatories to the Paris Agreement of 2015. It hence becomes Canada's responsibility to reduce these emissions and transition its electricity sector towards cleaner, greener, and more sustainable options.

- To assess Canada's approach to reduce emissions, its international rankings and numbers are proofs of the country's efforts to do so and are also the implications of Canada's historical policy approaches towards the solar industry. This study has therefore followed a quantitative research method and done a ranking analysis to assess this.
- Secondly, this research has picked up a Case Study of a permaculture farm in Ontario in order to assess the cost feasibility of solar installations in Canada, especially in Ontario whereby, the actual quote provided for the installation of the 10-kW solar project at the farm, is analyzed and compared with the simulation of RETScreen Expert software. This not only helps us analyze the financial feasibility of the project, but also throws light on the importance of incentives in order to receive positive project returns for solar projects in Ontario, which is then linked with the policy environment in Canada.
- Thirdly, the report has tried to assess the future of Canada's solar industry based by analyzing the historical trend of the installations data and thereby predicting the assumptions using the data representation software, Tableau.

## Section 4 A | Quantitative Assessment

In this section, we are comparing the numbers and ranks of various countries with respect to Canada from global data reports. Quantitative analysis of the following three datasets would give us a better clarity on Canada's standing.

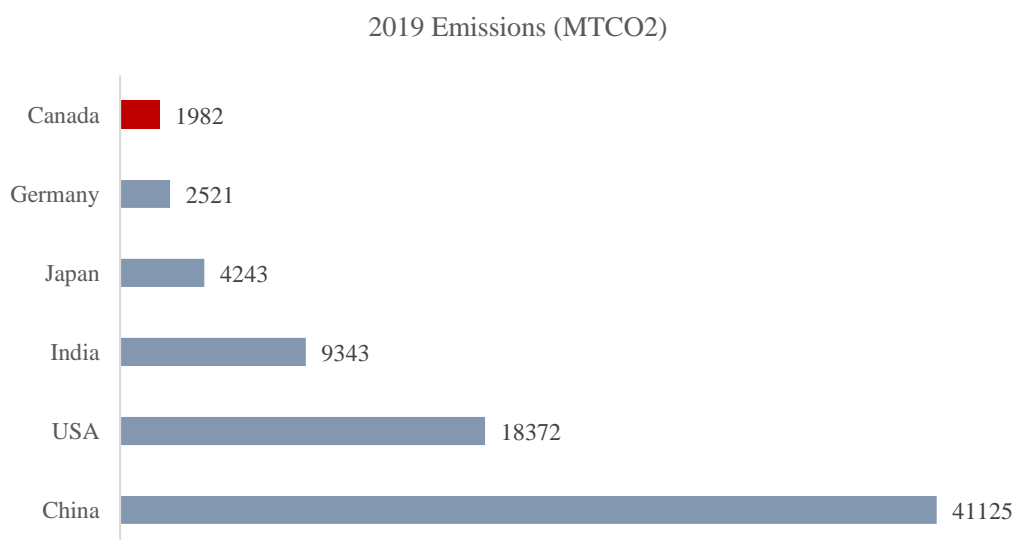
1. Greenhouse gas (GHG emissions) of top countries
2. Solar installed capacities of top countries in MW
3. Total solar installation costs of top countries

By comparing these parameters and representing them in graphs and tables would help analyze these datasets better.

### GHG Emissions of Countries

The 2019 emissions data released by IEA shows that China contributes to the maximum number of GHG emissions in the world, followed by the USA and India. Canada is amongst the top 10 contributors of GHG emissions in the world at the eighth spot. However, Canada's steps towards reducing GHG emissions do not seem promising as they have a history of cancelling policies favoring renewable energy policies.

On the other hand, countries like China and India, that are also major emission producers, have been working vigorously to reduce their emissions have brought renewable energy policies with yearly targets for renewable power installations in their countries.



*Figure 15: Emissions of top countries in 2019 including Canada (IEA,2021)*

Rank	Country	2019 Emissions (MTCO <sub>2</sub> )
1	China	41125.3
2	United States of America	18371.6
3	India	9342.6
4	Japan	4242.7
5	Germany	2521.2
6	Indonesia	2355.7
7	Korea	2302.3
8	Canada	1981.9
9	Brazil	1644.1
10	Mexico	1639.0
11	South Africa	1611.5
12	Australia	1465.8
13	Turkey	1444.7
14	United Kingdom	1288.8
15	Italy	1194.7
16	France	1121.2
17	Poland	1120.9
18	Thailand	1012.6
19	Spain	914.3
20	Kazakhstan	777.1

Table 7: GHG Emissions data of top countries for 2019 (IEA,2021)

### Solar installation capacities

China leads the world in total solar installation by a significant number. 2019 figures from IRENA, reveal that China is followed by the US, Japan, Germany and India as the top 5 countries with solar installations in the world. These countries have been able to focus on growth of solar industry in their respective countries by passing laws and making policies that define targets as well support solar installation such as financial incentives and tax rebates.

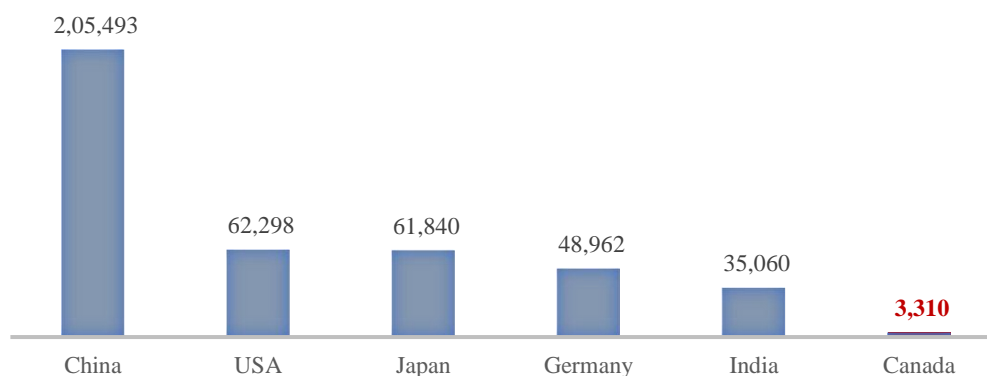


Figure 16: Solar installed capacities (MW) of top 5 countries v/s Canada (IRENA,2020)

China contributes a massive per cent to the world numbers i.e., 35%, whereas Canada is listed twentieth in this list by contributing 0.6% of the world’s total solar installations. The numbers also have significant differences. Where China has installed 205 GW of solar projects, Canada lags behind by installing only a mere GW. These numbers are evident enough to show Canada’s seriousness in promoting the growth of Solar projects and thereby reducing GHG emissions to achieve the 2030 targets committed in the Paris Agreement.

Rank	Country	Capacity (MW)	% Of World’s total in 2019
1	China	2,05,493	35.0%
2	USA	62,298	10.6%
3	Japan	61,840	10.5%
4	Germany	48,962	8.3%
5	India	35,060	6.0%
6	Italy	20,906	3.6%
7	Australia	15,930	2.7%
8	UK	13,398	2.3%
9	Spain	11,065	1.9%
10	France	10,571	1.8%
11	Korea	10,505	1.8%
12	Africa	7,443	1.3%
13	Netherlands	6,725	1.1%
14	Turkey	5,996	1.0%
15	Ukraine	5,936	1.0%
16	Viet Nam	5,695	1.0%
17	Belgium	4,531	0.8%
18	Mexico	4,440	0.8%
19	Taiwan	4,150	0.7%
20	Canada	3,310	0.6%

*Table 8: Solar installed capacities of top countries (IRENA,2020)*

### **Solar installation costs**

The installation costs of solar projects have been falling rapidly across the world. The latest figures for the year 2020 from IRENA reveal a picture that shows that solar installations costs vary a lot from country to country. While some countries like India and China have been successful in bringing down their installation costs, others like Canada and Japan have not worked towards the costs. India has the lowest solar installation costs at \$596 per kW whereas Canada has installation costs that are more than double this number at \$1275 per kW. Lower costs attract market players and investments and hence, Canada is far behind other countries in doing so. These costs are not feasible as compared to other countries and this suggests that major policy changes are required in Canadian system for solar power projects

Utility-scale Solar Installation Costs  
(US\$/kW) - 2020

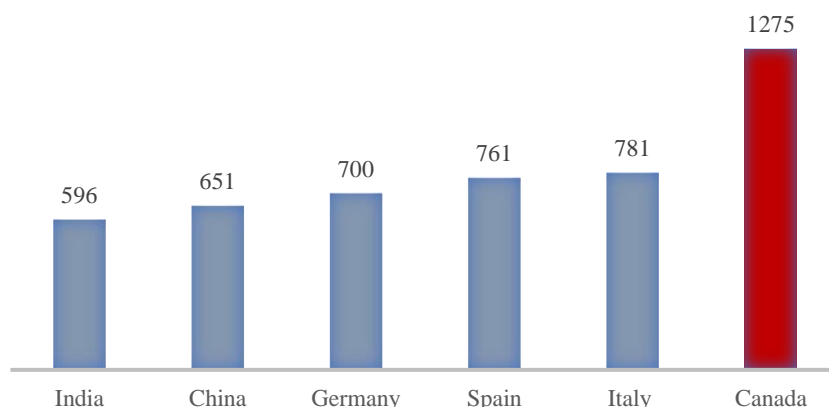


Figure 17: Solar installation costs of top 5 countries v/s Canada (IRENA,2020)

Rank	Country	Utility-scale solar installation costs (USD/kW) - 2020	% Difference from lowest installation cost
1	India	596	
2	China	651	9.2%
3	Germany	700	17.4%
4	Spain	761	27.7%
5	Italy	781	31.0%
6	Turkey	827	38.8%
7	Mexico	866	45.3%
8	France	942	58.1%
9	Korea	949	59.2%
10	Australia	1061	78.0%
11	Indonesia	1073	80.0%
12	USA	1101	84.7%
13	Brazil	1103	85.1%
14	Saudi Arabia	1108	85.9%
15	South Africa	1148	92.6%
16	Argentina	1167	95.8%
17	Canada	1275	113.9%
18	Japan	1832	207.4%
19	Russia	1889	216.9%

Table 9: Solar installation costs of top countries (IRENA,2020)

## Ranking

This ranking calculation is based on the ranking data, used in the preceding section for

1. GHG emissions of countries derived from the data from IEA.
2. Solar installation capacities derived from the data from IRENA.
3. Solar installation costs derived from the data from IRENA.

This ranking assessment considers top 10 countries producing the most emissions on the earth. This is then compared with their solar installed capacities and the installation costs. As per the detailed data assessment of this study.

Country	Emissions' rank	Installations' rank	Costs' rank
China	1	1	2
United States of America	2	2	12
India	3	5	1
Japan	4	3	18
Germany	5	4	3
Indonesia	6	64	11
Korea	7	11	9
Canada	8	20	17
Brazil	9	26	13
Mexico	10	18	7

*Table 10: Solar rankings of top 10 GHG emitting countries*

Based on the above world rankings for top 10 countries generating the most emissions in the world, this study has tried to infer the country having maximum world emissions and its effort to increase the solar installation along with decreasing the solar installation costs.

Country with “Emissions” rank 1 has been ranked the lowest and given the least point, which is 1, meaning that the country generating the maximum emissions and therefore be discouraged.

Country with “Installations” rank 1 has been ranked the highest and given the maximum point 10, meaning that the country is making efforts in installing solar power projects and therefore be encouraged.

Country with “Costs” rank 1 has been ranked the highest and given the maximum point 10, meaning that the country is making efforts in reducing the costs of installing solar power projects and therefore be encouraged.

### Calculations

- P1, P2 and P3 are the points assigned to the 3 parameters in the calculation.
- P1 = Points against the parameter “Emissions”.
  - P1=1 for maximum “Emissions” rank, which is 1 for China
  - P1=10 for minimum Emissions rank, which is 10 for Mexico.
- P2 = Points against the parameter “Installations”.
  - P2=1 for minimum “Installations” rank, which is 64 for Indonesia
  - P2=10 for maximum “Installations” rank, which is 1 for China

- P3 =Points against the parameter “Costs”
  - P3=1 for minimum “Costs” rank, which is 18 for Japan
  - P3=10 for maximum “Costs” rank, which is 1 for India
- P<sub>T</sub>= Total number of rank points for a country
  - P<sub>T</sub>=P<sub>1</sub>+P<sub>2</sub>+P<sub>3</sub>
- Rank=Final rank calculated based on P<sub>T</sub>.
  - Rank = 1 for P<sub>T</sub>= 21, which is the maximum total of points for Mexico.
  - Rank = 10 for P<sub>T</sub>= 12, which is the minimum total of points for Indonesia.

Country	Emissions	Installations	Cost	P1	P2	P3	P <sub>T</sub>	Rank
Mexico	10	18	7	10	4	7	21	1
China	1	1	2	1	10	9	20	2
Germany	5	4	3	5	7	8	20	2
India	3	5	1	3	6	10	19	4
Korea	7	11	9	7	5	6	18	5
United States of America	2	2	12	2	9	4	15	6
Brazil	9	26	13	9	2	3	14	7
Japan	4	3	18	4	8	1	13	8
Canada	8	20	17	8	3	2	13	9
Indonesia	6	64	11	6	1	5	12	10

*Table 9: Average world ranking calculations of countries for solar projects*

### Analysis of results

- Mexico is making the most efforts to increase its solar installations and reduce the installation costs to tackle the emissions that the country is producing.
- Similarly, China, Germany and India have also been making significant efforts to reduce their GHG emissions and are next in the rankings.
- Canada however ranks 9 in the list of 10 countries studied which shows that the country is not working on increasing the solar installations in the country and in bringing down the costs of installations, as compared to a high volume of GHG emissions that it is producing.
- Overall, China and India emerge as the top countries in the world that are serious about reducing their GHG emissions and have been setting examples for the rest of the world in terms of working towards a holistic growth of the solar industry.

## **Section 4 B | Case Study Analysis**

The second research methodology used in this paper is a Case study analysis. The case is the working on an already installed 10 kW solar PV project, at a permaculture farm called the Wheelbarrow Farm, located in Uxbridge, Ontario.

In November, 2020 a powerful windstorm hit southern and central parts of Ontario damaging several properties and leading to power outages that left 240,000 homes and businesses without power according to Hydro One. (*Toronto city news,2020*). As per the Insurance Bureau of Canada (IBC), the total insured damage was estimated to be around \$87 million. (*Newswire.ca,2020*). The Wheelbarrow farm was also one of the many victims of the windstorm and the 10kW solar array installed at the farm was damaged.

This incident acted as an opportunity for us to understand the nature of the damages and work on finding out reasons for the same and if funds permit, try to revamp and restore the system. These damages made us question the feasibility of the project based the cost estimates initially provided for the project when the project was built. Consequently, I identified that my best role in the project was to understand the project feasibility using a Clean Energy Management simulation software, called RETScreen Expert and determine a cost analysis.

### **Case Study: The Wheelbarrow Farm**

Solar PV farms in Canada are growing in number as well as have the largest installed capacities. At present, 138 solar PV farms with an average capacity of a minimum of 1 MW have been installed in Canada, the total of which cumulatively is more than 1700 MW. The largest solar farms in Canada are Sol-Luce in Kingston and the Renewable Energy Park, Haldimand County. Both these farms are in Ontario and have a capacity of 100 MW each. (*NRCan,2020*)

### **About: The Wheelbarrow Farm**

Wheelbarrow farm is a 10-acre farm located in Sunderland, Ontario. The farm was founded in 2008 by a non-farm family person and the now head farmer, Tony Neale, who was not raised on the farm. The farm grows more than 50 different types of vegetable crops, fruits as well as nuts trees and sells to Toronto farmers' markets and a Community Supported Agriculture (CSA) program. The crops grown do not use any spray, synthetic fertilizers, GMOs, or black plastic mulch. The team at Wheelbarrow farm works hand in hand to expand the farm

operations in the most environmentally friendly way and to supply the best quality crops along with planting more trees and reducing waste. Public farm tours are also provided to people. (wheelbarrowfarm.com)

### ***Solar Electric tractor***

One of the most ambitious and larger projects that the team took on, was to decide to run the farm operations powered by solar energy and invest in Canada's first electric tractor.

