Leveraging Solar Photovoltaic Technology for Sustainable Development in Ontario's Aboriginal Communities

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Abstract

The Ontario feed-in tariff (FIT) for solar photovoltaic (PV) technology has provided Ontario's Aboriginal communities with an opportunity to i) weaken the cycle of poverty; ii) directly counteract climate change by producing renewable energy; and iii) become more self-sufficient. This paper critically analyzes the technical, cultural, and economic viability of leveraging the FIT for PV to provide green electricity and revenue to assist First Nations communities in sustainable development. A generalized free GIS energy-based protocol was developed to determine the PV potential for Aboriginal communities. This model was applied to a case study of the Constance Lake First Nations community and an economic analysis showed financially viable rates of return over 20 years. By generalizing these findings to Ontario, the potential PV deployment on First Nation rooftops alone is over 200 MW, which clearly provides an opportunity for developing pride associated with owning a community-led, environmentally beneficial, local energy project.

Keywords: Sustainable development, Solar photovoltaics, Feed-in tariff, First Nation communities

1. Introduction

The unrestrained use of fossil fuel-based energy sources has contributed to global warming, pollution and resource depletion at a rate that seriously threatens the future of the world's climate system and ecological stability (Bilen et al., 2008; Hansen et al., 2007; IPCC, 2008). Additionally, the rapid development of heavily populated countries such as China and India are accelerating the rise in global energy demand at a rate of up to 5% per year (Hrayshat, 2009). As it is becoming more clear that energy policy needs to be informed by life cycle carbon emissions (Kenny et al., 2010), many of the world's governments have produced policies to expand renewable energy, such as the Feed-in Tariff (FIT), which has been implemented in over 64 jurisdictions (REN, 2009). Globally, more governments and organizations are incorporating sustainability as a primary consideration in the planning of developmental projects (REN, 2009; Rylatt, 2000). The majority of this attention has originated from the well-established problems in developing nations as it is clear that these nations will largely shoulder the negative consequences of climate destabilization (Stern, 2007; Brown et al., 2007). However, easily overlooked and often ignored are the Aboriginals in industrialized nations such as Canada and the U.S.

The living standards of Canada's Aboriginal (First Nations, Métis and Inuit) communities are well below those of the average Canadian citizen (INAC, 1996). This is due to many varying problems that plague Aboriginal communities across Canada including economic, health and social problems (Loppie & Wien, 2009). These issues tend to emerge because of cultural barriers between the community and the rest of society, as well as the challenges that exist within Aboriginal community development (INAC, 1996). As a result, while the rest of Canada continues to grow and embrace technological advances that boost the economy and provide numerous health and social benefits, many Aboriginal communities are unable to take advantage of these same benefits.

Esmerus, the past National Chief of the Assembly of First Nations (AFN), explains "our people have been relegated to the lowest rung on the ladder of Canadian society; suffer the worst conditions of life, the lowest incomes, the poorest education, and health; and can envision only the most depressing futures for children" (1989). Additionally, many of these communities have been forced into remote parts of Canada, which offer few resources and opportunities for growth within the community. As a result, the communities become entrapped in a cycle of poverty, unemployment, and psychological and health problems (INAC, 1996). These trends are being further exasperated by climate change as most aboriginal communities lack the economic and technical resources that are available to non-aboriginal communities (CANA, 2006).

The recent passage of the *Green Energy and Green Economy Act* (Smitherman, 2009) has provided Ontario's Aboriginal communities with an opportunity to help break out of this cycle and directly counteract climate change by becoming renewable energy producers, which will also assist the communities in being more self-sufficient economically. The Act included a FIT program for renewable energy in Ontario, which is particularly well-suited for deployment of solar photovoltaic (PV) technology in Aboriginal communities (OPA, 2009).

This paper reviews the technical and economic viability of leveraging the Ontario FIT for PV to provide green electricity and a revenue stream to assist Aboriginal communities in sustainable development. First, the technical viability of using PV in northern Ontario will be reviewed and design limitations highlighted. Then, a geographical information system (GIS)-based protocol will be developed to determine the PV potential for a community. Next, this model will be applied to a case study of the Constance Lake First Nation community and an economic analysis will be performed. Finally, this case study will be generalized to all of the 127 First Nations communities in Ontario and the results will be discussed in the context of sustainable development and cultural boundary conditions.

