Solar Energy Feasibility Study

Kings County Landfill Site

Meadowview, Nova Scotia

May, 2016

Ryan Ferdinand and Wayne Groszko

Nova Scotia Community College, Energy Sustainability Engineering Technology Program

Executive Summary

A solar photovoltaic (PV) array at the former site of the municipal landfill in Meadowview, Kings County, is technically feasible. Such a site could be sized to at least 3.87 megawatts (MW) of capacity and could be financially feasible at today's retail price for the sale of electricity.[1]

Development of a solar array at this site would re-use a brownfield site for which it would be difficult to suggest alternate uses. It could also offer opportunities for technological development/exploration of energy storage solutions.[2] In addition, because this site is located in close proximity to two major electrical users (Department of National Defence's Land Force Atlantic Area Training Centre at Aldershot and the Annapolis Valley Health Regional Hospital) financial feasability could be enhanced through a direct sale of electricity produced to potential federal and provincial partners.

Financial viability for a PV generating station at this site depends on many factors, including the type of ownership, installed cost, availability of grants, interest rates on borrowing and method of delivery. Feasibility analysis in this study is based on power being sold to a customer of Nova Scotia Power at the current retail rates for electricity.

The amortized cost of generating electricity at the site ranges from $177 to $274 per megawatt-hour (MWh), depending on various factors that are discussed in the body of the report.

Scenario	**Cost of production ($/MWh)**
Estimate for a municipality	$ 177 / MWh
Estimate for a community or private entity	$ 208 / MWh
High estimate	$ 274 / MWh

1 This considers only the flat top of the closed landfill. The area available could be larger if an engineering study shows that the sloped land could support solar panel installation.

2 Closed landfills are unsuitable for most uses because it is not possible to install foundations for buildings, and because environmental concerns rule out alternate uses. On the other hand, solar panels can be installed without the need for heavy foundations and provide a green energy source.

The cost of electricity for retail sale in Nova Scotia (through Nova Scotia Power) in 2016 ranges from $110 to $170 per MWh, depending on the customer type, demand charges, and time-of-day rates. These prices are likely to rise in future years, while the prices calculated for the solar electricity generation are fixed for 25 years. Therefore, it is quite possible that a solar PV generating station at this site could be economically viable. In particular, as a municipal or non-profit community project, grants and low-interest financing can make the cost of production advantageous.

Based on this work, we consider the possibility of a solar generating station at this site to be worthy of serious consideration. Projects of this type, at this time, should be of great interest to all levels of government. Notably, the Government of Canada, in partnership with the provinces, is seeking green energy projects as part of an effective climate change action plan aimed at meeting Canada's international commitments.

Acknowledgements

This feasibility study was inspired by residents working to create a greener economy for Kings County.

The Meadowview Community Development Association (MCDA) played a key role in seeking the funds to employ a student to conduct the study required. One third of the funds came from the association's "Colour Us Green" event and two thirds was contributed by the Nova Scotia Youth Conservation Corps (2015).

The commitment of Joe Benjamin and Mitchell Foley (MCDA President & Vice President) are particularly notable as is the knowledge of the Frank Veinot (MCDA Member) who was a careful observer during the landfill's operation and closure. We are also very grateful to Kings County municipal employees Monica Beaton, Scott Quinn and Tim Boutillier for information provided.

Pauline Raven, the municipal councillor for the district where the landfill is located, helped establish this project and gave it the crucial attention it needed and deserved at several points along the way.

We also thank the students, staff, and faculty at the Nova Scotia Community College Energy Sustainability Engineering Technology (ESET) program for their technical assistance and guidance on this project.

Lastly, mention of the late Edgar Bishop, a life-long and much loved resident of Meadowview is very much warranted. Edgar was a great supporter of all things of benefit to the community of Meadowview and a proponent of this project.

Introduction

The community of Meadowview, in North Kentville, Nova Scotia, hosts the site of the former Kings County landfill. This facility was opened as a repository for solid waste in the 1970s and was closed in the mid-1990s. During this period 18 acres of land was filled with largely unsorted waste approximately 100 feet deep. Figure 1 shows a satellite view of the site.

Figure 1: Satellite view of Kings County's closed landfill site in North Kentville, showing two large electricity consumers in the area – Valley Regional Hospital and Camp Aldershot.