Tony Neale and Steve Heckerth of Soletrac in Mendocino, California connected online via emails, met in 2017, and worked together to build an electric tractor in California, which was then shipped to the farm in Canada in February 2018. The tractor uses solar power for its charging.

Soletrac electric tractor was first of its kind in Canada. Unlike the regular combustion engine farm tractor that uses around 800 litres of diesel in a year, the electric tractor uses solar power for its charging, is very silent and there is no CO<sub>2</sub> release. In Tony's words, the efficiency of the electric motor of the tractor is 95%, meaning 95% of the power in the batteries is turned to energy and only 5% is wasted as heat.

### ***10 kW Solar array***

In May 2018, a 10-kW solar array system was installed at the farm by Haliburton Solar and Wind, to support farm needs and operations. The system generates power for irrigation and is used for vegetable cooling, heating of the house, produces enough energy to supply all farm needs and majorly to power the electric tractor.

### ***Project financing***

The project has been a great example of being initiated with community bonds. In order to finance it, the team reached out to friends and family and even their customers to secure loans to purchase the tractor. They were also able to receive a generous grant from the Greenbelt Foundation to finance the project. The community investors received a 4% rate of return and more importantly, got to invest in a green technology.

The Wheelbarrow farm is a perfect example of teamwork and community coming together to grow the best quality organic crops, showcases harnessing of renewable energy on the farm and educating people at the same time.

## **RETScreen Expert**

RET Screen or Renewable energy technology screen is a Clean Energy Management simulation software system that was a software developed by the Canadian Government, industry and academia. It is also one of the major Economic evaluation tools used in the solar industry. (Sharma, Verma, & Singh, 2014). In April 2018, the software completed 20 years since its first version was launched by the CanmetENERGY Varennes Research Centre. RET Screen's popularity can be estimated by At present, there are more than 575,000 users and customers of RET Screen worldwide. It is also widely used by professors and students at more than 1100 colleges and universities around the world. (*Gregory Leng,2018, LinkedIn*)

The software is primarily used to determine project feasibility and energy performance analysis of an existing or a new establishment, which could be any sort of building, a site, or a power plant. It is used to track and assess energy efficiency and renewable energy aspects of a project.

RET Screen acts as a decision-making tool that empowers professionals, experts to decide on financial as well as technical viability of renewable and clean energy projects. The software platform is decision intelligent, specially aimed at feasibility analysis of clean energy technologies, that allows analyzers and managers to measure, assess and test the performance of a working facility, and thereby working on finding solutions to save more energy and investing in better production opportunities. (Natural Resources Canada, n.d.)

The software boosts working efficiency, as the analysis is fast, and needs minimal time and effort to assess the project feasibility and take a decision based on the project merits to finally conclude whether the clean energy project is worth investing or sufficiently promising.

The core of the tool consists of a standardized and integrated project analysis software which can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of proposed energy efficient and renewable energy technologies. Just like all clean energy technology softwares that have a common integration platform with a standard interactive interface, delivering reliable results, RET Screen also has various in-built and pre-fed databases for products, costs and weather data along with a user-friendly manual available for instructions and help at every step. These features help in reducing time and cost drastically and prepare pre-feasibility reports on the go. "The RETScreen Software is perhaps the quickest and easiest tool for the estimation of the viability of a potential clean energy project." (Natural Resources Canada, 2012)

## Key elements

- 1 **Performance Analysis:** It determines the performance of the building in relation to the benchmark data. Energy intensity and energy usage can be tracked by using this tab. Performance Analysis allows a user to monitor, analyze, and report key energy performance data to facility operators, managers and senior decision-makers, including a facility's actual energy performance versus predicted performance. The Performance Analysis module integrates near real-time satellite-derived weather data from NASA for the entire surface of the planet and is connected to the Green Button Standard.



Figure 18: RETScreen Software Homepage

- 2 **Benchmark Analysis:** Benchmark analysis allows the user to enter the location of any location or site on the earth and establishes reference climatic conditions based on its in-built NASA's database. It then compares the actual estimated (calculated or modeled) energy performance of the referred or entered site, with different similar benchmark facilities. It calculates the difference in the actual energy data and how it varies with the benchmark data by representing the same using bar charts. Energy benchmarking works as a powerful tool for designers, facility operators, managers, and senior decision-makers to promptly gauge a facility's energy performance by giving a true picture of the facility's energy production and consumption relative to other reference facilities, thereby pushing towards scope for improvements.

- 3 Feasibility Analysis: The tab helps determine the overall energy profile of a system, project or a facility. Feasibility Analysis allows the users to conduct a detailed and comprehensive five step analysis i.e., energy analysis, cost analysis, emission analysis, financial analysis, and sensitivity/risk analysis by integrating pre-fed benchmark, product, project, hydrology, and climate databases, along with active into links to worldwide energy resource maps. To help the users, an extensive database of generic clean energy project templates as well as specific case studies have also been readily provided.
- 4 Finance Analysis: This is an important tab, and it works like a financial model where all financial assumptions can be put in to determine the Payback analysis and yearly cash-flows until the lifetime of the system.

### **Core components**

Virtual Energy Analyser: This feature, going by its name, analyses energy of any location in the world without the requirement of an actual site visit by allowing for accurate estimation of generation of energy as well as the potential in energy savings with the help of an in-built “five-star benchmark ranking system”. For example, loading the five-star "Large Office" archetype (Facility type: *Commercial/Institutional*; Type: *Office Building*; Description: *Office - Large*) will rapidly model the energy profile, costs, emissions, financial returns, and risk of an archetypical large office building in the chosen location, automatically adjusting calculations for geographic location.

Smart Project Identifier works like a cherry-picking processor, whereby it identifies the best workable sites that can be used for implementation at a particular facility and then completes a diligent energy audit or returns a pre-feasibility analysis which can be used for further refinements on the site.

Financial Risk Assessor: The assessor identifies and does sensitivity analysis of important parameters impacting the project feasibility by doing a risk assessment of the proposed investment.

Performance Tracker: tracks and comprehensively measures the energy performance of already installed facilities or implemented projects with suggestions on further needed improvements in energy performance.

Project Life-Cycle Analysis: RETScreen Expert helps analyze projects for their entire life cycle. For example, a solar project has an approximate life cycle of 25 years which is due to the life of the solar panels. (Huang *et.al.*,2017). Hence, the software would assess the performance as well as do financial modelling spanning over the entire project life of 25 years.

Portfolio Analysis: helps create and manage the portfolio of a user. It allows to assess energy performance and energy efficiency across different facilities in a single building or multiple buildings at a site or multiple sites at multiple locations which could comprise of power plants, factories, residential complexes, hospitals or educational institutions. Individual facilities can be analyzed within a widespread portfolio. Subsequently, additional facilities can be added in the database of an existing portfolio as well as sub-portfolios can be created to compare data spanning different geographic locations and visualizing it across the globe using the mapping tool. Additionally, a portfolio dashboard can be created for visual analysis that consolidates results of all respective facilities spread worldwide including their energy, cost, greenhouse gas emissions and finances which can then be sorted based on the country, fuel-type, etc. and can be easily presented to the stakeholders for efficient decision-making.

## **Project Analysis**

### ***Preliminary Analysis/ Site visit***

My team and I visited the farm on 8<sup>th</sup> Feb,2021 to have an initial look at the damaged solar system. One of the solar panels of the array had flown away due to the high wind speed. It was surprising to see that the main foundation was made of wood and there were no concrete materials for firm support of the aluminum structures and the heavy solar modules. Based on our initial analysis, the system had toppled due to the base foundation being weak. This came as a shock as this was the first time for us to see a system like this. (Site visit photos can be referred to in Appendix 1)

After talking to the lead farmer, Tony Neale, we discussed that he wanted the solar array to be restored and possibly double the capacity to a 20kW system. He was also open to ideas to make the farm better with green houses and solar on a container system.

### ***System Components used***

The initial 10 kW system was installed by an Ontario based renewable solutions company, Haliburton Solar and Wind. Based on the quote submitted for the system at Wheelbarrow farm, the following core components were used: (Appendix 2)

Component	Make
Module	Hanwha - Q cells: 300W PERC 60Cell
Micro Inverter	APS Inverter YC500A dual Inverter
End Caps	End Caps for APS YC500A APS Strings
Termination Cable	APS Termination Cable 2M
Monitor	APS Monitor
Legs	FastRack Ground Mount 60 or 72C LEGS
Rails	FastRack Ground Mount 60 or 72C RAILS

*Table 10: System components of 10kW solar project at the Wheelbarrow Farm*

### **Modules**

The Solar modules used in the system are Hanwha-Q cells of a rating of 300 W which are based on PERC (passivated emitter and rear contact) technology. Solar panels built with PERC cells have an additional layer on the back of the traditional solar cells. This additional layer allows more sunlight to be captured and turned into electricity, that makes PERC cells far more efficient than the traditional cells. (*Aurorasolar.com,2021*)

Each Hanwha module is made of 60 cells and has a power rating of 300 W. In total, 40 panels were installed which makes up a 12-kW panel system. The company claims that the efficiency of the modules is 18.9%.

### **Inverters**

APSystems (APS) inverter is a grid-tied microinverter with intelligent networking and monitoring systems to ensure maximum efficiency. The inverter is highly dependable and extremely cost effective, the YC500A can accommodate PV modules up to 365W. It is ideally suitable for modules from 280 to 310W. The model APS YC500A is a dual inverter with a dual MPPT, meaning that two modules can be connected to a single inverter. (*apsystems.com,n.d.*)

### ***Cost of system components***

Haliburton Solar and Wind's proposed and submitted cost for a 12kW Net-metered system at the Wheelbarrow farm, was around \$29,574. Following is the break-up of the costs based on

the quote provided in the name of Tony Neale in March,2018. A detailed break-up of the costs of every component was not available in the quote. The project quote covers only upfront capital costs and does not mention any costs required for annual operations and maintenance (O&M) of the system. (*Appendix 2*)

System components	Cost
Net metered 40 Panel Equipment	\$20,171.30
Net Metering installation	\$ 650.00
Net Metering Electrical	\$ 5,000.00
Hydro One	\$ -
Delivery	\$ 350.00
Sub-total	\$26,171.30
HST	\$ 3,402.27
Total	\$29,573.57

*Table 11: Cost of system components of 10kW solar project at the Wheelbarrow Farm*

### **Simulation using RETScreen Expert:**

For this project, we have considered the results of two simulations:

1. Self-simulation wherein the data has been fed as inputs to the software.
2. Using the inbuilt software feature, Virtual Energy Analyzer that picks up inputs from the system database.

### **Self-Simulation**

RET Screen Expert analysis proceeds step by step. Inputs are fed at each stage, which then lead to the next stage. Outputs generated as analysis from the preceding stage are saved at each step, thereby forming a part of a bigger analysis and ultimately the final report. The final generated report can be referred to in *Appendix 4*.

### **Site Location:**

The very first stage of the process starts with the user identifying the type of facility that he wants analysis for. The facility could be a power plant, an educational institution, a residential building, commercial property, agriculture land or even any individual facility.

After selecting the type of location, the data for the actual location or the geographical coordinates is asked for. The software requires two location related inputs: Facility location and Climate data location.


The facility location needs the user to enter the facility's latitude and longitude. This can be found out by using Google Earth or Google Maps. By entering the location's name and address, Google tells the coordinates. These coordinates can then be entered as the inputs.

For Climate Data location, the nearest location pre-fed is picked up, or it can be manually set by dragging the location icon and placing it as per the facility coordinates. Nearest climate data locations are suggested with can be selected for moving in the process further. RET Screen Expert used NASA's data for climate and weather locations as well as for solar radiations.

For our simulation, we used the Wheelbarrow Farm's coordinates from Google maps which were: 44.21°N and -79.01°E

Site reference conditions

Climate data location: Canada - Ontario - Lagoon City      Facility location: The Wheelbarrow Farm, Uxbridge, ON



	Unit	Climate data location	Facility location	Source
Latitude		44.5	44.2	
Longitude		-79.2	-79.1	
Climate zone		6A - Cold - Humid		
Elevation	m	221	283	Ground+NASA
Heating design temperature	°C	-20.7		Ground - Map
Cooling design temperature	°C	26.2		Ground
Earth temperature amplitude	°C	22.1		NASA

Figure 18: RETScreen Expert self-simulation: Location

Based on the location entered RETScreen, from the pre-fed system database, determines and shows air temperature, relative humidity, precipitation, solar radiation, atmospheric pressure, wind speed, etc.

### Facility:

The next step is named “Facility”. This requires information about the facility type and the description. For example, an educational facility with a gas turbine. The description requires the type of energy plant at the facility for which the analysis is being done.

For our simulation, we entered the Facility type as “Power plant” and the Type as “Photovoltaic”.

The output is the benchmark Energy production cost in (\$/kWh) based on RETScreen values. The values are shown in Canadian \$ which makes it easier to feed in the data and interpret it.

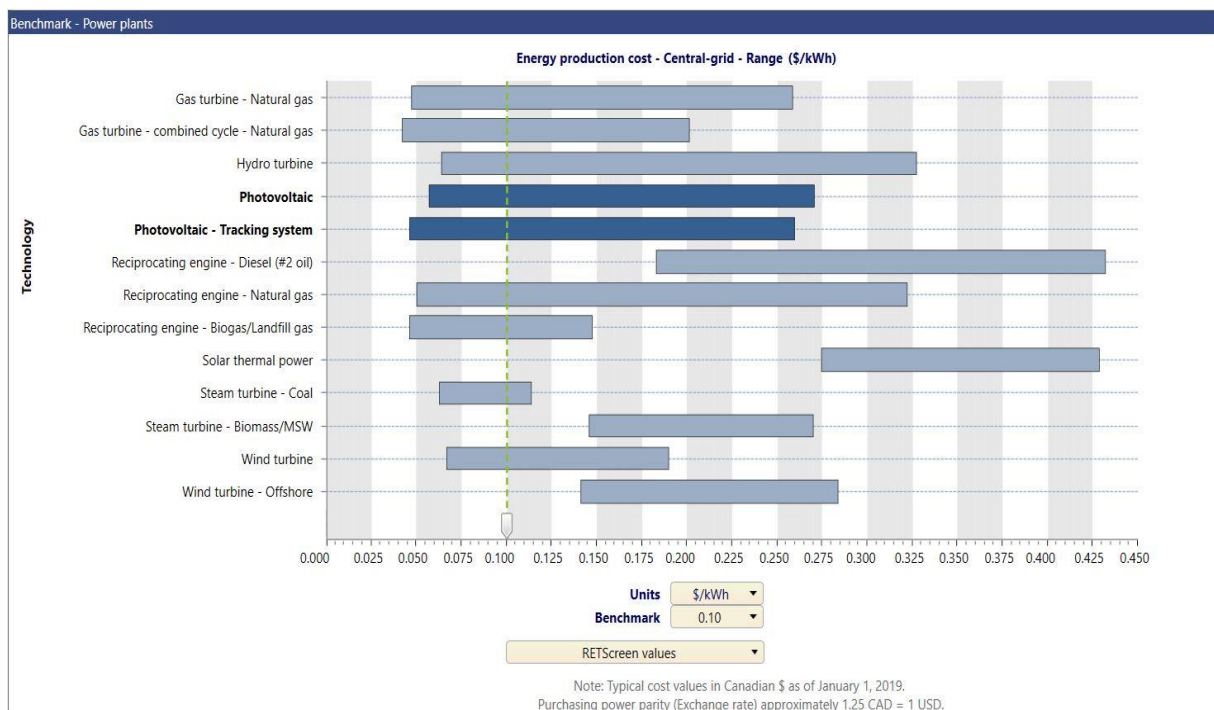


Figure 19: RETScreen Expert self-simulation: Benchmark

### Energy:

At this stage, energy modelling is done. It requires user inputs for the following,

1. Plant type i.e., Gas or nuclear or solar or wind
2. Sizing details of the plant (kW or MW)
3. Capacity factor (%)
4. Initial costs (\$/\$/kW-year)
5. O&M Costs
6. Electricity exported to the grid (kWh/MWh)

Our inputs for the above were:

- Photovoltaics of size 10 kW which is the size of the solar array at the Wheelbarrow farm. The Capacity factor entered was 13.4% which was an average capacity factor in Ontario derived from CER's website. (CER,2020)
- Initial costs of \$29,574 have been picked from the system quote provided by Haliburton Solar and Wind for the system at the Wheelbarrow farm. (Appendix 2)
- O&M costs of \$40/kW for non-rooftop systems up to 10kW, have been taken from CanSIA's data on costs for FIT programs. (Canadian Solar Industries Association [CanSIA],2017)

RETScreen - Energy Model Subscriber: Viewer

Power plant - Photovoltaic

**Fuels & schedules**  
Electricity and fuels

**Technology**  
Power  
Photovoltaic

**Summary**  
Include system?  
Fuels

Photovoltaic - Level 1

Description	Photovoltaic
Note	
Level	Level 1   Level 2
Power capacity	12 kW
Manufacturer	
Model	
Number of units	
Capacity factor	13.4%
Initial costs	29,574 \$
O&M costs (savings)	40 \$/kW-year
Electricity export rate	480 \$
Electricity export rate	Electricity export rate - annual
Electricity exported to grid	14,086 kWh
Electricity export revenue	1,409 \$

Go to: Cost

Figure 20: RETScreen Expert self-simulation: Energy Model

At this stage, data for multiple plants under the same location or facility can be added into the portfolio. It also inputs two levels of data wherein the Level 2 is for detailed inputs. Since, the inputs were limited for this project, data from only Level 1 has been considered.