2. Background

2.1 Solar Photovoltaics: An Appropriate Technology

Solar PV technology converts sunlight directly into electricity and is well-established as a technically viable, sustainable and renewable energy source (Pearce, 2002; Green, 2000). Modern PV cells based on silicon technologies pay for themselves in terms of energy in a few years (1-5 years) and thus generate enough energy over their lifetimes to reproduce themselves many times (6 to >30 reproductions under warranty) depending on the type of material, balance of systems, and the geographic location of the system (Pearce & Lau, 2002). The rapid energy payback time of PV illustrates how PV is a partial solution to the problems of energy, environmental sustainability, and long-term CO_2 mitigation. Following Shumacker (1973), solar PV has a number of other attributes that makes it a well-suited appropriate technology for use in Aboriginal communities. First, PV is modular, which enables the number of panels to be easily expanded for a given application following population and energy use changes. Next, the actual energy production is completely emission-free and silent. Since solar panels are solid state devices with no moving parts, they are likely to function well beyond the 20-30 year standard warranties making them true investments in the future of the community. Finally, PV systems require very little maintenance post-installation (Pearce, 2002), which is important for communities without close or economical access to parts providers and technicians. However, in order to take advantage of the FIT program a community must still be grid-connected as the electricity produced is sold back to the grid.

Despite these benefits there are several constraints that must be met when designing PV systems for First Nations communities. The majority of Ontario's 127 First Nations communities are located in northern Ontario (INAC, 2009) where they must occasionally cope with harsh winter conditions. Fortunately, solar panels are well-suited for low temperatures having been originally designed for space applications (Jackson & Oliver, 2000) and many of which have temperature coefficients that actually improve efficiency with lower temperatures. A study was performed by Williams and Rand (2000) from the South Pole by the Cold Regions Research and Engineering Laboratory looking at the effects of extreme cold on four different crystalline silicon-based solar panels. After a period of 410 days in strong winds and temperatures ranging from -20°C to -70°C, no noticeable degradation was found in the PV modules, aluminum frame or electrical connections. However, there were significant performance reductions due to snow and frost accumulation on the panels as well as wind-blown snow reducing visibility. While the combination of wind, sunlight and panel tilt is usually sufficient to prevent snow accumulation, the panels stop producing electricity entirely if covered in a thick layer of snow. Therefore, it is important to provide safe and easy mechanisms to access the PV system for manual removal if necessary. Additionally, the extra weight from snow accumulation on the panels must be factored into the load-bearing design aspect of any mounting equipment. While the durability of the panels and mounting/connection equipment must be given additional focus in some communities, another structural concern that must be studied when performing a project analysis is the integrity of the rooftops. First Nations' houses are less structurally sound than an average Ontario house (INAC, 1996) and therefore must be examined closely before inclusion in any PV project designs. For family residences, pole mounted systems <10kW in capacity may be a method to overcome both snow and roof structural concerns. However, there are other concerns regarding implementing PV on specific First Nations communities. Along with harsh climate, high rates of vandalism in the communities must be considered and thus pole mounted systems may not be appropriate. Depending on the community this challenge can be overcome through education and outreach, locking hardware, break-resistant panels and security systems.

2.2 The Ontario Feed-In Tariff

On May 14, 2009 the Ontario government passed into law the *Green Energy and Green Economy Act, 2009* which included North America's first comprehensive feed-in tariff (FIT) program for a variety of renewable energy production sources. The FIT is a fixed price under a long-term contract for which the Ontario Power Authority (OPA) will purchase renewable energy from any generators. This FIT is part of the Ontario government's plan to heavily promote and encourage renewable energy production with the goal of eliminating all need for polluting coal-fired electricity by 2014 (OPA, 2009). Solar photovoltaics has been recognized as an important clean energy source and, as a result, potential generators have been awarded a generous pricing schedule shown in Table 1.

The $0.802 per kiloWatt-hour (kWh) rate is for rooftop PV systems under 10 kiloWatts (kW) capacity and can be applied to most First Nations rooftops. Larger houses or buildings would likely fall under the 10 to 250 kW capacity range and these systems would earn $0.713/kWh. It should be noted that as of this writing <10kW ground mounted systems are also eligible for the full $0.802/kWh. However, the OPA has proposed a rule change where any family-sized ground mounted systems (<10 kW) would earn only $0.588/kWh. Communities with available land can also implement a large-scale ground-mounted PV system which would qualify for a $0.443/kWh tariff if under 10 megaWatts (MW) capacity. In addition, the FIT program provides additional incentives for Aboriginal communities in the form of reduced security payments and a "price adder". This price adder applies only for large-scale ground mounted PV systems, but increases the price by up to $0.015/kWh (depending on the percentage of equity ownership of the Aboriginal group) for a total of $0.458/kWh. This extra incentive is in recognition of the additional barriers and costs faced by Aboriginal communities looking to develop renewable energy systems. These FIT prices will be subjected to review by the OPA periodically therefore the economics outlined in this paper only apply for the current pricing schedule although the methodology is generalizable.