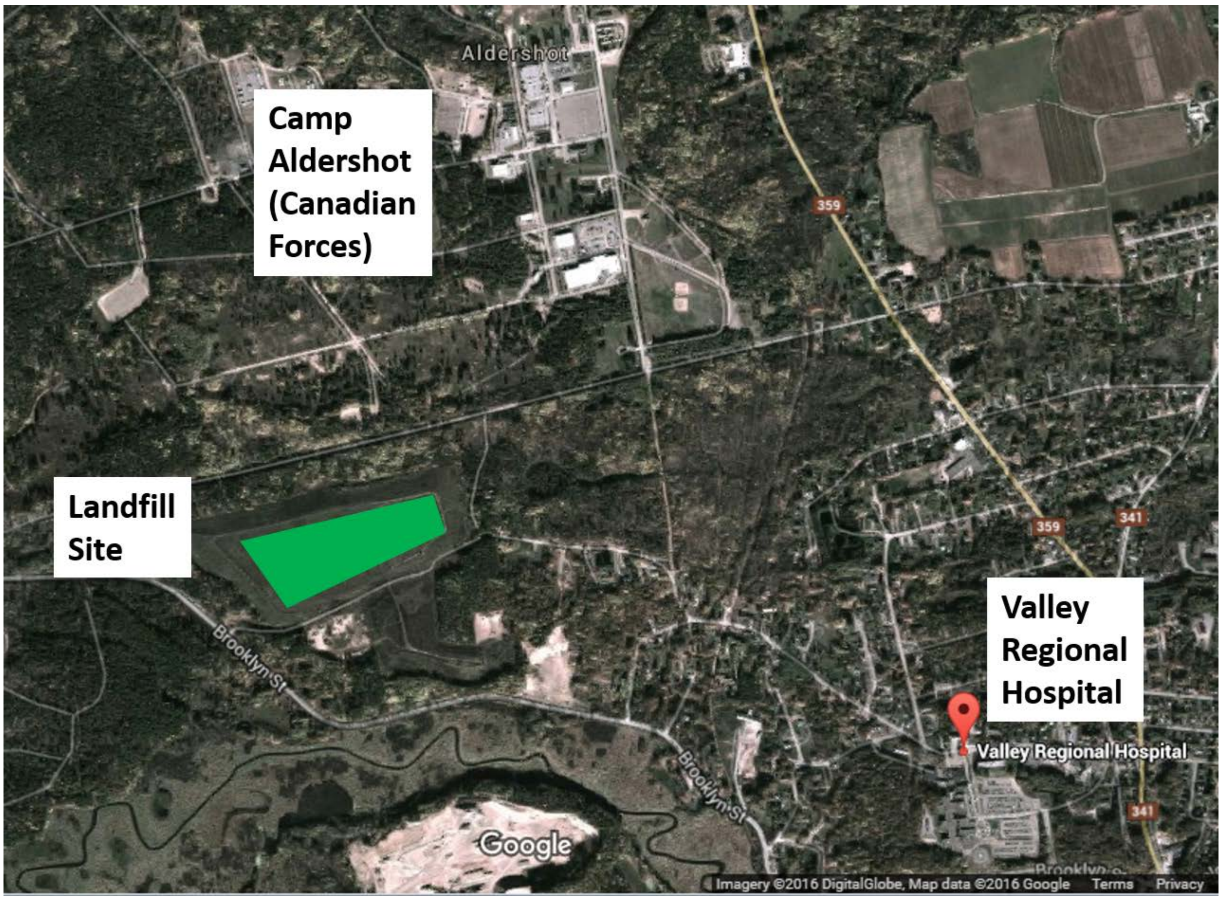

Image credit: Imagery © 2016 DigitalGlobe, Map data © 2016 Google

When the landfill was closed, a composite covering was put in place, which consists of a number of layers. Thirty-seven vents were placed throughout the cover to vent landfill gases. This landfill, unlike a typical landfill today, is not composed of segregated cells, it is a contiguous pile of waste.

There is one separate section that has compostable materials, but otherwise there are no separations.[3] See Figure 2 for details of capping at the Meadowview site.

Figure 2: Cross-section of landfill cap layers.