### Cost Analysis

This stage asks for inputs for detailed cost data that is divided into three steps.

1. Initial cost
2. O&M costs (Initial and O&M costs amount to Total annual costs)
3. Total annual savings

For this simulation, the above inputs were not needed to be entered, as the software had automatically filled in the data entered, from the previous stage.

RETScreen - Cost Analysis Subscriber: Viewer

Initial costs (credits)	Unit	Quantity	Unit cost	Amount
Initial cost				\$ 29,574
<input type="checkbox"/> Show data				
<input type="checkbox"/> User-defined	cost			\$ -
<input type="checkbox"/> +				
<b>Total initial costs</b>				<b>\$ 29,574</b>

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M costs (savings)	project			\$ 480
<input type="checkbox"/> Show data				
<input type="checkbox"/> User-defined	cost			\$ -
<input type="checkbox"/> +				
<b>Total annual costs</b>				<b>\$ 480</b>

Annual savings	Unit	Quantity	Unit cost	Amount
<input type="checkbox"/> User-defined	cost			\$ -
<input type="checkbox"/> +				
<b>Total annual savings</b>				<b>\$ -</b>

[Go to: Emission](#)

Figure 21: RETScreen Expert self-simulation: Cost Analysis

This stage enables users to enter detailed costs specifying the quantity and the cost for each unit (Unit Cost). The Units can be the Cost or Credit.

**Emission analysis:**

The output at this stage tells us the gross annual GHG emission reduction after taking the default values for the fuel types present at the facility, GHG emission factor and the T&D losses (transmission and distribution). Since the Wheelbarrow farm is powered by Solar energy for all its operations, we did not enter comparisons with another fuel type. RETScreen considered 7% as the T&D losses, post which GHG emission reduction for this simulation came up to be 93%.



Figure 22: RETScreen Expert self-simulation: Emission Analysis

### Financial Analysis:

This was one of the crucial steps in this study. The inputs demanded from the user are critical to analyze the financial returns of the project. Following were the required inputs:

1. Inflation rate (%)
2. Project life (Year)
3. Debt ratio (%)
4. Debt interest rate (%)
5. Debt term (Year)
6. Incentives and grants (\$)

The output at this stage reflects the financial viability of the project. This is determined by the following major financial outcomes:

1. Pre-tax Internal Rate of Return - equity
2. Pre-tax Internal Rate of Return – assets
3. Simple payback
4. Equity payback

For this simulation, I did a scenario analysis by varying these figures to understand the internal rate of return or IRR of equity which means the overall profits or return on the equity investment, as well as the payback years of equity which means the number of years that would take for the project to return the equity, or the initial amount invested in the project.

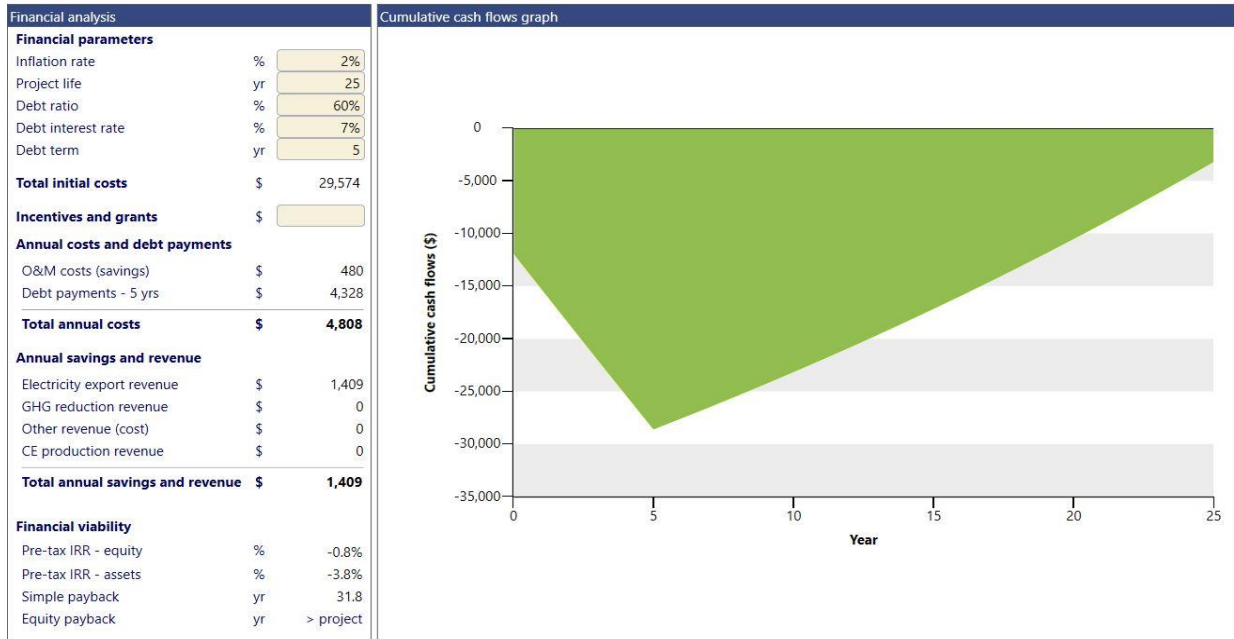


Figure 23: RETScreen Expert self-simulation: Financial Analysis

The financial scenario analysis had interesting and note-worthy outcomes, especially in terms of assessing the need for incentive for solar projects in Canada.

**Financial scenarios**

Inflation	Project life	Debt ratio	Debt Interest	Debt term	Incentives	Equity payback	Pre-tax IRR equity
2%	25 Yr	0%	0%	0 Yr	\$15,000.00	13.5 Yr	6.0%
2%	25 Yr	0%	0%	0 Yr	\$12,000.00	15.9 Yr	4.30%
2%	25 Yr	0%	0%	0 Yr	\$10,000.00	17.5 Yr	3.40%
2%	25 Yr	50%	5%	5 Yr	\$10,000.00	19.2 Yr	3.0%
2%	25 Yr	60%	6%	5 Yr	\$10,000.00	19.9 Yr	2.70%
2%	25 Yr	50%	5%	10 Yr	\$10,000.00	20.7 Yr	2.60%
2%	25 Yr	70%	7%	5 Yr	\$10,000.00	Immediate	2.30%
2%	25 Yr	0%	0%	0 Yr	\$ -	24.5 Yr	0.18%
2%	25 Yr	60%	6%	5 Yr	\$ -	> project	-0.66%
2%	25 Yr	70%	7%	15 Yr	\$10,000.00	Immediate	-1.40%
2%	25 Yr	60%	6%	10 Yr	\$ -	> project	-1.60%
2%	20 Yr	0%	0%	0 Yr	\$ -	> project	-2.20%
2%	25 Yr	60%	6%	15 Yr	\$ -	> project	-2.90%
2%	20 Yr	70%	7%	15 Yr	\$ -	> project	-11.50%

Table 12: Comparison of various financial feasibility scenarios

### ***Assumptions***

1. Inflation is fixed at a default of 2%.
2. Incentives are assumed at a rate of \$1 per Watt based on Ontario's GreenON's Solar rebates. So, a total of \$10,000 has been assumed for a 10kW system.
3. Debt interest assumed at 10% of the Debt ratio. So, for a 60% debt ratio, debt interest is assumed as 6%.
4. Project life of 25 years is assumed as a standard as most of the solar panels have a life of 25 years or more.

### **Analysis of simulation results**

1. The ideal RET Screen scenario with the project life of 20 years, 70% debt ratio, 7% debt interest and 15 years of debt term, with no incentive, has an equity payback that is greater than the project life and a negative IRR.
2. All scenarios with assumed incentives have a positive equity IRR, and a payback period less than the project life.
3. Reducing the debt ratio to zero leads to a positive equity IRR.
4. Considering 70% debt ratio even with incentives yields negative equity IRR.

### ***Deductions***

Following deductions can be made from the financial simulation results from RET Screen:

Equity payback years and equity IRR increase by:

- Increasing the incentives
- Increasing the project life
- Decreasing the debt ratio
- Decreasing the debt term

Financial terms of debt ratio, debt interest rate and the debt term are determined by the equity in hand and the terms agreed upon with the lending bank or the financial institution. Hence, these cannot be changed much. Project life cycle is a market standard as it depends on the life of solar panels which is 25 years.

The only variable and significant factor for positive equity returns and paybacks seems to be the incentives from government schemes. This also proves that in order to achieve smaller

payback periods for solar projects and good returns from equity, incentives have a primitive role to play. This would also lead to increased installations as incentive schemes would boost the solar markets and ultimately bring down the solar costs in Canada, in this case in Ontario. But the unfortunate reality is that GreenON's solar rebate scheme was closed within two months of its announcement. Researchers and small industry players should reach out to the government to bring in federal rebates schemes that would benefit the entire renewable industry in Canada.

## Virtual Energy Analyzer

This tool or RET Screen Expert feature, works like a magic wand and it saves all the time and effort while doing a simulation and renewable project feasibility analysis. By selecting the plant type and the location, the software automatically fills up all the information related to the cost and the system. It also completes a financial analysis thereby generating a yearly cash flow statement that makes it convenient for the users. The inbuilt database is huge, and it covers the information of millions of locations worldwide. Initial simulation is just a click away with the Virtual Energy Analyzer tool in the RETScreen Expert software. The generated report can be referred to in *Appendix 5f*.

### Location

After filling in the Facility type and its description, the next step is selecting the location. At the bottom of the page, the prompt for importing the data is available and hitting that lets the user enter the world of an automatic simulation.

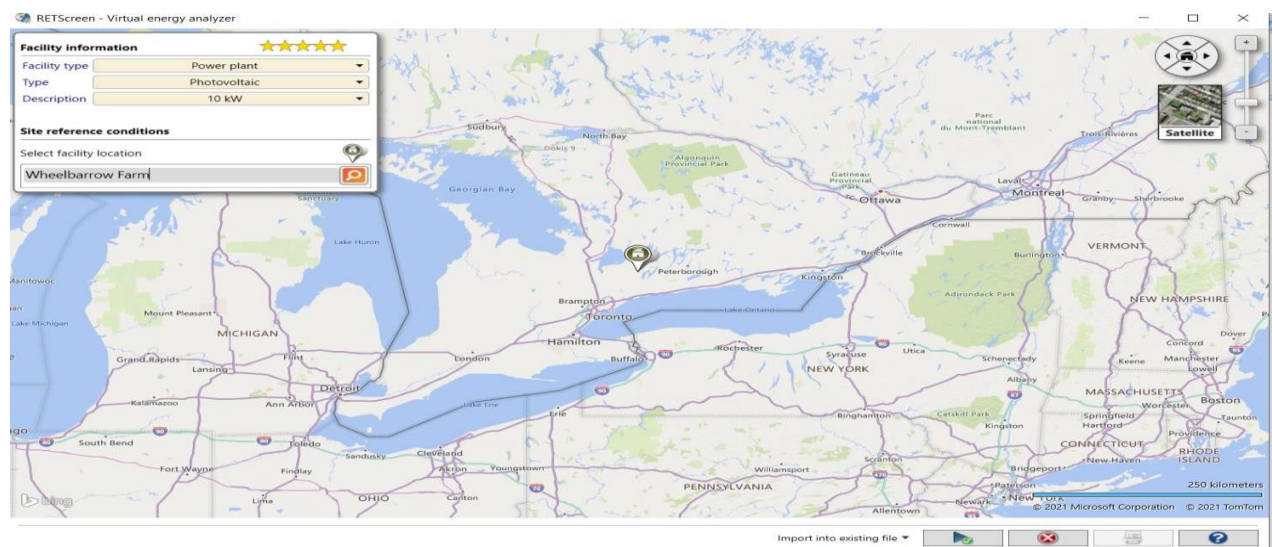


Figure 24: RETScreen Expert Virtual Energy Analyzer: Location

## Energy model

The energy model at the next stage gives a wholesome information about the following:

1. Total electricity generated (MWh/kWh)
2. Initial costs
3. Electricity export revenue
4. O&M savings
5. Simple payback year

The information can however be modified according to the realistic initial costs by editing in the “Costs” section of the software. Only the spaces highlighted in yellow can be entered or edited by the user.

RETScreen - Energy Model Subscriber: Viewer

Power plant - 10 kW - Photovoltaic

	Capacity	Electricity	Initial costs	Electricity export revenue	Fuel cost	O&M costs (savings)	Simple payback	Include system?
	kW	MWh	\$	\$	\$	\$	yr	<input type="checkbox"/>
<b>Electricity exported to grid</b>								
<b>Power</b>								
Photovoltaic - 10 kW	10	11.3	27,000	1,126	0	330	33.9	<input checked="" type="checkbox"/>
<b>Total</b>	<b>10</b>	<b>11.3</b>	<b>27,000</b>	<b>1,126</b>	<b>0</b>	<b>-330</b>	<b>33.9</b>	

Go to: Cost

Figure 25: RETScreen Expert Virtual Energy Analyzer: Costs

The energy model generated by the Virtual Energy Analyzer fills up detailed Level 1 and Level 2 information of the power plant, which is very convenient in case the user has lack of any information required to be entered in the software. In that case, the default inputs can be used for simulation.

### Level 1

This level only covers basic information, but what is sufficient to produce results. In this case, The Virtual Energy Analyzer fills up details for capacity factor as well as the initial and O&M costs from its database. It also assumes that the electricity would be exported to the grid.

Power plant - 10 kW - Photovoltaic

**Fuels & schedules**

- Electricity and fuels

**Technology**

- Power
  - Photovoltaic - 10 kW

**Summary**

- Include system?
- Fuels

Photovoltaic

Description: Photovoltaic - 10 kW

Note:

Level: Level 1 | Level 2

Photovoltaic - Level 1

Power capacity	kW	10
Manufacturer		
Model		
Number of units		50
Capacity factor	%	12.86%
Initial costs	\$/kW	2,700
	\$	27,000
O&M costs (savings)	\$/kW-year	33
	\$	330
Electricity export rate		Electricity export rate - annual
	\$/kWh	0.10
Electricity exported to grid	MWh	11.3
Electricity export revenue	\$	1,127

Go to: Cost

Figure 26: RETScreen Expert Virtual Energy Analyzer: Energy Model Level 1

## Level 2

The simulation at this level is detailed. For the solar photovoltaic system, the Virtual Energy Analyser puts in the following additional values:

1. Solar tracking mode (Fixed, One-axis, Two-axis)
2. Slope
3. Azimuth angle
4. Modules
  - a. Type (Mono-Si, Poly-Si, CdTe (thin film), etc.)
  - b. Power capacity
  - c. Number of units (number of modules)
  - d. Efficiency
5. Inverter
  - a. Efficiency
  - b. Capacity
  - c. Miscellaneous losses
6. Summary
  - a. Capacity factor
  - b. Costs

RETScreen - Energy Model Subscriber: Viewer

Power plant - 10 kW - Photovoltaic

**Fuels & schedules**

Electricity and fuels

**Technology**

Power

Photovoltaic - 10 kW

**Summary**

Include system?