2.3 Constance Lake First Nation

The Constance Lake First Nation community agreed to act as a case study to test the methodology discussed below. Constance Lake First Nation is situated in northern Ontario, near the southwest tip of the Hudson Bay and has a population of 702 people (Statistics Canada, 2009). The median private household income in 2005 was $36 000, which is far lower than Ontario's average of $60 500 (Statistics Canada, 2009). Correspondingly, in 2006, almost 48% of the homes on the reserve required major repair. Constance Lake First Nation also suffers from a 26.5% unemployment rate compared to the 6.4% unemployment rate in the rest of Ontario (Statistics Canada, 2009). Additionally, about 61% of community members 15 years and older do not have any type of certification, diploma or degree, which is extremely high compared to the 22% of people in Ontario (Statistics Canada, 2009).

The reality for many First Nations communities in Ontario is that unemployment, poverty, and lack of education are a way of life (INAC, 1996). Once this principle becomes entrenched in the community members, it becomes very difficult to help the community move toward growth and economic sustainability through community development projects. The lack of education combined with the cultural barriers associated with many developmental initiatives prevent this progress despite the fact that these projects would help First Nations communities break the vicious cycle of poverty and unemployment. However, there are still some First Nations communities, such as Constance Lake First Nation, which acknowledge the problems that exist within their community and refuse to accept them. These communities tend to have very strong leadership and receptivity in dealing with new projects and off-reserve people or companies. Furthermore, these band councils make the effort to engage members of their community in new projects, such as the one proposed here.

Malhotra's factors influencing success of a community-based energy project include conditions, residents' contributions, leadership and institutional contribution/presence (2006). There must be an existing felt need, strong village leadership, appropriate community contributions (land, labour, money) and strong but limited institutional support. Constance Lake First Nation has been chosen as the case study in this paper because it satisfies the majority of these conditions. First, the band council and community have expressed significant interest in expanding its economic development particularly through renewable energy projects. Second, its band council has the self-stated ability to raise significant funds for a project of this magnitude. Third, the community has 200 homes and buildings (mostly owned by the band council) available for rooftop PV as well as 29 acres of farmland which may be used for ground-mounted PV. Finally, Constance Lake First Nation is planning to establish its own energy company, which would limit the institutional assistance in the initial analysis and installation.

3. Methodology

3.1 Overview

In order to perform the economic analyses for Constance Lake First Nation's rooftop and ground-mounted PV systems, the cost of the systems and the yearly revenue generated were required. To avoid predicting the prices of solar panels and other associated costs of installing a PV system, cost sensitivity analyses were used with a range from \$5 to \$10 per peak watt (W_p) as PV is normally sold on a cost per unit power basis. However, specific values for revenue were needed. These were obtained using the RETScreen Clean Energy Project Analysis version 4 software provided by Natural Resources Canada (Retscreen International, 2009). This software runs in a spreadsheet and provides a very good first approximation of solar energy output and was chosen because it is made available free of charge. This means the methodology is easily accessible to any First Nations communities to complete the analyses themselves. RETScreen uses environmental data from NASA including air temperature, daily solar irradiation and wind speed in its solar electricity output calculations. Since Constance Lake First Nation’s data is not in RETScreen's database, the climate data from nearby Hearst was selected being the closest available location. This data was deemed acceptable as its daily horizontal solar radiation differs from Constance Lake First Nation’s by less than 0.3% (Hearst = 3.39 kWh/m^2/day, Constance Lake First Nation = 3.40 kWh/m^2/day) (NASA, 2009).