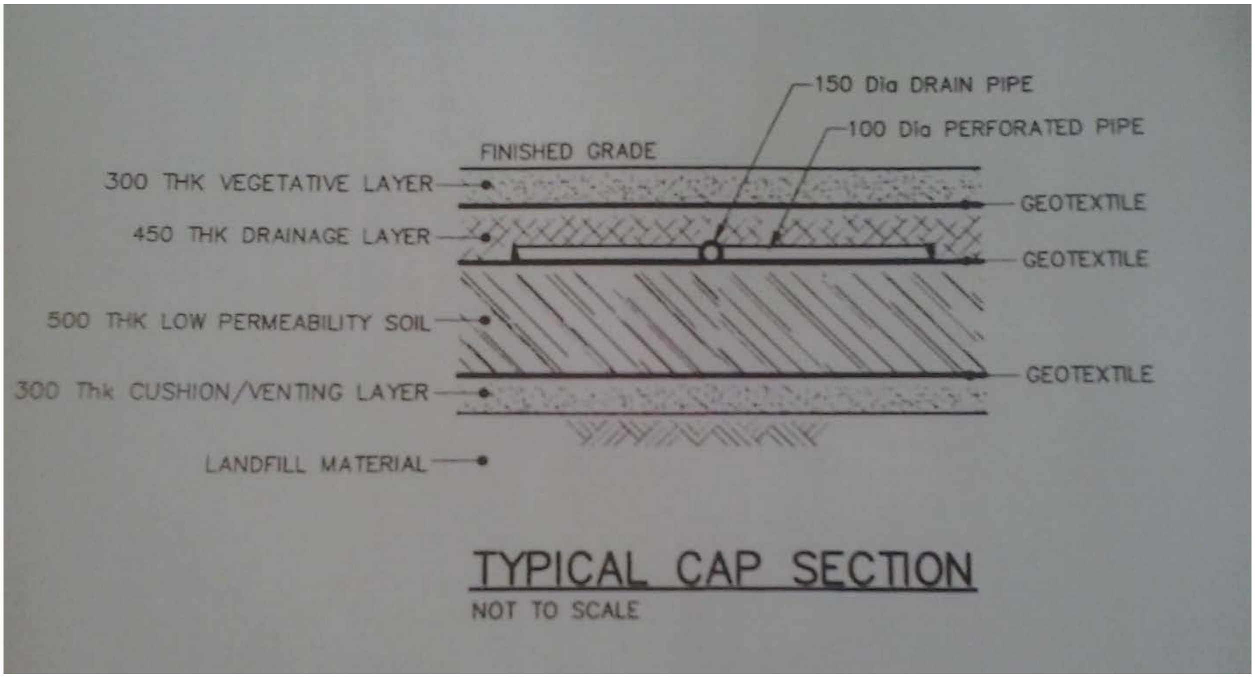

Image credit: Municipality of the County of Kings

The flat, level land area on the top of the waste repository is a large, open space with unobstructed access to sunlight. This area represents a significant opportunity for a solar photovoltaic (PV) electricity generating station.

The landfill has been a brownfield site and has had no productive use for over 20 years, other than being a habitat for bare land wildlife. Its use for solar energy production is an opportunity to use at least 18 acres of the site not only to produce green energy but also to create the rural economic development Nova Scotia very much needs.[4]

In other jurisdictions in North America, closed and unused landfill spaces are being used as platforms to install solar photovoltaic (electricity-generating) arrays. The state of Massachusetts,

---

3 Kings County staff members (2015) and Frank Veinott, long term Meadwiew resident, personal communication and site tour (2015).

4 By 2014 the State of Massachusetts had permitted 52 sites with a capacity of 103.9 Megawatts (MW), an average of 2 MW per site. This study aims at a capacity of 3.87 MW or more. A two-minute read of why solar makes sense for closed landfills can be found here. http://www.fastcoexist.com/3034869/why-it-makes-sense-to-put-solar-farms-on-old-landfill-sites

for example, has encouraged the development of solar electricity stations on many former landfill sites. In fact, to encourage solar energy production, this state's government has published a “how-to” guidebook for developing solar energy on landfill sites.[5] That guidebook has provided useful information to this report.

Project Goal & Objectives

The goal of this project is to conduct a preliminary assessment of the feasibility of developing a solar photovoltaic generating station on the site of the closed municipal landfill site in Meadowview, Kings County. To meet this goal, the following three objectives have been considered:

Objectives:

1. Site Plan and Size Estimate
2. Electricity Production Estimate
3. Financial Analysis

Methodology

We took the following steps to complete this study:

- Site inspection tour (guided by local resident Frank Veinot);
- Solar array site plan creation (preliminary design and sizing);
- Estimated electricity production;
- Analyzed greenhouse gas emission savings, and;
- Analyzed financial cost and return.[6]

During the site tour, we investigated the landscape and looked for any apparent features that could cause challenges or need to be considered when designing the solar site plan. Following the site visit, maps were obtained from staff member Monica Beaton, at the Municipality of the County of Kings.