Fuels

Photovoltaic - Level 2

Description: Photovoltaic - 10 kW

Note:

Level: Level 1 | Level 2

**Resource assessment**

Solar tracking mode: Fixed

Slope: 44

Azimuth: 0

Show data

**Photovoltaic**

Type: mono-Si

Power capacity: kW 10

Manufacturer:

Model:

Number of units: 50

Efficiency: % 15.75%

Nominal operating cell temperature: °C 45

Temperature coefficient: % / °C 0.4%

Solar collector area: m<sup>2</sup> 63.5

Miscellaneous losses: % 15%

**Inverter**

Efficiency: % 95%

Capacity: kW 9

Miscellaneous losses: % 1%

**Summary**

Capacity factor: % 12.9%

Initial costs: \$/kW 2,700 | \$ 27,000

O&M costs (savings): \$/kW-year 33 | \$ 330

Electricity export rate: Electricity export rate - annual

Electricity exported to grid: \$/kWh 0.10 | MWh 11.3

Electricity export revenue: \$ 1,126

Go to: Cost

Figure 27: RETScreen Expert Virtual Energy Analyzer: Energy Model Level 2

### Financial Analysis

For a detailed financial analysis of the project, the Virtual Energy Analyser pulls up and enters the following information:

1. Fuel cost escalation rate
2. Inflation rate
3. Discount rate
4. Reinvestment rate
5. Project life
6. Debt ratio
7. Debt interest rate
8. Debt payments
9. Electricity export escalation rate

All this entered information can be edited by the user. This is critical financial information which then help build a chart for the costs, savings and revenue. The Analyser calculates and reveals the project viability by showing the equity IRRs and the payback time in years. It also calculates the Net Present Value (NPV) as well as the annual lie cycle savings. Additionally, yearly cash flows until the project life are shown. This detailed financial analysis is really helpful because it shows both pre-tax and cumulative numbers.

RETScreen - Financial Analysis			Subscriber: Viewer					
<b>Financial parameters</b>			<b>Costs   Savings   Revenue</b>			<b>Yearly cash flows</b>		
<b>General</b>			<b>Initial costs</b>			<b>Year</b>	<b>Pre-tax</b>	<b>Cumulative</b>
Fuel cost escalation rate		2%	-	\$	0	#	\$	\$
Inflation rate	%	2%	<b>Total initial costs</b>			0	0	0
Discount rate	%	9%				1	812	812
Reinvestment rate	%	9%	<b>Yearly cash flows - Year 1</b>			2	828	1,641
Project life	yr	20	<b>Annual costs and debt payments</b>			3	845	2,486
<b>Finance</b>			<b>O&amp;M</b>			4	862	3,348
Incentives and grants	\$		<b>Debt payments - 15 yrs</b>			5	879	4,227
Debt ratio	%	70%	<b>Total annual costs</b>			6	897	5,123
Debt	\$	0				7	915	6,038
Equity	\$	0	<b>Annual savings and revenue</b>			8	933	6,971
Debt interest rate	%	7%	<b>Electricity export revenue</b>			9	952	7,923
Debt term	yr	15	<b>GHG reduction revenue</b>			10	971	8,893
Debt payments	\$/yr	0	<b>Other revenue (cost)</b>			11	990	9,883
<b>Income tax analysis</b>			<b>CE production revenue</b>			12	1,010	10,893
						13	1,030	11,923
			<b>Total annual savings and revenue</b>			14	1,051	12,974
						15	1,072	14,046
			<b>Net yearly cash flow - Year 1</b>			16	1,093	15,139
						17	1,115	16,254
						18	1,137	17,391
						19	1,160	18,551
						20	1,183	19,734
<b>Annual revenue</b>			<b>Financial viability</b>					
<b>Electricity export revenue</b>			Pre-tax IRR - equity			%		
Electricity exported to grid	MWh	11	Pre-tax MIRR - equity			%		
Electricity export rate	\$/kWh	0.10	Pre-tax IRR - assets			%		
Electricity export revenue	\$	1,126	Pre-tax MIRR - assets			%		
Electricity export escalation rate	%	2%	Simple payback			yr		
<b>GHG reduction revenue</b>			Equity payback			yr		
Gross GHG reduction	tCO <sub>2</sub> /yr	1	Net Present Value (NPV)			\$		
Gross GHG reduction - 20 yrs	tCO <sub>2</sub>	21	Annual life cycle savings			\$/yr		
GHG reduction revenue	\$	0	Benefit-Cost (B-C) ratio					
<b>Other revenue (cost)</b>			Debt service coverage					
			GHG reduction cost			\$/tCO <sub>2</sub>		
<b>Clean Energy (CE) production revenue</b>			Energy production cost			\$/kWh		

Figure 28: RETScreen Expert Virtual Energy Analyzer: Financial analysis

### Sensitivity and risk analysis

Virtual Energy Analyzer does a very detailed sensitivity and risk assessment analysis. RETScreen gives several options on which the performance analysis can be assessed. In this case, the sensitivity range taken was 25 per cent and the level of risk as 10 per cent.

## Comparison | Self-simulation v/s Virtual Energy Analyzer

Analysis	Factor	Type	Units	Self-simulation	Virtual Energy Analyzer	Absolute Difference
Facility	Benchmark	Output	\$/kWh	0.10	0.276	0.2
	Power capacity	Input	kW	10	10	0.0
	Capacity factor	Input	%	13.4	12.86	0.5
Energy	Electricity exported to grid	Output	MWh	11.7	11.3	0.4
	Electricity export revenue	Output	\$	1174	1127	47.0
	Initial Costs	Input	\$	29574	27000	2574.0
Cost	O&M savings	Input	\$	400	330	70.0
	Total cost	Output	\$	29974	27330	2644.0
Emission	GHG emission reduction	Output	%	93	93	0.0
	Inflation rate	Input	%	2	2	0.0
	Project life	Input	Yr	25	20	5.0
	Debt ratio	Input	%	60	70	10.0
	Debt interest rate	Input	%	7	7	0.0
	Debt term (Year)	Input	Yr	5	15	10.0
	Debt payments	Output	\$	4328	0	4328.0
	Total annual costs	Output	\$	4728	330	4398.0
Finance	Total annual savings revenue	Output	\$	1174	1126	48.0
	Pre-tax IRR– equity	Output	%	-2.2	Positive	
	Pre-tax IRR– assets	Output	%	-4.9	Positive	
	Simple payback	Output	Yr	38.2	0	
	Equity payback	Output	Yr	> project	Immediate	

*Table 13: Comparison of results of Self-simulation and Virtual Energy Analyzer*

### Analysis

- The benchmark cost changes from \$0.10/kWh to \$0.276/kWh from self-simulation to the Virtual Energy Analyzer
- The capacity factor taken for simulation is 13.4% while it is less by a value of 0.5 of what is taken for simulation by the Virtual Energy Analyzer which is 12.86%. This impacts the total energy generated and hence there is a difference in the electricity exported to the grid as well as the electricity export revenue. Since, the capacity factor was less in the second case, the electricity export numbers are also less.
- The costs taken by the Virtual Energy Analyzer are less than the original cost that was quoted for the solar project at the Wheelbarrow Farm. Both the initial costs and the O&M costs are less. The difference in the initial costs is \$2574 as the Virtual Energy Analyzer enters the initial costs as \$ 2700, and in the O&M costs is \$70 as the costs

taken were \$3.3 per Watts where the O&M costs in the self-simulation have been taken at \$4 per Watts as an average O&M costs specified in the FIT regime. Although overall the costs differences are not very significant, but they surely impact the project feasibility analysis.

- The greenhouse gas emission reduction of 93% is the same in the two cases.
- The major and the most significant change comes in the financial analysis.

The Virtual Energy Analyzer takes into consideration the following:

- Fuel escalation rate at 2 %.
- Discount rate at 9%
- Reinvestment rate at 9%

These factors were not taken into consideration while doing the self-simulation and have significantly impacted the feasibility assessment results. Due to the debt refinancing and reinvesting, the debt amount is nil in the calculations. A high discount rate of 9% has also been covered.

The other factors that are different from the self-simulation, that skew the results to a large extent, are the

- Debt term as 15 years
- Project life as 20 years
- In our simulation, we have taken the debt term as 5 years and the project life as 25 years which have led to a lower IRR and payback period. Some other small differences have been the escalation of the electricity export rate which is 2% taken in the simulation done by the Virtual Energy Analyzer. Considering the values used by the virtual simulation, the self-simulation results with the default values gives negative IRR values and that makes the project infeasible.

### **Assessing project feasibility**

Project feasibility assessment is determined by the internal rate of return or IRR of the project.

It is a percentage yield that an investment would provide across span of the entire total project life. This percent yield is comparable to the minimum acceptable rate of return (MARR) or the discount rate of the project. This comparison determines project profitability and hence its financial feasibility. If the IRR is greater than the MARR, the project is said to be economic otherwise not. (*Ruegg & Marshall, 1990*).

1. With Debt ratio, no incentive

In our simulation, all scenarios having any debt ratio, debt term or debt interest rate do not yield any positive cash flows. The equity IRR is negative, and the payback period is greater than the project which means that no profits would be achieved in the project. Hence, the project is not financially feasible. However, the simulation by Virtual Energy Analyzer suggests that refinancing the project would yield positive cash flows and a positive equity IRR.

2. No debt ratio, no incentive

A scenario that assumes no debt ratio and no incentive which means that, if a 100 % equity was invested in the project, then the project has a positive equity IRR of 0.18% and a payback period of 24.5 years considering the project life of 25 years.

3. With incentive, with or without debt ratio

Scenarios assuming an incentive or grant, even if there was any period of debt, make the project feasible and viable as the equity IRRs turn positive and the payback period becomes half of the project life.

### **Limitations in simulation**

- The only information about the project received from the Wheelbarrow farm was the Quote that was provided to them by Haliburton Solar and Wind for the 10kW solar system installation.
- No detailed financial information such as funds or the debt ratio, was available either on the Wheelbarrow Farm's website or from the lead farmer, Tony Neale. The debt: equity ratio is important to estimate how much investment was made initially. This is also linked to the debt term period and the rate of interest for that debt.
- No details about any further costs that might have been paid, in addition to the quote provided, to complete the project was available.
- The capacity calculations from the quote lead to the system capacity being 12kW. However, the website mentions about a 10kW solar array.
- Capacity factor could not be found in the documents. Hence, an average capacity factor was considered for the simulation calculations.
- O&M costs were not mentioned in the quotation provided or on the website to estimate future cash flows.

- The simulation was done in the Viewer mode of the RETScreen Expert software which does not have complete features as it is the free version and hence only a basic simulation could be achieved. Due to this, some critical financial inputs such as discount rate and refinancing rates, were not allowed to be entered.

No availability of discount rate in the actual project facts as well as the viewer mode RETScreen Expert simulation, leaves us with no way to find out if the project was profitable. Comparing equity IRRs with the discount rate would have enabled us to determine the economics of the project.

The project emissions are not compared against any fossil-fuel based system that was present at the farm prior to the solar project installation.

#### Section 4 C | Analyzing and Estimating the Future of Solar Industry in Canada

Considering the past data related to Canada and the political ecosystem, the future of the solar industry does not seem as promising, however, the numbers have been on an increasing trend despite a slow growth and year on year changes. But these numbers are not sufficient to off-set the rising GHG and carbon emissions in Canada. By doing a trend analysis and using forecasts for solar installations would paint a better picture to understand the overall scenario.

	Capital Cost (2019 US\$/ kilowatt (kW))	Fixed Operating and Maintenance Costs (2019 US\$/kW)	Variable Operating and Maintenance Costs (2019 US\$/ megawatt hour (MW.h))	Capacity Factor (%) <sup>10</sup>
Gas (Combined Cycle)	1 100-1 450	16	4	70
Gas Peaking	800-1 100	14	4	20
Wind (2020)	1 036	20-45	0	35-50
Solar (2020)	1 131	16-20	0	10-20
<b>EVOLVING SCENARIO</b>				
Wind (2030)	877	20-45	0	35-50
Wind (2040)	705	20-45	0	35-50
Wind (2050)	562	20-45	0	35-50
Solar (2030)	765	16-20	0	10-20
Solar (2040)	491	16-20	0	10-20
Solar (2050)	313	16-20	0	10-20

Figure 29: Solar future estimations for Canada (CER,2020)

Canada Energy Futures report published by the CER,2020 has estimated near and far future evolving scenarios for wind and solar projects in Canada. These figures clearly predict that there would be sharp rises in the capital costs of solar projects from the present figures. The capital costs are expected to decline at a pace of around 35% every decade from 2020 to 2050. The fixed operation and maintenance costs are expected to be in the range of 16-20 US\$/kW. The capacity factors, however, have not been expected to change although technological improvements are expected. Overall, since the capital costs have been estimated to decline, this is a positive sign for the industry to progress and install more solar projects in the coming future.

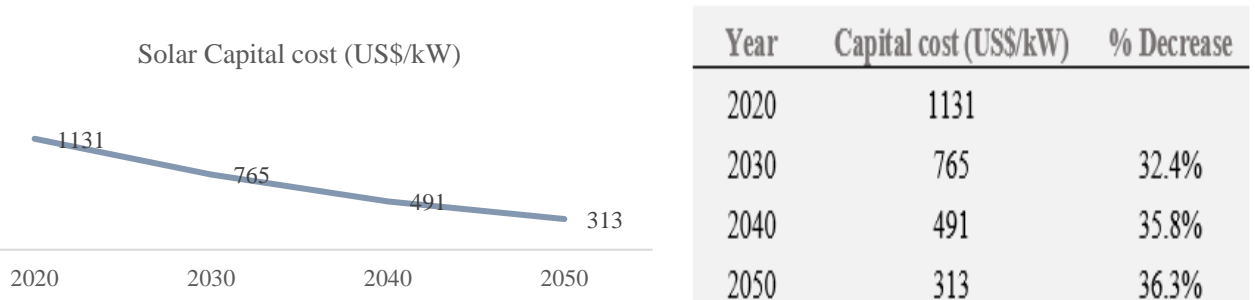


Figure 30: Solar capital cost projections for Canada (CER,2020) Table 14: Solar capital cost projections for Canada (CER,2020)

### Solar installation forecast: Canada

Using the software Tableau, future forecast estimates were calculated based on the historical data. Although, the forecast shows that the solar installation numbers are going to increase, the overall increase is not manifold. There are not significant predictions in the numbers which leads to the conclusion that solar industry does not seem to have a bright future in Canada. This when compared to China or India is still far behind.

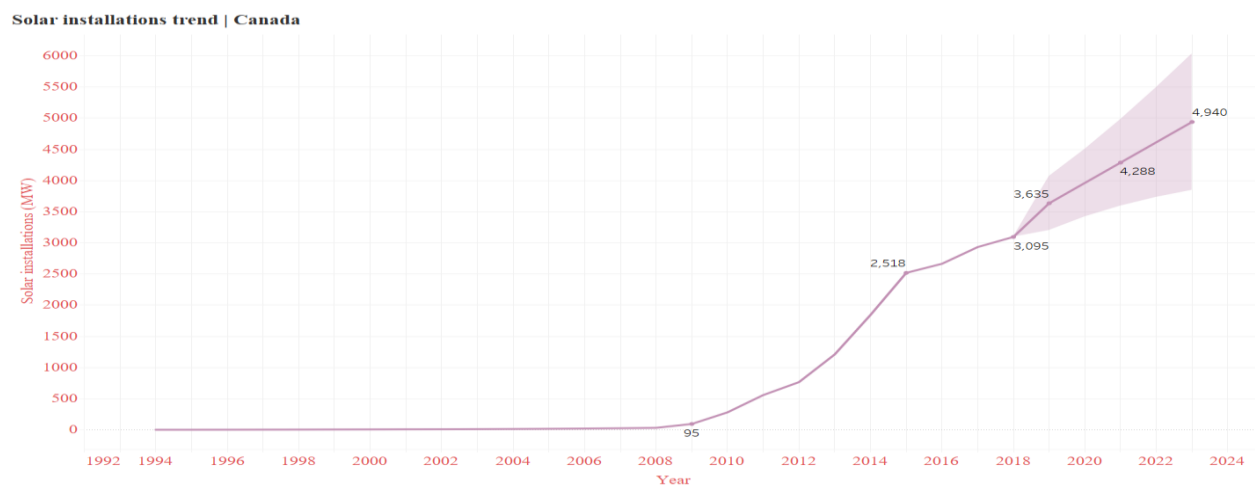


Figure 31: Solar installation trend projection for Canada using Tableau

## Module prices

The trend of module prices has been on a decline and Tableau predicts that the prices are going to fall further. This can be positive in case of Canada because falling module price would lead to cheaper solar system costs and hence might promote future installations.