3.2 GIS-Based Protocol for Rooftop PV

In order to determine the system size for the input to RETScreen, free georeferenced orthographic images of Constance Lake First Nation were obtained from the Ontario Ministry of Natural Resources (OMNR, 2009). The geographical information system (GIS) program, ArcGIS (ESRI, 2009), was used to outline the available and PV-appropriate roof space on each of the community’s buildings. Conservative outlines were made with regards to orientation size and shading. Since the amount of sunlight reaching the panels decreases the further they are angled away from due south (in the Northern Hemisphere), only roofs within an azimuth angle of 90° were included. Partial or entire roof spaces were excluded if there was a chance of shading from nearby trees or building structures. Additionally, each house or building was limited to the most ideal face of its roof (if there were multiple). ArcGIS was then used to calculate the areas of each outlined shape (horizontal rooftop area suitable for solar panels). Although a license is required for ArcGIS, this process could also be performed by communities using the free open-source program QuantumGIS (QGIS, 2009). The program is in fact simpler to use than ArcGIS, but does not yet support an attribute table which means that a spreadsheet such as the free OpenOffice (OpenOffice.org, 2009) must accompany the digitization. This spreadsheet can be used to manually register the outlined rooftop areas and organize them into categories (further detail in Section 3.3). It is important in this case to label the buildings on the community’s map or image to match the area values put on the spreadsheet. An error analysis was performed to compare the area outputs of ArcGIS and QuantumGIS. The areas calculated for the same outlined rooftop were 265.65 m^2 and 265.43 m^2 respectively which correspond to a difference of 0.08%. This minute difference falls well within the error associated with the manual outlining meaning the areas determined in this paper can be accurately reproduced using QuantumGIS.

3.3 RETScreen Categorization for Rooftop PV

Three solar PV panels were selected for analysis: BP Solar’s ‘BP Millenia MST 50 MV’ amorphous silicon (a-Si) panel, Canadian Solar’s ‘S4D 40W’ polycrystalline (p-Si) panel and Sanyo’s ‘HIP-200BA3’ monocrystalline (m-Si) panel. The efficiencies are 6.1%, 10.5% and 17% respectively. These were chosen because they are the most common solar PV materials and offer a wide range of efficiencies and costs for analysis and comparison. The solar panel information is given in Table 2.

RETScreen requires a single set of values for electricity export rate, slope and azimuth angle, therefore the rooftop areas were categorized by these three factors for each panel type. Since the feed-in tariff price decreases after systems exceed 10kW capacity, the rooftop areas needed to be split into those above and below this capacity (Note 1).

RETScreen was used to determine the panel areas that would equate to this capacity. However, these true areas of the tilted panels are greater than the horizontal areas determined by GIS. Therefore, the 10 kW capacity cutoff area determined by RETScreen had to be converted into the equivalent horizontal area. First, the tilt angle of the roofs were adjusted for by multiplying by the cosine of the angle (45° was the assumed tilt for visibly angled rooftops). The panels on the tilted roofs were assumed to be laid flat and close-packed. For simplicity to avoid row to row shading, the panels on the flat rooftops were chosen to be at a 10° angle, which allows no spacing with minimal impact of row on row shading. It should be noted that the optimal angle for total yearly solar energy conversion at Constance Lake First Nation’s latitude is 40°.

It was then assumed 80% of this available roof space would be used for actual panels to account for shading, small obstructions and leaving a portion of roof space open for access. This is a more conservative estimate than the 90% Lehmann and Peter (2003) use for similar system designs. So, these area values were then divided by 0.8 to give the final horizontal area as would be extracted from ArcGIS. The same considerations (but reversed calculations) were taken into account when converting the outlined GIS areas from ArcGIS to actual tilted panel areas.

Each panel has a different efficiency meaning these cut-off areas varied for each technology (i.e. more efficient m-Si panels would reach 10kW capacity in a smaller area than a-Si or p-Si). The areas were then grouped into three azimuth categories to enable the calculations to be completed in a reasonable time: south (azimuth angle = 0°), southeast/southwest (azimuth = 45°) and east/west (azimuth = 90°). Finally, the tilted (assumed 45° angle) and flat rooftop areas were separated.

These areas were then entered into RETScreen for the energy model and financial analyses. An inverter efficiency of 95% was selected (NREL, 2006; Duan & Chang, 2009) and miscellaneous losses of 5% were assumed for RETScreen's energy calculations. This miscellaneous loss can be further refined as data is made available from energy losses due to snow cover (Note 2). In addition, twenty years was used as the project life for the financial and economic analyses as the FIT program's contract is guaranteed for this length.

3.4 Large-Scale Ground-Mounted PV

Constance Lake First Nation owns 29 acres of farmland near its reserve, which can be used to develop a commercial-sized, multi-megaWatt PV system. Potential PV farms in other Aboriginal communities could be calculated following recently developed open source methods (Nguyen & Pearce, 2010). The revenue stream for this potential ground-mounted PV system was determined using the program PVSyst version 4.33 (ESRI, 2009). Communities could use RETScreen again to give reasonable estimations, but PVSyst was used because the software package provides for a more detailed analysis for the sizing and simulation of complex systems. Unlike panels laid flat on angled rooftops, panel-to-panel shading considerations must be taken into account for ground-mounted systems. PVSyst makes use of its accurate solar geometry calculations to factor in shading and panel spacing in determining the PV system's electricity output to the grid. The Hearst climate data from RETScreen was entered into PVSyst and a preliminary design was performed. The outputs obtained include PV system capacity and electricity generated. The annual revenue was then calculated as the product of the electricity generated and the appropriate FIT price.