---

5 The Guide to Developing Solar Photovoltaics at Massachusetts Landfills (2012). http://www.mass.gov/eea/docs/doer/green-communities/pubs-reports/pvlandfillguide.pdf

6 The results of a more detailed analysis by the authors is summarized in this report.

Results

(1) Site Plan and Size Estimate

Level area: 73,452 m^2 (18.15 acres)
The site visit revealed that the top surface of the landfill is relatively level, and nearly free of tall vegetation or other obstructions. The top surface of the landfill appears to be suitable for installing a solar array, as it has a large level area of about 18 acres with full sun exposure.

Load-bearing support: An engineering assessment would confirm what appears to be the suitability of the land to support a solar array.

It is beyond the scope of this study to assess the load-bearing strength of the top of the landfill cap to determine how much weight of solar array it can carry without a detrimental amount of additional compaction or sinking. Settling of a landfill site can cause challenges for a solar installation over time, particularly differential settling in which some parts may settle more than others. However, the fact that this landfill has been closed for about 20 years increases the probability that most of its settling has already happened.[7]

According to the cross-section design drawing of the cap (Figure 2 above), there should be 1.5 metres of constructed soil and drainage layers in the cap, above the deposited waste. The landfill surface appears promising as a support for ballasted (weighted) solar racking to hold solar panels, as shown in Figure 3 below. A ballasted system would likely be the best choice to secure the solar racks to the earth, rather than buried footings or helical drilled-in-ground posts. This is because systems such as posts that disturb the ground may extend too deep into the cover and could damage the drainage or cover layers. Figure 3 illustrates a ballasted solar PV array on a landfill.

Figure 3: Example photo of a ballasted solar PV array on a landfill.

Image credit: Solar Power World, January 24, 2016

---

7 United States Environmental Protection Agency (USEPA), 2013,

***Vents* –** The landfill gas vents are the only significant obstacles that would pose an issue, due to the shadows they would cast on a solar array. There are 37 vents distributed around the top of the landfill, and they are estimated to be about 12 feet, or 3.65m, in height. The vents consist of a galvanized steel chimney with an opening at the top and a rain cover.

To avoid shadows cast by the vent stacks on a potential solar array, either the array would have to be built with a buffer zone around each vent to avoid the shadows, or the vents would need to be modified to be shorter and not cast shadows on the array. In either case, best practice from projects in Massachusetts suggests that a 10-foot radius be left clear around each vent stack.[8,9]

Solar Array Layout:

There are various ways to design and lay out a solar PV array for this space on the landfill cover. To estimate the size and number of PV modules that can be installed, we chose an example solar module and designed a simple layout of rows, as shown in Figure 4 below. In this layout, there is a single row of solar PV panels on each stand.

Figure 4: Plan view of a proposed layout for a solar PV array at Meadowview landfill site.

Base Image credit: Imagery © 2016 DigitalGlobe, Map data © 2016 Google

8 The Guide to Developing Solar Photovoltaics at Massachusetts Landfills (2012). http://www.mass.gov/eea/docs/doer/green-communities/pubs-reports/pvlandfillguide.pdf.

9 Tighe & Bond, Inc., (2014).

These are the specifications of the solar array on which this feasibility study was based:

***Brand**:* Heliene 96M module

***Rated Output Capacity**:* 440 Watts per module

***Dimensions of each module**:* 1.976 m x 1.310 m

***Orientation**:* Portrait (long edge vertical)

***Azimuth (facing direction)**:* 11 degrees east of solar south
This choice of azimuth is for simplicity of layout and installation, because this direction will have the long rows line up with the longest edge of the available land. This makes the rows more consistent in length. According to analysis using RETScreen software provided by Natural Resouces Canada, this arrangement would result in just 0.25% lower output than facing the modules due solar south. It may be worthwhile to align the modules with the long side of the space rather than due south, if it decreases installation costs by keeping the row lengths more consistent. If it is found later to be preferable to face the modules due south, this will not cause a significant change in the estimated production results given here.

***Tilt angle**:* 40° up from the horizontal, which is optimal for the latitude of the site.

***Row spacing**:* To avoid the rows shading each other at any time of the year, for this example module our calculations indicate that a total width of 5 metres is needed for each row, which includes the width of the solar stand itself (1.4 m) and a space between rows to avoid shading from the other rows (3.6 m). With this spacing, twenty-seven (27) long rows of solar panels can easily fit on the flat top surface of the landfill site, as shown in Figure 4 above. This occupies approximately 70,000 m^2 of land area.