Module prices trend | Canada

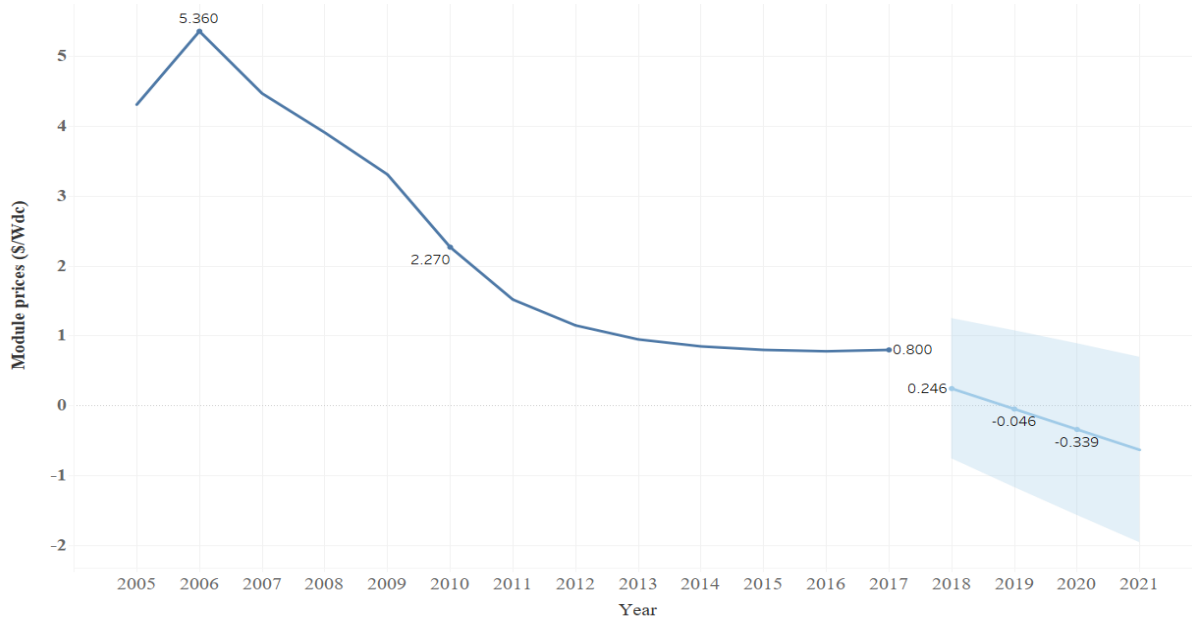


Figure 32: Solar module prices trend projection for Canada using Tableau

All these future estimations and forecasts predict that the component costs as well as the system costs are in line with the declining trends of other countries but is still not conducive to expect large additions in solar installation capacities in Canada.

## **Section 5 | Conclusion**

This research paper has focused on an analysis of the solar industry sector in Canada with a detailed focus on the Ontario market. Based on the literature review and the research methods used in the paper, the following conclusions were derived.

### **Cost feasibility of solar projects in Canada**

Analyzing Canada's international ranking in terms of costs of solar projects as well as its capacity installation numbers; Canada falls behind many countries. Furthermore, by assessing and considering various financial scenarios using RETScreen Expert software, the research concludes that the cost of solar projects requires the implementation of new policies and incentives to reduce initial capital costs and to foster the development of a national industry. Also, as compared to other major countries in the world, Canada is not yet competitive in terms of solar projects due to very high costs of local solar installations. Solar projects do not seem to be profitable and hence the industry is not able to attract significant investments. The rate of return on investments is quite low and the project payback periods are even more than the entire project life. Due to these high costs related most solar projects are not viable in Canada and the lack of incentive systems and proactive policies have led to low installed capacities in the past. Efforts to reduce costs are not being made as evidenced by the lack of national targets and limited policies/regulations in place that are present in other G7 countries (e.g., Germany) where empirical evidence illustrates that they can bring down costs and benefit the solar market. Government incentives can bring costs down significantly and make solar (and other renewable energy) projects financially viable, so that investors are attracted, and financial institutions can fund projects.

Very diverse countries such as Germany and China share a commonality: they both invest heavily on research, development, and deployment (RD&D), which has brought technological advancement, lower GHG emissions and new employment to their nations. In short, targets and timelines, favorable incentives and smart renewable energy policies have led them to achieve cheaper local manufacturing costs for solar modules and systems with better efficiency. More specifically, China's efforts in reducing solar module costs have brought the system costs down significantly throughout the world. In the case of Canada, system costs are evolving to be competitive with the world market (for example thanks to the Ontario policies that were in place 2004-2018), but installation costs remain significantly higher, causing overall system

costs to shoot up in the absence of national targets, poor policy landscapes and limited incentives to renewable energy.

### **Policy barriers for solar industry growth in Canada**

As discussed in various sections of this report, Canada's policy initiatives have been very weak in the past in terms of renewable energy. The cap-and-trade system as well as the Feed in Tariff (FIT) schemes that led to many new solar installations on Ontario were discontinued mainly due to political reasons and the strength of competing energy lobbies (e.g., nuclear in Ontario, fossil fuels in Alberta-Saskatchewan-Manitoba and hydroelectricity in Newfoundland and Labrador).

A cautionary and illustrative tale is provided by the GreenON's solar rebates scheme implemented in Ontario. That incentive system was, surprisingly, stopped only after two months from its launch. Worldwide experience indicates that policies and programs require time to change entrenched habits and investment practices. Instead, presently in Canada, there are provincial cancelled programs (e.g., Ontario FIT) and there are no active federal incentive systems for solar or renewable projects in Canada. In short, Canada has a series of bad policy decisions that have affected the solar industry and has proven to be a demotivating factor for old and new solar players in the market.

The Canadian energy sector remains dominated by the hydro, nuclear as well as oil and gas sectors.

Furthermore, as the Canada Energy Futures report (2020) shows, Canada aims to increase its nuclear capacity further by fostering investment in small nuclear reactors. Canada prides in having a nuclear sector which is promoted now a non-emitting electricity generation fuel. This focus stops Canada from moving towards solar and wind energy sources. Nuclear energy is not cheap and most importantly is the most dangerous energy source as it can be diverted for the manufacturing of nuclear weapons and also presents a clear target for terrorists. The Canadian government also favors fossil fuel subsidies instead of renewable energy subsidies, which is another policy flaw and bottleneck in the growth of the solar industry (as evidenced by the 2018 investment of \$4.5 billion by the Federal Government to purchase the Trans-Mountain Pipeline from Kinder Morgan and the failed investment of \$1.5 billion in 2020 by the Alberta Government to help finance the now defunct Keystone XL pipeline).

The good news is that Canada has a huge solar potential which is still largely untapped. The country has more solar generating potential than Germany, which is one of the leaders in renewable generation in the world and certain Canadian prairie cities like Calgary, Regina and Winnipeg have above average city potential for solar energy.

Canada can learn from countries and regions like China, India and the European Union which all have federal policies favoring solar installations that include rebates, incentives, feed-in-tariff schemes, and funding support for technological research and development. Those countries have seen tremendous growth in their respective solar industries and their installation capacities have doubled in a few years. These policy supports have led to technological improvements thereby leading to significant decline in system costs specially of major components such as solar modules as well as inverters. Solar is now the cheapest source of electricity in these countries and has come at par with the fossil fuels, reaching grid parity.

Although the Canadian solar market is not yet competitive, major policy and regulatory changes will benefit the sector and will generate much needed local jobs. Federal and provincial targets and timelines, supporting policies, and smart incentives will result in the growth of the Canadian solar industry. Smart incentive schemes can bring down system costs and eventually will help change the national, provincial, territorial, and municipal energy mix. Focusing on installing solar projects to reduce GHG emissions will help to “build back a better” Canada.

The Canadian and all other levels of government need to understand the empirical evidence emanating from other nations that shows that through ambitious and focused policies Canada can achieve a greater solar and wind investments, diversify the country’s overall energy mix, create local high value jobs and eventually move on the path of net zero with the aim of having a greener and cleaner future Canadian energy and electricity sectors.

## **Section 6 | Recommendations**

### **1. Policy changes**

Canada requires major policy changes regarding the renewable energy sector. The Federal government needs to set yearly targets in line with its stated plan to reduce emissions by 30 per cent until 2030 from 2005 levels. These yearly plans should include federal targets with stringent implementation plans for solar installations, which could then be adopted by provinces accordingly. Since Ontario is the province with a majority of solar installations in the past, a national focus on understanding lessons emanating from Ontario will help to increase national numbers. With yearly National, Provincial and Territorial renewable energy targets, commercial and residential solar incentives will become a logical policy concern at the local level.

More specifically, provincial governments (such as Ontario, Alberta, Saskatchewan and Nova Scotia) need to adopt new and updated feed-in-tariff programs specifically designed for fostering residential, community and large-scale solar projects in the range of (1-500 kW and above), so that the sector attracts investments due to the assurance of power purchase security and revenue streams at fixed tariffs for prolonged periods of time.

The Canadian government needs to adopt methods that have been successful in the energy sectors of top G7 countries, especially focused on how to tackle GHG emissions with renewable energy. The Canadian government also needs to make changes in existing regulations to accommodate the changes needed in the electricity sector by creating payment security funds. Just like any other industries must experience a planned transition (due to economic or technological changes), the Canadian energy sector needs to explore a fair transition into greener fuel alternatives to address the climate emergency, re-train workers from obsolete industries, to create new local job opportunities, and to create the conditions for local technological development.

The Canadian government has a pivotal role to help Canadians achieve a fair transition that allows workers in the energy sector evolve from fossil fuels to renewable energy sources to diversify the national energy mix, increase local energy security, create new local jobs and eliminate pollution and to address climate threats.

## **2. Exploring varied solar technologies**

Canada has a huge potential of solar energy which is several times greater than G7 solar world leader Germany. Canada needs to make efforts to tap its huge geographic potential and utilize it to the fullest. Steps to achieve that include promoting off-grid solar technologies in remote areas and rooftop solar. New solar technologies such as wind-solar hybrid plants, floating solar PV plants and solar with battery energy storage systems, should be further explored for implementation in the Canadian solar market. Those technologies are still in their nascent stages and Canada can tap into them by investing in research and development.

Canada also needs to move towards setting up large scale solar parks on lands that are not yet utilized and that have limited use (for example parking lots, train tracks, and landfills). This focus would not only shoot up the installed capacities but also bring down costs due to economies of scale.

## **3. Realizing the importance of incentive schemes to bring down installation costs**

To bring down the costs and promote the solar industry, the Canadian government needs to realize the importance of incentive schemes and create funding mechanisms to disburse these incentives specially for small scale commercial and residential rooftop solar projects. Rooftop incentive schemes in India have been successful to provide an initial boost to the rooftop industry. Incentives act as economic motivators and would lead to increasing installations due to cost off-sets. Incentives would also make the solar projects financially viable. Ontario had come up with GreenON's solar rebates scheme, which was a move in the right direction but was scraped off within two months. Similar schemes should be launched in the future at federal and provincial levels but with a long-term support focus.

## **Section 7 | Area for Further Research: Solar on A Shipping Container**

All research includes additional work that requires more time and resources to be fully developed and completed. In my case an area for further research has to do with practical solar work that I started during the COVID pandemic. Sustainability-oriented Canadian farms, such as Wheelbarrow Farm, are all looking for solutions to power their farm needs cleanly and thereby reduce their greenhouse gas emissions. A very promising solution includes using the ubiquitous shipping container for a promising project that was started by York University Professors, students, NGOs and private sector partners and that we titled: “Solar in a Box”.

My preliminary research (summarized in Appendix 1) indicates that a solar container could be manufactured locally in Ontario to be placed in rural locations such as Wheelbarrow Farm to thereby become a showcase for farm-tours and to inspire other farmers to implement such solutions (for on-grid or off-grid applications) and to inspire urban and rural people about the potential of developing local renewable energy sources that can be used to power all types of new electric local solutions such as electric tractors, drones, and all types of electric vehicles.

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## Appendix 1: Solar in a Box Project

My participation in this project was focused on an internship for my Business and Sustainability Diploma and is part of an ongoing effort that aims at developing a new product that can be sold and marketed locally and internationally to support the development of renewable energy and electric mobility solutions at the local level.

### **About: Shipping Containers**

A shipping container is a large container that has great strength to transport and ship from one place to another and are designed so that they are transferrable from one mode of transport to the other without having to unload and reload the contents inside the container. They are often used as freight containers. Shipping containers can be large steel boxes or corrugated boxes. (*Wikipedia.org,2021*).

Shipping containers comprise a large proportion of the long-distance freight transport used for international trading among countries across the globe. There are about 17 million containers in the world that are being used for transporting goods and materials from one country to the other. These containers, however, are being discarded due to the high shipment costs specially while sending the containers back to the point of their origin.

### ***Container sizes***

Majority of the containers come in standard sizes of 10 feet or 20 feet or 40 feet or 45 feet. A 10 feet container weighs approximately 2500 pounds and a 20 feet container weighs its double. (*securecontainer.ca,n.d.*)

### **Shipping Container Utilities**

A recent trend has seen shipping containers been used as the base or a box for a large number of customized solutions ranging for all sorts of activities. Customers can choose the container sizes as per their needs, space, and convenience.

Storage: Containers can be used at a property to safely store and keep heavy equipment, inventory, supplies and records. (*securecontainer.ca,n.d.*)

Residential: Shipment container homes are customized homes that are been built by companies to provide affordable housing solutions. (*giantcontainers.com,2021*). These are stackable, prefabricated, come with a quick and easy assembly and are cost-effective.

Industrial: Shipment containers can be used for a wide variety of industrial purposes starting from storing huge generators to fire training facilities or be used as mining containers and utility spaces/ buildings. These containers can be shipped across the world securely and are purpose built and prefabricated.

Commercial: Shipping container act as innovative and out of the box design solutions for commercial spaces. These can be hubs for market, can be small stores or small office spaces or largely stacked commercial markets built out of containers. They look modern and trendy at the same time and are different than rest of the regular commercial spaces. The Stackt Market in Toronto is one such fine example of container built commercial spaces that are customized and fully operable. (*giantcontainers.com,2021*)

Experiential: Other than large storage spaces, the obvious reasons for using the shipping containers are pop-ups. These can be used for hundreds of utilities and can act as multi-functional spaces. One can think of opening a pop-up shop or a restaurant or a food truck or a bar or a kiosk or even a gym training facility in that space, that can vary as per their needs. Nowadays, a COVID pop-vaccination clinic or COVID kit supplies can be one of the many options that the shipping containers be used for.

Shipping containers open doors for hundreds of possibilities that are chic and stand-out. Since these can be transported from one place to another and act as fully functional spaces, they are the best options for providing basic facilities to people of remote areas that do not have access to power or learning opportunities.

Imagining solar panels on every roof is a dream. According to Green Building Education Services (GBES) that is a part of US Green Building Council (USGBC), installing solar panels on buildings qualifies for additional points for LEED (Leadership in Energy and Environmental Design) certification as green buildings. Solar arrays provide shading and hence reduce the heat island effects in the buildings. Using efficient solar water heaters is another use of solar panels on the buildings, apart from the basic fact that solar generates additional renewable energy for the building and contributes to diversifying the power sources. (*Green Building Education Services [GBES],2021*)

Solar panels on containers: Just like solar panels are installed on the rooftops of buildings to generate electricity and obtain LEED green building certifications, solar panels on shipping containers could have a wide number of possibilities. They can act as active power generating sources that would have the facilities running on electricity, on the go.