3.5 Economic Analysis Calculations

The payback period is the amount of time required to recoup the initial investment from the revenue stream. The annualized return on investment (ROI) is the ratio of the net profit (P) to the initial investment (I) over the length of the project (N) expressed as a percentage. In this case, the project life is the 20-year length of the FIT contract. Thus the ROI is given by:

$$ROI = \frac{P}{I*N} \tag{1}$$

The internal rate of return (IRR) is the effective interest rate that makes the net present value zero. In other words, it is the discount rate at which the project becomes profitable over its lifetime. It is found using the yearly cumulative cash flow (C_n) over the course of the project's length. The IRR was solved for from:

$$NPV = 0 = \sum\left(\frac{C_n}{I+IRR^n}\right) \tag{2}$$

4. Economic Analysis

4.1 Total Rooftop PV Potential

An energy and economic analysis was performed comparing the three panel types for the full-scale implementation of PV on Constance Lake First Nation's designated rooftop area. Taxes were not taken into account since the Canadian *Indian Act* states that income generated from on-reserve activities is tax-exempt (CRA, 2008). Additionally, inflation and financing rates were not taken into account in order to ensure the economics were clear. These rates can be simply included to determine a hurdle rate for investments in the community. The latest Canadian PV power report for 2008 (IEA, 2009) reported an average PV system turnkey price of $6-8 CAD/W. As a result, this paper's analysis uses a worst-case cost scenario of $10/W, which would take account for travel to the relatively remote location for installation and parts. This total installed cost includes the price of the panels, inverters, mounting (if required), installation, metering, connection etc. The results are illustrated in Table 3.

As seen in Table 3, the total PV potential of Constance Lake First Nation's buildings is quite large. Depending on the panels used, the total capacity ranges from 1.29 to 3.58 MW. This project would require a significant initial investment with initial costs ranging from $12.87 million to $35.78 million. This analysis does not rate the panel types in terms of economic attractiveness since the total installed costs were fixed for each. Rather, it gives an idea about the relative scales of each panel type with regards to initial costs, total electricity produced and revenue generated. For this reason the payback period, ROI and IRR from equations 1 and 2 are very similar. These economic indicators for m-Si are slightly worse than a-Si and p-Si because its panels have a higher efficiency. Thus, a greater fraction of Constance Lake First Nation's rooftop areas will have a capacity above 10 kW and would then fall into the lower priced FIT category. Nonetheless, the IRR for each panel type is above

7%. It is clear that even for the worst-case cost scenario the economics are acceptable, which ensures the PV project in Constance Lake First Nation will be profitable.

4.2 South-Facing Rooftop PV Potential

While covering all the appropriate rooftop area in PV appears profitable, the massive initial costs could be afforded by few First Nations communities even with financing. Since PV is modular, the investment can be reduced to any level by decreasing the amount of PV installed. This has the additional benefit of improving the economics of the system as the panels installed can be prioritized towards the most profitable rooftops first. Therefore, the next analysis was performed for PV installation on the south-facing rooftops in Constance Lake First Nation. A single solar cell material, polycrystalline silicon (p-Si), was chosen in order to show the effects of the cost sensitivity analysis. The economics for each installed cost is shown in Table 4.

The initial investments are still significant, but a more manageable \$3.24 million to \$6.48 million for this scale of a project. The economics are an improvement over the full-scale PV system. The payback period ranges from 4.8 years to 9.6 years depending on the installed cost per watt. The minimum ROI and IRR values are 5.4% and 8.3% respectively. At a realistic cost of \$8/W, the ROI and IRR are 8.0% and 11.6% respectively, indicating a very economically attractive project. The corresponding cumulative cash flows as a function of the range of installed costs are illustrated in Figure 1.

4.3 Ground-Mounted PV Potential

In addition to the rooftop PV, a simple energy and economic analysis was performed for a potential solar PV farm developed in Constance Lake First Nation's available land. The total capacity, electricity output and corresponding revenue for each panel type are given in Table 5.

The total capacity for this PV system is 7 MW using thin-film panels. The use of p-Si and m-Si panels would in fact exceed the FIT maximum capacity of 10 MW. However, thin-film panels are often favoured for large PV farms due to their lower per-Watt costs (Green, 2000). For this reason a cost sensitivity analysis was performed using thin-film panels. Additionally, since the morphology of the land is unknown, it was assumed that 25% of the farmland is available for PV. The capacity and revenue is then one quarter that given for thin-film in Table 5 above. This information was used to perform the economic analysis summarized in Table 6.

The economics of the ground-mounted system are not as promising as the rooftop PV systems due to the lower FIT prices. However, the massive size and output of the PV farm means that even slightly positive margins can create large profits. An installed cost of \$6/W or lower would result in a pre-tax (although revenue generated off the federal reserve land is taxable) IRR of 7.1% or higher which is an acceptable rate. It should be noted that the efficiencies for thin-film modules even of a-Si have been steadily improving and there are now panels on the market that are 10% efficient (Osborn, 2009). Utilizing these newer panels would increase the revenue for a given installed power by more than 50%. If First Nations communities do not have the financial capability to develop these solar farms in addition to the rooftop PV systems, other options such as leasing out the land could be examined. This will not hurt the land if appropriate racking is implemented as the land can be reverted to agricultural uses after the term of the PV production is over.

4.4 PV Potential for All of Ontario's First Nations

This paper has shown that a full-scale implementation of p-Si PV panels on Constance Lake First Nation's appropriate roof space would create 1.836 MW of peak capacity. This can be extrapolated by population count to obtain an estimate of the total potential PV capacity for all of Ontario's First Nations communities following the work by Wiginton et al. (2010), which showed a very consistent correlation between population and roof availability for PV in Ontario. Comparing Constance Lake First Nation's population of 702 residents to Ontario's total on-reserve Aboriginal population of 81 901 (INAC, 2009) gives a total capacity of 214 MW. To put this value in perspective it can be pointed out that the installed PV capacity in October 2009 in Ontario was 10.8 MW (Gipe, 2009). Although it should be noted that with the FIT there is also rapid development of PV in non-First Nations communities, it is clear that the potential for PV development in Ontario's First Nations is significant.

5. Discussion

5.1 Economics

The financial analyses clearly demonstrate how profitable rooftop solar PV can be with Ontario's feed-in tariff. The worst-case cost scenarios of \$10 per watt still show favorable economics, in particular for south-facing rooftops. If covering every rooftop in PV is not financially feasible, the community can cut down the initial cost to any desired amount by prioritizing for the most profitable rooftops. Since the FIT contract is guaranteed for twenty years and the solar irradiation does not change significantly from year to year, there is virtually no risk to the communities if the initial analysis is done correctly. Additionally, the economic analyses in this paper only covered the 20-year fixed-price FIT contract. However, most solar PV panels are expected to last much longer with only slight electrical performance degradation. Typical warranties provided by manufacturers cover 25-30 years, and maintain that the modules will still perform at about 80% of the initial efficiency at the end of the warranty (Kazmerski, 2006). Thus, the true financial outlook will be further improved if the energy produced over the entire lifetime of the panels is taken into account.

5.2 Funding and Financing

This paper has shown that a large-scale PV project requires a sizable initial investment. Many of Ontario's First Nation communities do not possess this financial capital and will require funding and financing means. Fortunately, both the federal and provincial governments provide financial assistance for First Nation communities developing renewable energy projects. The federal government's Indian and Northern Affairs department offers Large Energy Project funding of up to $250 000 for Aboriginal renewable energy projects that result in a clear reduction of greenhouse gas and air contaminant emissions (INAC, 2009). This non-repayable grant of up to 30% of the project's costs would be another major financial advantage for PV development in First Nation communities. In the 2009 Ontario budget, the provincial government created the Aboriginal Loan Guarantee Program to support Aboriginal participation in green energy projects (OMAF, 2009). The program provides a guarantee for loans of up to 75% of an Aboriginal corporation's equity. This greatly improves the likelihood of a First Nation community's corporation receiving a substantial loan from a financial institution. Assistance from this loan program requires the community to have a corporation undergoing the project. Since a PV project would be community-led, one option for any band council to examine is the establishment of its own electric utility firm similar to Five Nations Energy Inc., which is an Ontario power supplier jointly owned by three First Nation communities (FNEI, 2009). This action would give First Nation communities more independence and control over their energy projects as well as creating jobs for its residents. For example, the T'Sou-ke project is modeling energy autonomy for other Aboriginal communities by installing PV (Kimmett, 2009).