Clubbing these systems with battery storage would make the containers more accessible as electricity can be stored even when the container is not connected to an electric connection or the grid power.

### **Successful Examples of Solar Powered Shipping Container Facilities**

#### *Solar powered computer lab in a shipping container | University of Houston*



*Figure 33: Solar-container system: University of Houston*

In 2017, some engineering students at the University of Houston, designed a similar solar on a container set-up with batteries. The container is being used as a mobile computer/computing lab for elementary school students. The power that is generated from the solar panels on the roof of the container is sufficient to run the entire lab that has 14 laptops, an air conditioner, a couple of batteries and lights. The makers intent to ship this container to Mali, a country that has one of the lowest literacy rates in the world for educating students.

Educational solutions like these can bring revolutionary changes to less developed countries and remote areas where the people and students do not have access to electricity or basic education. (*University of Houston,2017*)

## *Anchored shipping container homes as solutions to natural disasters / Puerto Rico*



*Figure 34: Solar-container system: Puerto Rico*

A 5.8 magnitude earthquake hit Puerto Rico in Jan 2020 where one of the victims was Gautier Castro whose house was affected in the earthquake damages. Earlier, Naguabo in Puerto Rico, was hit badly by a hurricane where hundreds of people lost their homes as they were damaged by high-speed winds. Gautier Castro, an architect, came up with a long-term disaster resistant solution for homes. By using an anchored shipping container, Gautier Castro created a home that could withstand both earthquakes and hurricanes with winds having speeds greater than 175 miles per hour. This was a milestone solution for vulnerable areas that are hit by natural disasters such as the Puerto Rico. These can be engineered and researched better for future solutions as residential homes. (*Cable News Network [CNN].com,2020*).

## *Off-grid solar power container home in Australia*

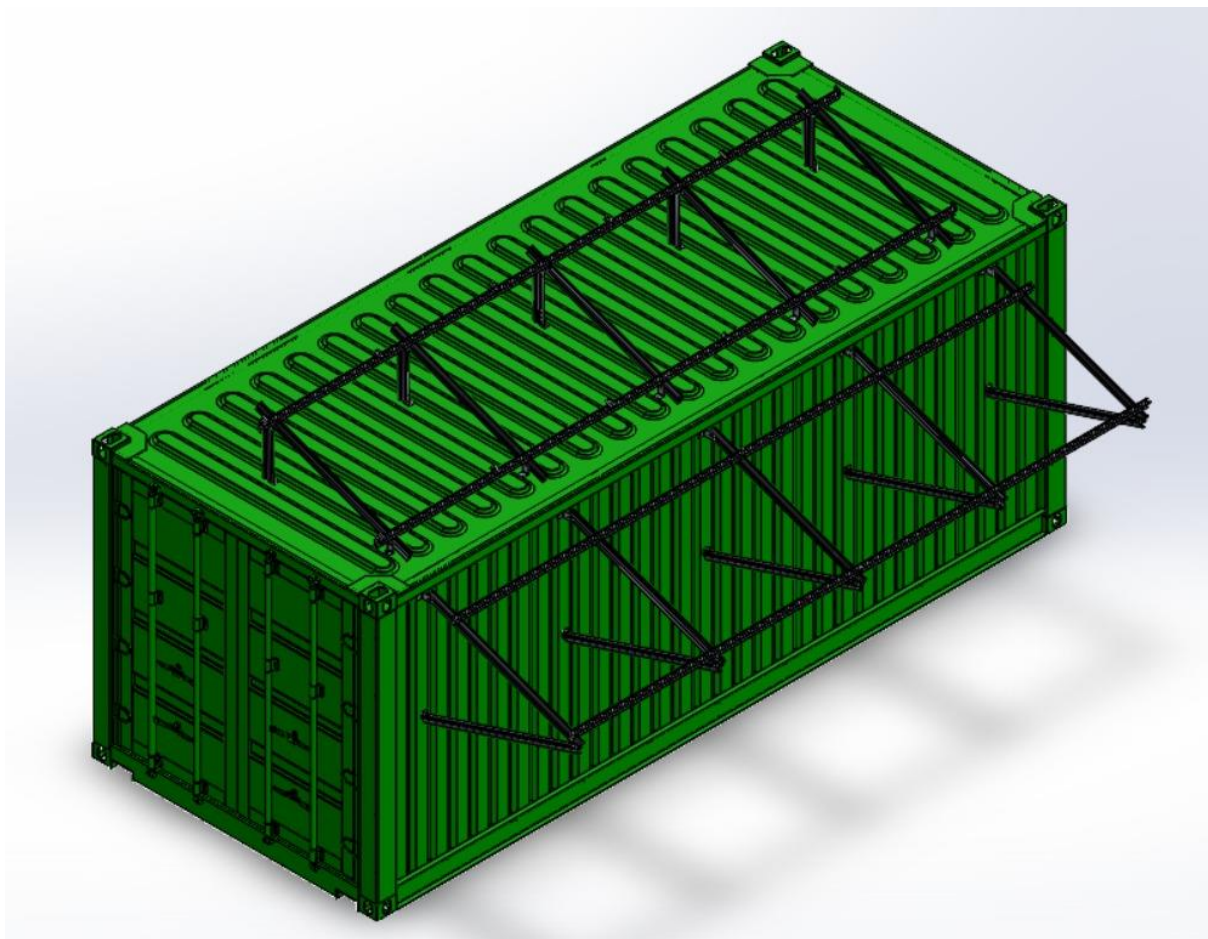


*Figure 35: Solar-container system: Australia*

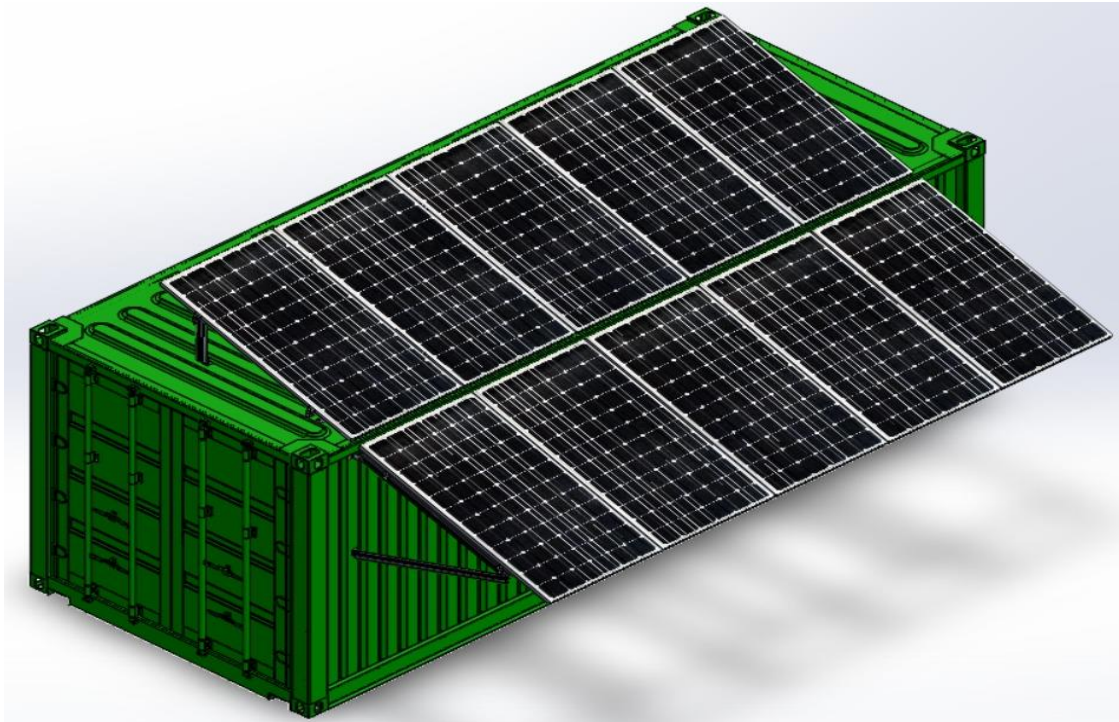
In 2017, an Australian, Paul Chambers, living in the mountains, wanted to come up with a complete off-grid solar powered solution for his family needs. He built a set-up with solar panels on top of two cargo containers and also installed batteries to store the excess energy generated. This was a complete off-grid solution that was out of shipping containers. Paul says that they generate sufficient solar energy and store the unused energy in the batteries. They are also able to run an air conditioner during the day as well as the household appliances easily by the solar power. (*buildshippingcontainerhouse.com*)

### **Designing “Solar in a Box”**

Taking inspiration from the above successful examples of solar containers, a simple design of the system was done using the software Solidworks. The container would have batteries and will be mobile. It could be used for kiosks and portable clinics.

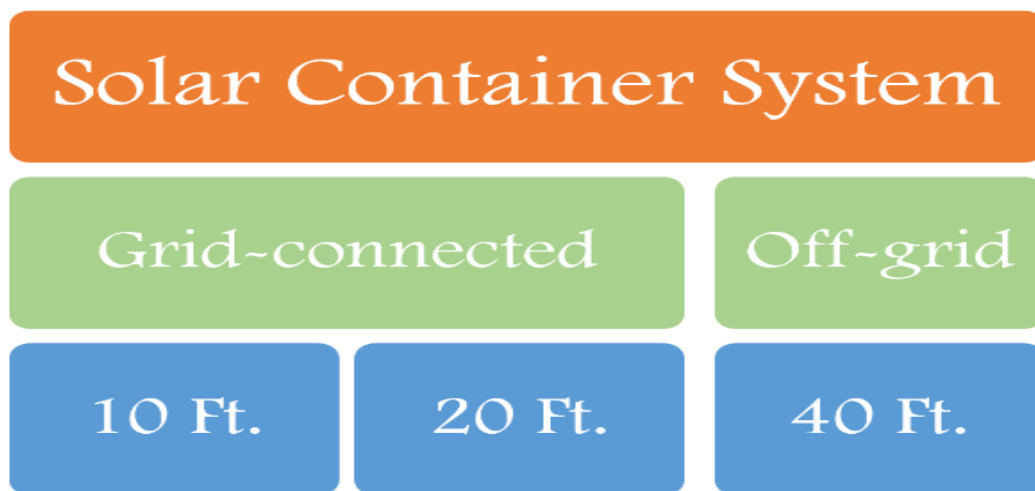


*Figure 36: “Solar in a box”: Structure design using Solidworks*



*Figure 37: “Solar in a box”: Structure prototype using Solidworks*

**Way forward and future: Customer centric website design**



*Figure 38: “Solar in a box”: Future website design*

Successful deployment of the project would enable us to develop a new product that can then be sold and marketed. In the future, we idealize and imagine a website for providing container-based options for grid-connected or off-grid with battery solutions. The customers would also be able to choose sizes from 10 ft. or 20 ft. or 40 ft., based on their needs and requirements. Further, these containers can be customized and designed as per the customer utilities

Appendix 2: Private Sector Quote for 10kW Solar Project for the Wheelbarrow Farm

	PO Box: 1479 1067 Garden Gate Drive Haliburton, ON K0M 1S0 <a href="http://www.haliburtonsolarandwind.com">http://www.haliburtonsolarandwind.com</a> P: F: e: <b>Project Manager:</b> P:	<b>Quotation:</b> <b>180087</b> <i>(Reference this Quotation Number on all Purchase Orders and Correspondance)</i> <b>Net-Metering</b> <b>Cust. Order #:</b> <b>Quotation#03/13/2018</b> <b>Date:</b> <b>Terms:40% Deposit - Balance COD</b> <b>Gst #:882761125 RT0001</b> <b>Ship Date:</b>
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**To:**  
 Neale Tony (ID: NEA010)  
 535 Durham rd 13  
 Sunderland, ON  
 Attn: Tony Neale  
 Phone: 647-335-3190

**Location:**  
 Wheelbarrow Farms (ID: NEA)  
 535 Durham rd 13  
 Sunderland, ON  
 Attn: Tony Neale  
 Phone: 647-335-3190

Quantity	Description	Unit	Extended
(1)	<b>Net-Metered 40 Panel System Equipment</b> Hanwha 300W PERC 60Cell HD MC4 BLK FRAME APS Inverter YC500A dual Inverter End Caps for APS YC500A APS Strings APS Termination Cable 2M APS Monitor Fast Rack Enphase Install Hardware Fast Rack Device Install Hardware Only FastRack Ground Mount 60 or 72C LEGS FastRack Ground Mount 60 or 72C RAILS Custom Label Package for System Install	\$20,171.30	\$20,171.30
(1)	<b>Net-Metering 40 Panel Installation (Option B)</b> Customer to provide the following:  All labour and equipment to install pier foundations, laminated beams for mounting feet, assembly of rack to piers and beams, installation of panels all in accordance to our specification sheets and assembly instructions to be provided to the client. Customer is also responsible for trenching Big O with rope to the meter base in accordance with ESA requirements also to be provided to client.  Haliburton Solar and Wind to provide two on site visits for layout and guidance as follows: Layout piers and trench, Review racking assembly and panel installation.	\$650.00	\$650.00
(1)	<b>Net-Metering 40 Panel Electrical</b> SLD review by Master electrician. Connecting panels in strings as per the SLD. Run suitable tech cable from the array to the Main panel. Wire cable into main Panel. All work to be permitted and approved by the ESA at completion. Includes return trip for ESA.  NOTE: This cost is a maximum upset for budget purposes. Our electrician will be charged at cost based on actual hours at our cost rate of \$65.00 per hour and materials at cost as charged to HSW (disconnects etc)	\$5,000.00	\$5,000.00
(1)	<b>Hydro One</b> All paperwork and contracts to be completed by the customer. Haliburton Solar and Wind will provide technical guidance for the Net Metering application. Once project is completed, and ESA inspected, Hydro One will install the Bi-directional meter (Hydro One Charge). This scheduling is by the customer. The Hydro One charge of \$800 will be paid directly by the customer. Haliburton Solar and Wind will not incur any Hydro One charges.	\$0.00	\$0.00
(1)	<b>Delivery</b>	\$350.00	\$350.00
		<b>SubTotal</b>	\$26,171.30
		<b>ON HST</b>	\$3,402.27

Total \$29,573.57

**Special Instructions:**

The quote assumes 300 watt 60 cell panels.

**Customer Comments:**

Signed:

Approved:

**Terms and Conditions**

Thank you for choosing to place your business with us! We appreciate the opportunity.

**Terms of payment:**

- Upon Signing of Quote: 40% (Pre-tax)
- Upon Commencement of Work: 40% (Pre-tax)
- Balance of Payment: Due upon completion.

Method(s) of Payment: Cash, Cheque, or Electronic Funds Transfer (EFT).

All prices are based on current taxes, duties, freight, labour, and material costs which prevail on the date of this quotation. These prices are subject to change and must be confirmed at the time of placing the order.

In the case of H.S.T. exemption, a H.S.T. exemption certificate must be provided by the customer that indicates the customer's exemption number. This must be provided prior to providing confirmation of order.

All quotations are subject to a pre-install site evaluation(s) to confirm equipment and labour requirements. Prices noted may be subject to change.

Delivery will be as required and is conditional upon final approvals including engineering, availability of components from suppliers, and co-ordination with other trades where necessary.

Halburton Solar and Wind also retains title to all materials supplied until full payment is received. Should final payment not be received within the specified terms, Halburton Solar and Wind reserves the right to initiate proceedings to remove material supplied without further due notice.

It is the Customer's responsibility to protect and provide adequate insurance for all materials and equipment associated with the project while on their premises.

This quotation is valid for a period of thirty (30) days following date of issuance.

Final price may be adjusted based on weather delays, working around other trades, and other unforeseen site restrictions.

Owner understands and agrees that HSW warrants its services performed as set out herein solely, and makes no representation or warranty whatsoever nor renders any opinion concerning the owner's system's qualification or otherwise for applicable governmental compliance, including but not limited to ESA compliance. Owner hereby confirms the forgoing and releases HSW from any and all liability in that regard.