5.3 Education

Education of a community's residents is a vital first step towards gaining acceptance and implementing a community-wide PV project (INAC, 1996). While Constance Lake First Nation's band council owns the majority of houses, any PV installation would not occur without the approval of the residents. Therefore, it is important that the community members understand the purpose and benefits of photovoltaic energy generation to both the world and their community. This will not only increase acceptance, but also understanding in that certain houses are not as suitable as others for PV due to orientation, shading, or structure. Informational packages and community meetings are good starting measures for spreading awareness and knowledge about this type of project, as is seen by the success of a similar renewable energy project in Kyoquot, BC (Pembina Institute, 2007). Education of the youth could be done through the school's teachings as a component of science, technology and finance lessons. There are numerous teaching guides for solar energy suitable for elementary and high school students from organizations such as NEED (2007) and the Union of Concerned Scientists (2003). This is important to prevent vandalism as the young residents are less likely to damage the panels if they are aware of their value and benefits to themselves and the community.

5.4 Community Benefits

The benefits of revenue generation would be greater for the low-populated, less-developed First Nations communities as compared to most cities or towns in Ontario. Although there are persistent problems that are deeply rooted in the history of Aboriginal peoples, including domination, land claims, paternalism and attempted assimilation (INAC, 1996) providing additional revenue could help raise the standards of living. Problems such as poor housing conditions and inadequate water and sanitation systems can be directly improved with the revenue from the solar electricity sold to the OPA. These improvements would in turn be expected to assist with social problems such as the high levels of family violence, alcohol abuse and illness (INAC, 1996).

First Nations have always had strong ties to the environment (Ellis et al., 1997). Therefore, a community-designed, planned and developed renewable energy project that benefits the environment by reducing fossil fuel consumption is one that should increase the pride and outlook of its members. The Royal Commission on Aboriginal Peoples found that, most of all, Aboriginals seek control of their lives (INAC, 1996). A large solar PV project developed by the community that creates a significant annual revenue stream for twenty years and beyond is a big step towards self-sufficiency, sustainability and independence. This combination of an improved financial situation and the pride in developing a sustainable energy system is one that can be expected to help Ontario's First Nations communities break out of the cycle that has lead to such persistent social problems.

6. Conclusion

Ontario's generous feed-in tariffs for the production of solar photovoltaic energy give a substantial economic boost to any PV project in Ontario. However, First Nation communities stand to gain even further from special governmental considerations and incentives designed to encourage Aboriginal-led renewable energy projects. These include a price adder in the FIT program for ground-mounted PV, full tax exemptions for income generated from energy projects on reserve land (rooftop PV), federal grants for renewable energy projects and provincial government loan guarantees. A full-scale implementation of PV in all of Ontario's First Nation communities would add an estimated 214 MW to Ontario's existing PV capacity. This would be a significant step towards Ontario's renewable energy goals, while improving the financial conditions in the communities. This paper outlined a clear and inexpensive methodology that any Ontario Aboriginal community could use to determine the viability of local PV projects. The economic analyses performed here demonstrate how profitable a rooftop PV system in an Aboriginal community would be even in the worst-case installed cost scenarios. The additional revenue stream and pride associated with owning a community-led, environmentally beneficial solar PV project would improve the standard of living for the residents and help reduce persistent social problems. For these reasons, the feed-in tariff for solar photovoltaic energy is one that every grid-connected Ontario Aboriginal community should consider taking advantage of as a guaranteed course of financially, socially and environmentally sustainable development.

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Notes

Note 1. The areas were entered into the free OpenOffice.org Calc program and organized using the Sort Ascending function. The values above and below the capacity were manually separated and summed.

Note 2. Study underway on the effects of snow on PV performance in Ontario available here: http://www.appropedia.org/Effects_of_snow_on_photovoltaic_performance

Table 1. Applicable FIT pricing schedule

Solar PV Type	**Capacity**	**Contract Price (¢/kWh)**
Any	≤10 kW	80.2
Rooftop	>10 kW ≤250 kW	71.3
Ground-mounted	≤10 MW	45.8*
*Including 1.5 ¢/kWh Aboriginal adder Source: OPA, 2009		

Table 2. PV Panel Properties Chosen for RETScreen

Technology	**a-Si**	**p-Si**	**m-Si**
Manufacturer	BP Solar	Canadian Solar	Sanyo
Cell Model	BP Millenia MST 50 MV	S4D 40W	HIP-200BA3
Capacity per Unit (W)	50	40	200
Efficiency (%)	6.1	10.5	17