**OUTSIDE OF REGULAR HOURS PLEASE CONTACT AT**



CANADIAN SOLAR INDUSTRIES ASSOCIATION

Appendix 3: Wheelbarrow Site Visit Photos (8<sup>th</sup> Feb,2021)







## Feasibility report

### The Wheelbarrow Farm

10 kW



Power plant - Photovoltaic

**Prepared for:**

MES Major Project - York U

**Prepared by:**

Apeksha

## Executive summary

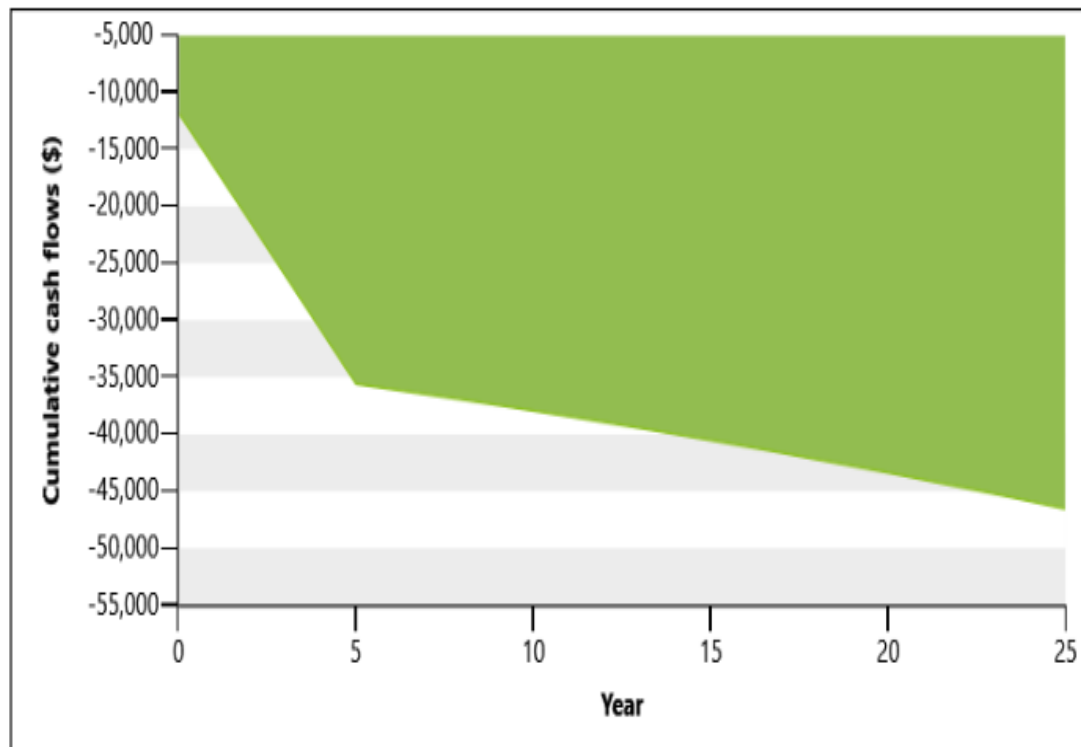
This report was prepared using the RETScreen Clean Energy Management Software. The key findings of this analysis are presented below.

### Target

	Electricity exported to grid MWh	Electricity export revenue \$	GHG emission reduction tCO <sub>2</sub>
Proposed case	0	0	0

The main results are as follows:

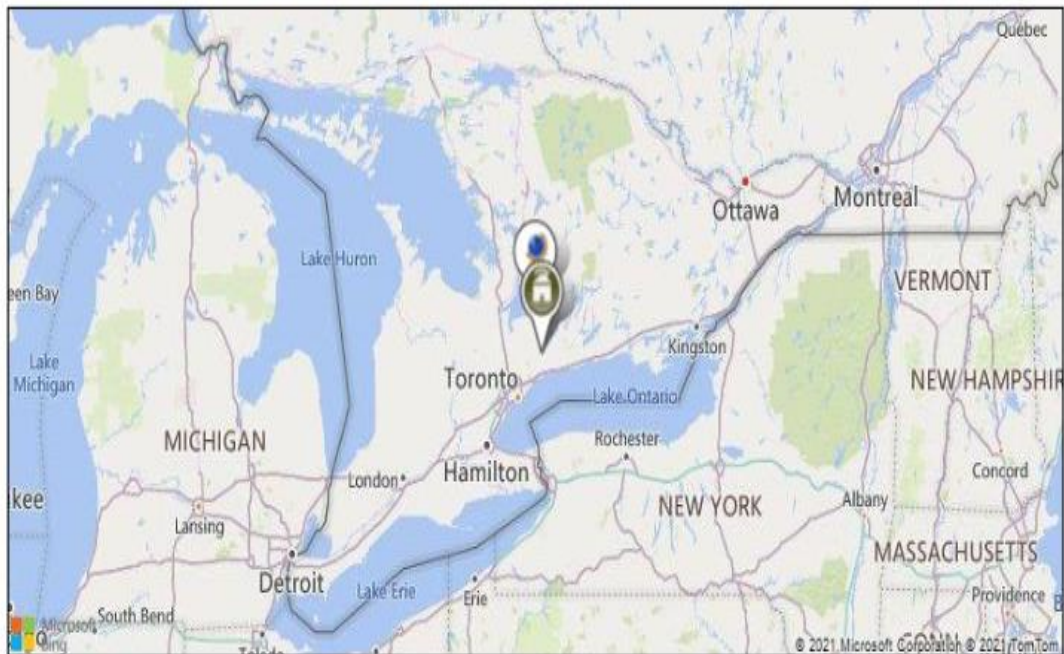
### Cash flow - Cumulative





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## Location | Climate data

### Location



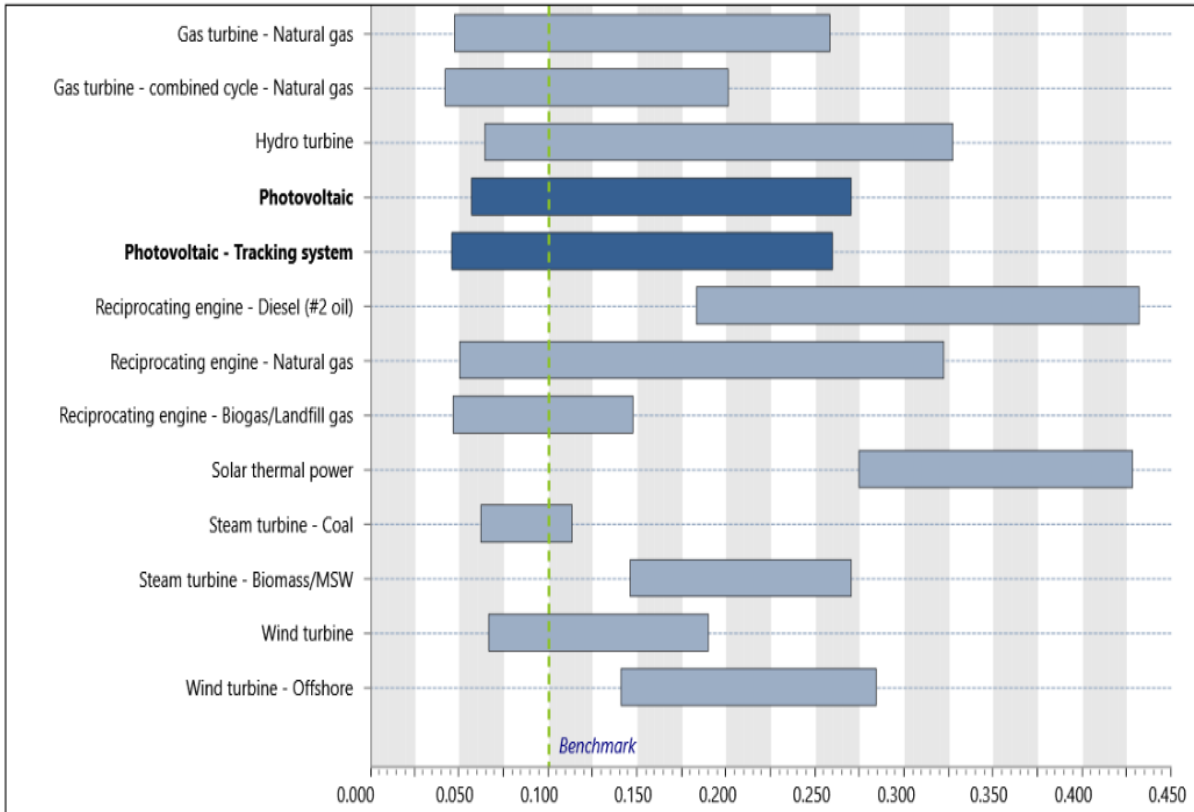
### Legend

-  Facility location
-  Climate data location

	Unit	Climate data location	Facility location
Name		Canada - Ontario - Lagoon City	Canada - ON - Brock
Latitude	'N	44.5	44.2
Longitude	'E	-79.2	-79.1
Climate zone		6A - Cold - Humid	6A - Cold - Humid
Elevation	m	221	287

# Benchmark

Energy production cost - Central-grid - Range (\$/kWh)



Benchmark: 0.10 \$/kWh

Power plant

Photovoltaic  
10 kW



<b>Photovoltaic - 10 kW</b>		
Capacity	10	kW
Electricity	11.3	MWh

Target

Summary

	<b>Electricity exported to grid</b> MWh	<b>Electricity export revenue</b> \$	<b>GHG emission reduction</b> tCO <sub>2</sub>
Proposed case	11.3	1,126	1.1

## Financial viability

### Financial parameters

Inflation rate	%	2%
Project life	yr	25
Debt ratio	%	60%
Debt interest rate	%	7%
Debt term	yr	5

### Costs | Savings | Revenue

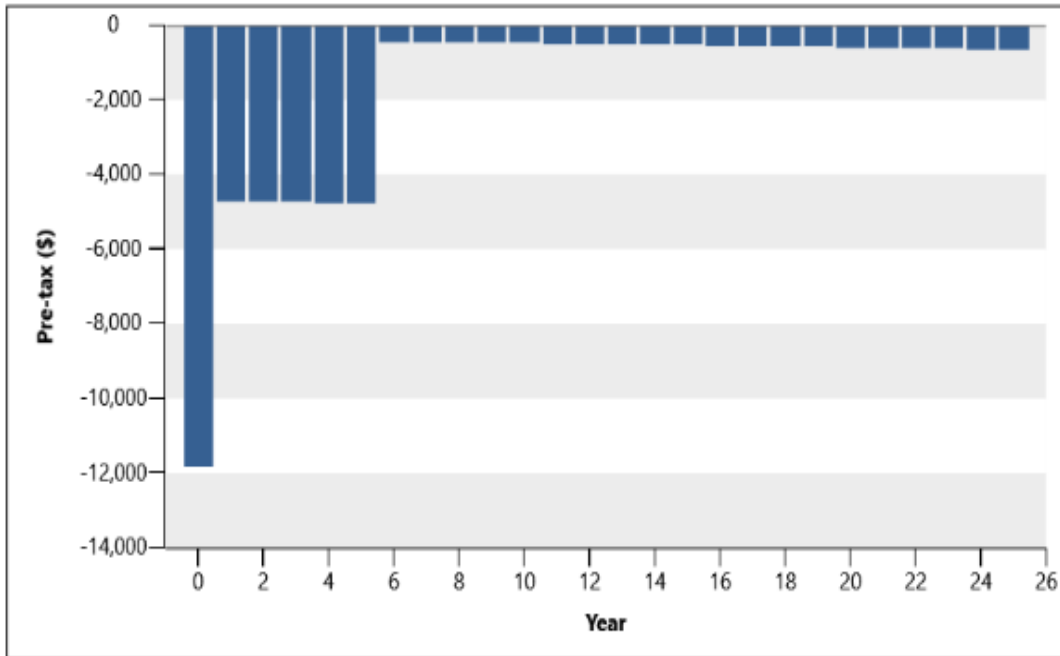
<b>Initial costs</b>			
Initial cost	100%	\$	29,574
<hr/>			
<b>Total initial costs</b>	<b>100%</b>	<b>\$</b>	<b>29,574</b>
<b>Yearly cash flows - Year 1</b>			
<b>Annual costs and debt payments</b>			
O&M costs (savings)		\$	400
Debt payments - 5 yrs		\$	4,328
<hr/>			
<b>Total annual costs</b>		<b>\$</b>	<b>4,728</b>
<b>Annual savings and revenue</b>			
GHG reduction revenue		\$	0
Other revenue (cost)		\$	0
<hr/>			
<b>Total annual savings and revenue</b>		<b>\$</b>	<b>0</b>
<b>Net yearly cash flow - Year 1</b>		<b>\$</b>	<b>-4,728</b>

### Financial viability

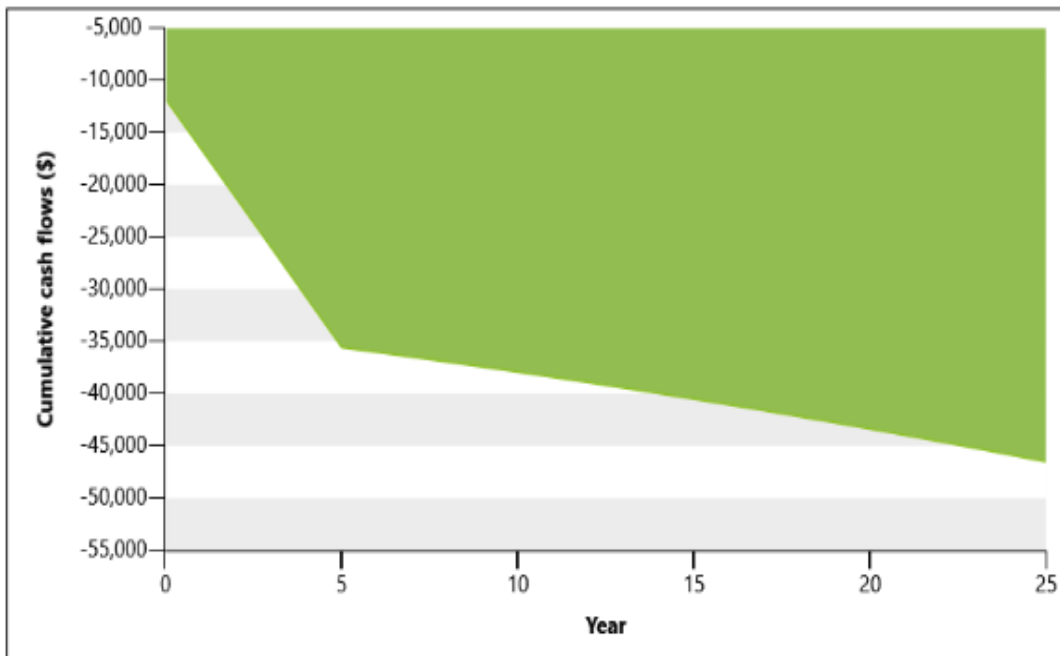
Pre-tax IRR - equity	%	Negative
Pre-tax IRR - assets	%	Negative
Simple payback	yr	None
Equity payback	yr	> project

## Cash flow

Annual



Cumulative



## Analysis type

Feasibility



# Feasibility report

## The Wheelbarrow Farm

10 kW



Power plant - Photovoltaic

**Prepared for:**

MES Major Project, YorkU

**Prepared by:**

Apeksha

## Executive summary

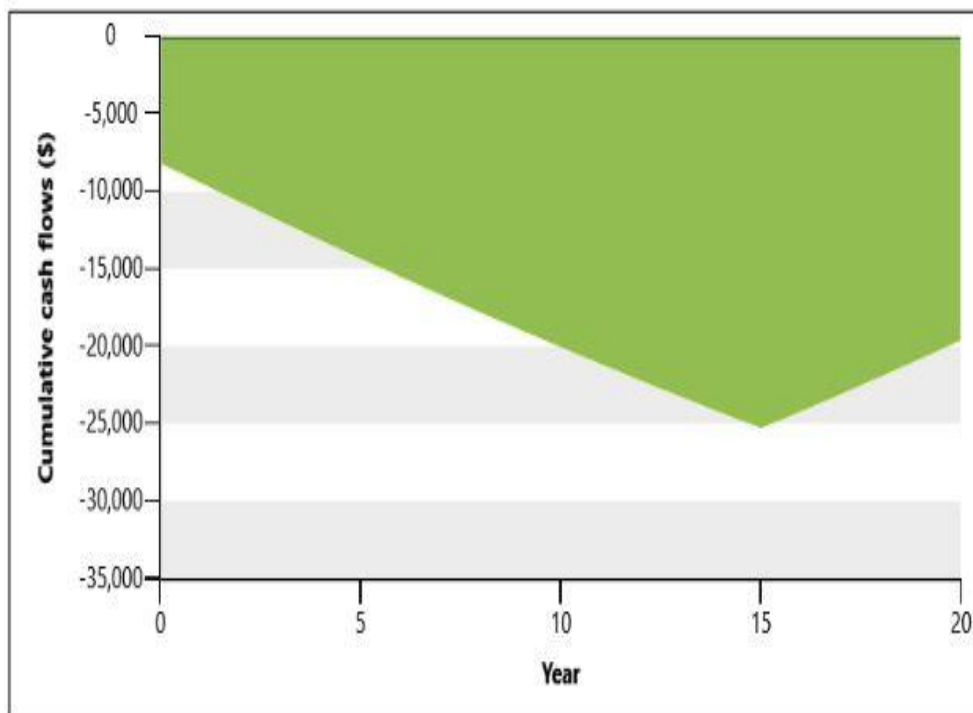
This report was prepared using the RETScreen Clean Energy Management Software. The key findings of this analysis are presented below.