Table 3. Comparing the economics for the three solar panel technologies

	a-Si	**p-Si**	**m-Si**
Panel Area (m^2)	21 113	21 113	21 113
Capacity (kW)	1,287	1,836	3,578
Elec to Grid (MWh/yr)	1,624	2,331	4,543
Annual Revenue ($)	1 233 422	1 756 800	3 366 578
Cost ($)	12 873 500	18 358 400	35 782 000
Total Profit ($)	11 794 940	16 777 600	31 549 560
Payback Period (yrs)	10.4	10.4	10.6
ROI (%)	4.6	4.6	4.4
IRR (%)	7.2	7.2	7.0

Table 4. Economics for p-Si PV on south-facing rooftops

	$5/W	$6/W	$7/W	$8/W	$9/W	$10/W
Cost ($)	3 239 800	3 887 760	4 535 720	5 183 680	5 831 640	6 479 600
Total Revenue ($)	13 499 360	13 499 360	13 499 360	13 499 360	13 499 360	13 499 360
Total Profit ($)	10 259 560	9 611 600	8 963 640	8 315 680	7 667 720	7 019 760
Payback (yrs)	4.8	5.8	6.7	7.7	8.6	9.6
ROI (%)	15.8	12.4	9.9	8.0	6.6	5.4
IRR (%)	20.3	16.5	13.7	11.6	9.8	8.3

Table 5. Comparison of panel types for ground-mounted PV

	a-Si	p-Si	m-Si
Capacity (kW)	7 041	12 323	14 083
Elec to Grid (MWh/yr)	8 794	15 389	17 587
Annual Revenue ($)	4 027 652	7 048 162	8 054 846

Table 6. Economics for 1.76 MW thin-film ground-mounted PV farm

	$4/W	$5/W	$6/W	$7/W	$8/W	$9/W
Cost ($)	7 041 000	8 801 250	10 561 500	12 321 750	14 082 000	15 842 250
Total Profit ($/20 yrs)	13 097 260	11 337 010	9 576 760	7 816 510	6 056 260	4 296 010
Payback (yrs)	7.0	8.7	10.5	12.2	14.0	15.7
ROI (%)	9.3	6.4	4.5	3.2	2.2	1.4
IRR (%)	13.1	9.6	7.1	5.2	3.7	2.4

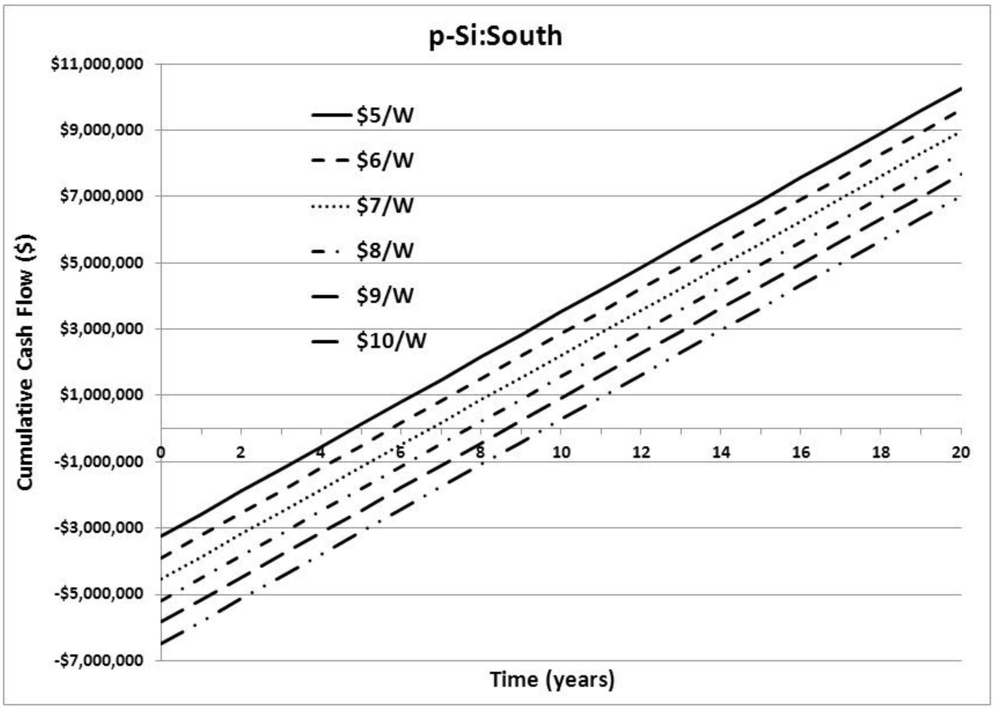

Figure 1. The cumulative cash flow as a function of time for poly-crystalline silicon solar cells facing south in Constance Lake First Nation. A sensitivity analysis is shown for the initial costs of $5/W to $10/W in $1/W increments.