### Target

	Electricity exported to grid MWh	Electricity export revenue \$	GHG emission reduction tCO <sub>2</sub>
Proposed case	11.3	1,126	1.1

The main results are as follows:

### Cash flow - Cumulative





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## Location | Climate data

### Location



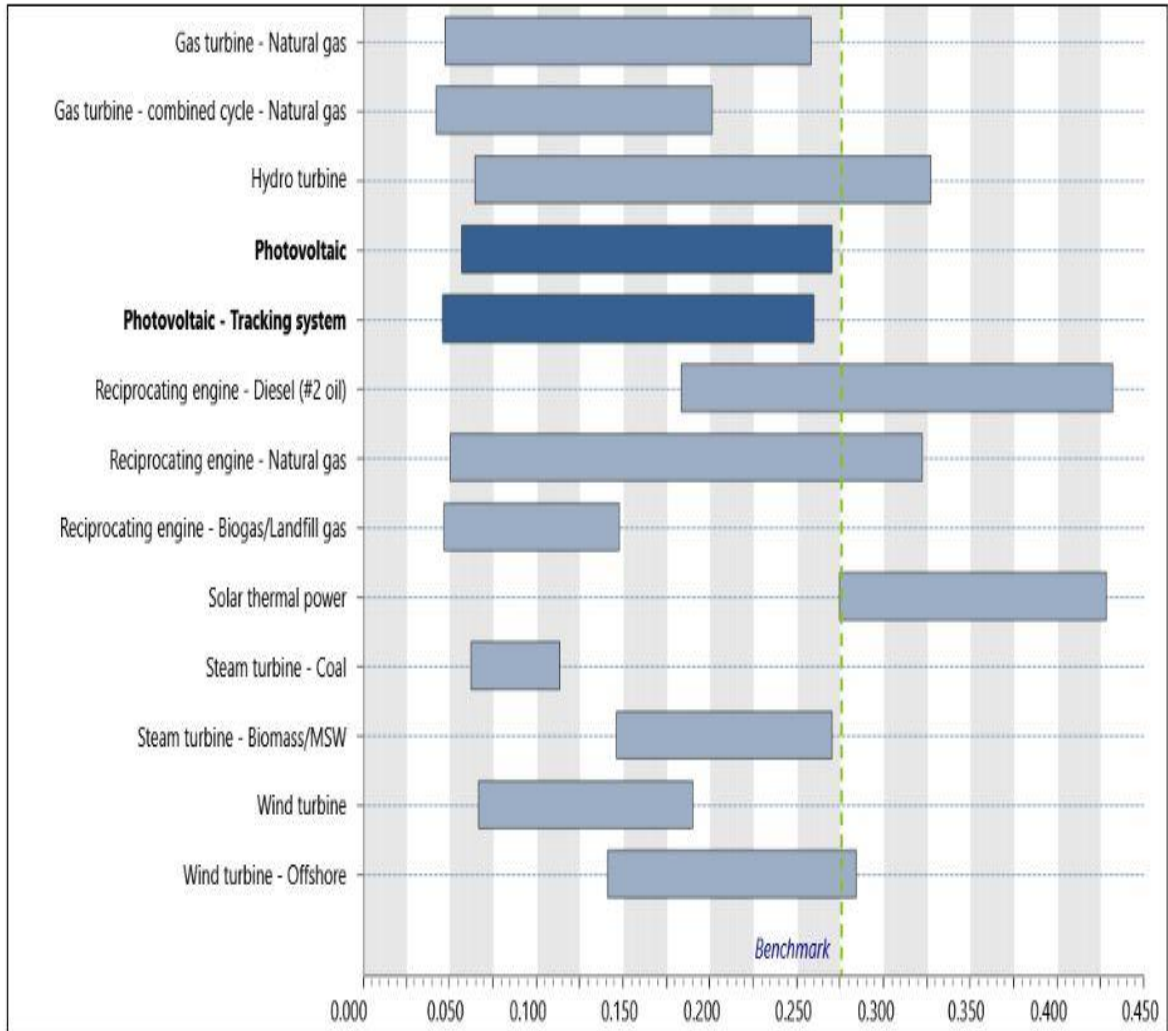
#### Legend

-  Facility location
-  Climate data location

	Unit	Climate data location	Facility location
Name		Canada - Ontario - Lagoon City	Canada
Latitude	'N	44.5	44.2
Longitude	'E	-79.2	-79.0
Climate zone		6A - Cold - Humid	6A - Cold - Humid
Elevation	m	221	291

# Benchmark

Energy production cost - Central-grid - Range (\$/kWh)



Benchmark: 0.28 \$/kWh

## Power plant

### Photovoltaic 10 kW



<b>Photovoltaic - 10 kW</b>		
Capacity	10	kW
Electricity	11.3	MWh

## Target

### Summary

	<b>Electricity exported to grid MWh</b>	<b>Electricity export revenue \$</b>	<b>GHG emission reduction tCO<sub>2</sub></b>
Proposed case	11.3	1,126	1.1

## Financial viability

### Financial parameters

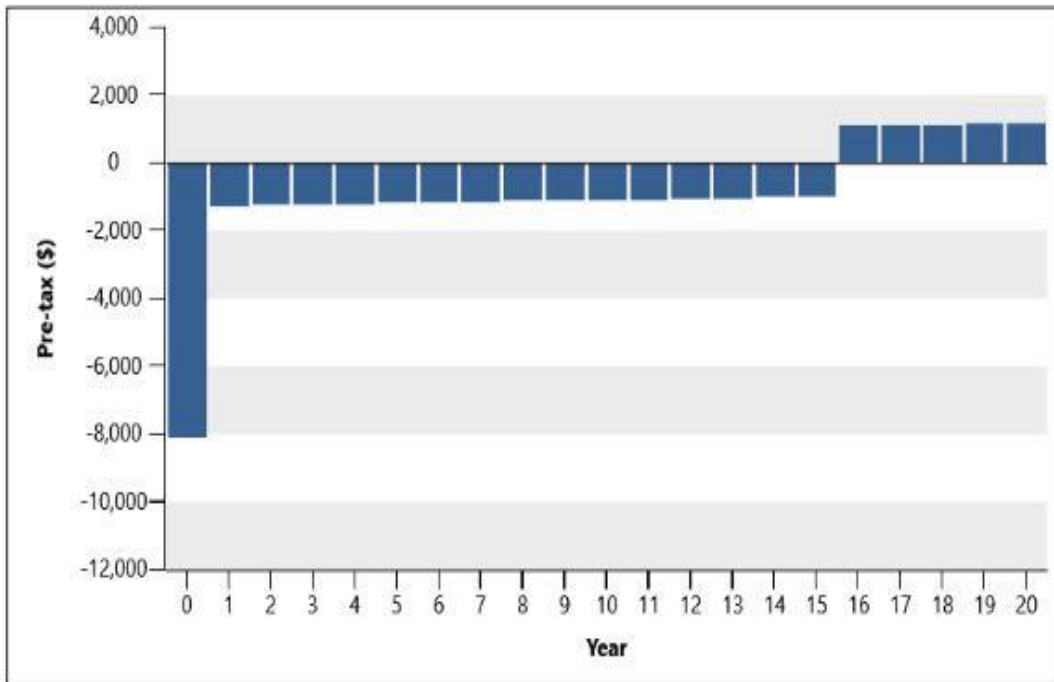
<b>General</b>		
Inflation rate	%	2%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	20
<b>Finance</b>		
Debt ratio	%	70%
Debt	\$	18,900
Equity	\$	8,100
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	\$/yr	2,075

### Annual revenue

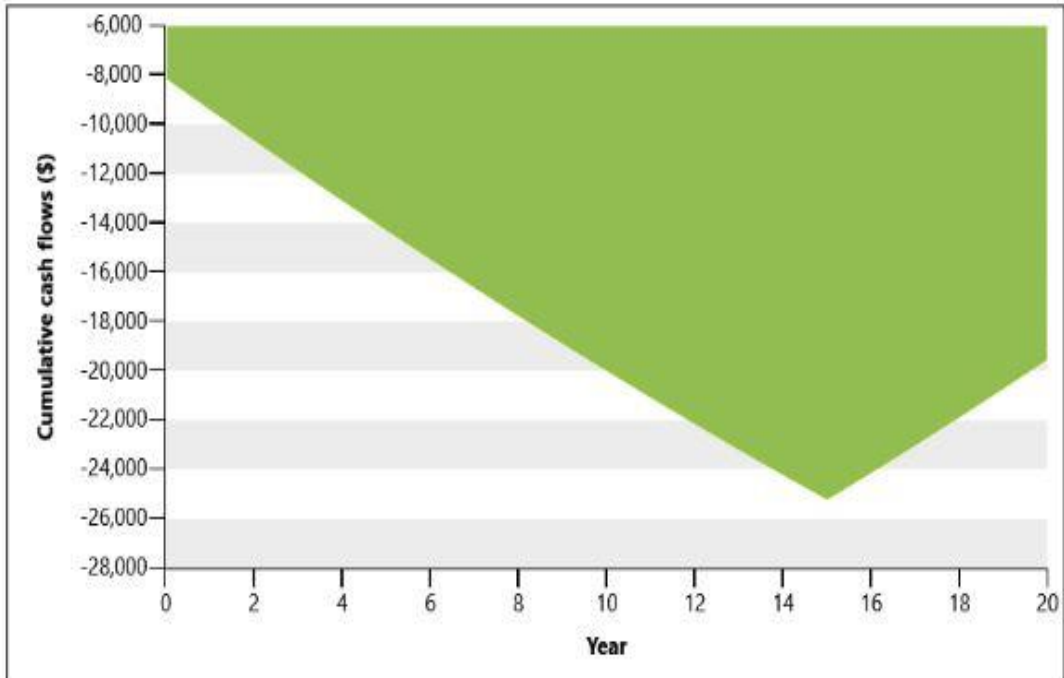
<b>Electricity export revenue</b>		
Electricity exported to grid	MWh	11.3
Electricity export rate	\$/kWh	0.10
Electricity export revenue	\$	1,126
Electricity export escalation rate	%	2%

# Cash flow

Annual

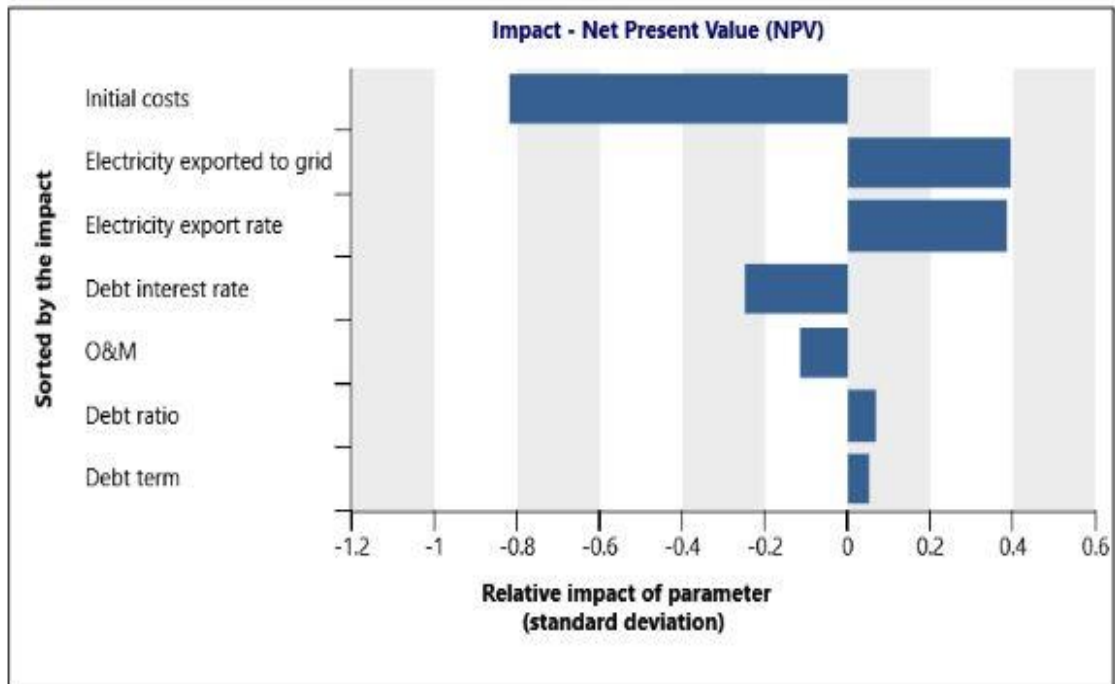


Cumulative

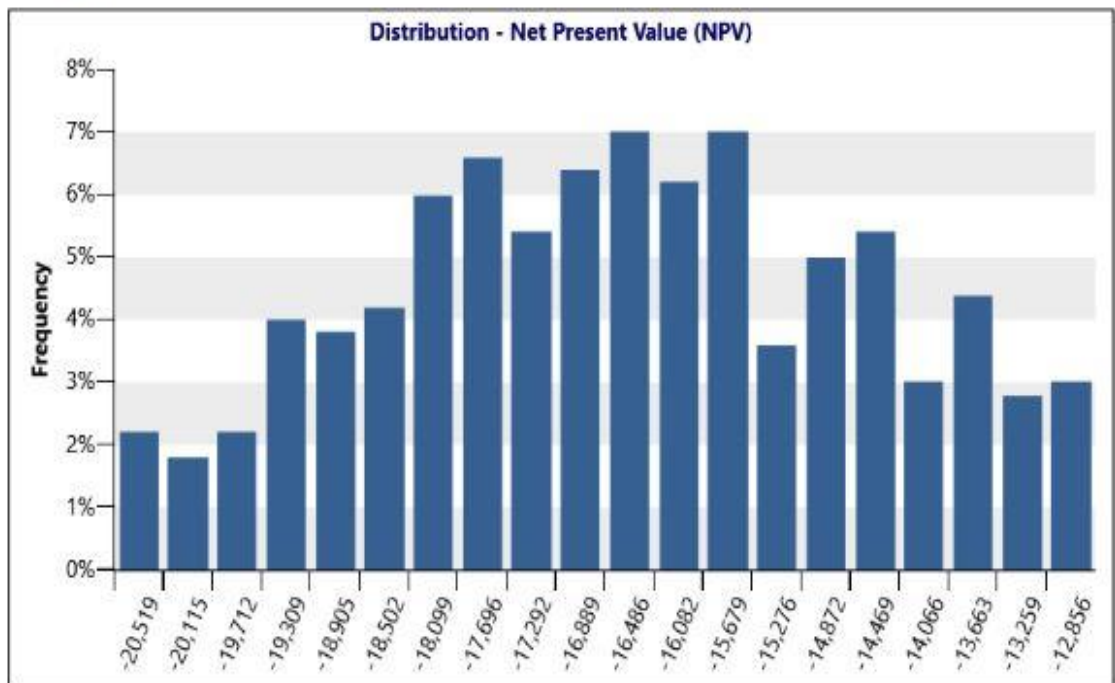


# Risk

## Impact



## Distribution



# Analysis type

Feasibility