This is a conservative estimate of the number of rows, because an energy optimization could show that placing the rows closer together and accepting a small amount of shading in mid-winter could be a net benefit to energy production by allowing more rows to be installed. An energy optimization calculation to determine if more rows are beneficial has not been made, because this preliminary report is based on a conservative approach to estimating the size of the array.

***Number of modules**:* ~8,800 total (based on the example Heliene 96M module).

***Estimated power capacity**:* 3.87 Megawatts (MW – DC array rated capacity).

This also represents a conservative layout because more short rows of modules could be added to the area in the lower left of the level space on the landfill. For this analysis, we have chosen to leave this space empty in order to offset the fact that gaps may have to be left in the array around the vent structures.

Avoiding shading from the vent stacks:
The vents for landfill gas have an average height of 3.65 m. With the bottom of the module rows designed to be 1.5 m above the ground (to keep above the snow), it was determined that at noon on the winter solstice, when the sun is lowest in the sky, each vent would cast a 5.2 m long shadow at the level of the bottom of the modules. The area affected by shading from each vent would be

roughly 50 m^2. Of the 37 vents on the landfill, 28 are within the proposed area of the array, which would reduce the available area for solar panels on the site by approximately 1,400 m^2. This relatively small reduction in the 70,000 m^2 of space in the array could be easily made up for by adding a couple of short rows in the area that was left open in the southwest corner of the plan (Figure 4). As a result, the full proposed capacity of 3.87 MW will fit on this site.

(2) Electricity Production Estimate

The annual electrical production of the proposed solar array was estimated using three methods with the most conservative of the three chosen for a final result. Estimates from all three methods are shown in Table 1 (Electricity Production Estimates for 3.87 MW Array). The most conservative estimate has been used for all calculations in this feasibility study.

Rated capacity of installed solar array: 3.87 MW

Table 1: Annual Electricity production estimates for 3.87 MW array.

Method	**Estimated annual electricity produced** (GWh/y) (gigawatt-hours per year)
Based on measured output from solar PV systems in Nova Scotia. (Groszko, 2015)[10]	4.45
PVWatts (NREL, US Dep't of Energy software)	4.67
RETScreen (Natural Resources Canada)	4.74
Most conservative estimate	**4.45**

(3) Financial Analysis

Installation cost:

Installed cost range: $9.288 million to $11.61 million.

Based on a number of case studies and typical solar PV prices in Canada, we estimate that the cost of installing a solar array of this size in 2016-17 will be in the range of $2.40 to $3.00 per Watt of installed capacity. Therefore, the cost of this 3.87 MW is estimated to be in the range of $9.3 to

10 Groszko, W. and M. Butler, "Solar Photovoltaics in Nova Scotia, Report on Costs and Measured Productivity", commissioned by the Province of Nova Scotia, 2014.

$11.6 million.[11] It is notable that many sources report that the cost of solar panels has decreased dramatically during recent years and the decline is expected to continue, if more slowly.

Maintenance & Operations cost:

Estimated annual operations & maintenance cost (2016): ~ $100,000 / year

The cost of operating a solar PV generating facility is relatively low. The work that would be needed to maintain this site includes landscaping, trimming vegetation, checking for excessive snow coverage in winter, road maintenance to the site, security, inspection, verification of output, occasional repairs and parts replacements, book-keeping, accounting, auditing, and communications, etc. All of these activities would be required in small quantities and could be contracted to local contractors or part-time workers.

The US National Renewable Energy Laboratory estimates an annual operation and maintenance (O&M) cost of US$20 per year, per installed kW of solar PV arrays in the size between 1 and 10 MW of capacity (NREL, 2013). In Canadian dollars at the exchange rate current as of May 5, 2016 ($CAD 1.29 / USD), this amounts to $25.80 / kW per year. For 3.87 MW (3,780 kW), this amounts to CAD $99,846 / year, which we have rounded up to $100,000 / year.

Revenue:

Annual revenue in first year (at $177/MWh): $787,650 / year
(4.45 GWh/year x 1000 MWh/GWh x $177 / MWh)

This analysis is based on the most conservative annual electricity production estimate of 4.45 GWh/y, which equates to 4,450 megawatt-hours per year (MWh/y). We calculated revenue based on the selling price for solar electricity that we calculated for a municipality (see Table 2 below).

Project operating lifetime: 25 years
Note that the average operating lifetime of solar generating systems of this size in the USA, according to NREL data, is 33 years, so it is likely that the facility would operate longer than 25 years. While, 25 years is the typical length of the manufacturer's warranty on the solar modules, it is notable that the potential for additional years of use further enhances the project's financial feasibility as revenues for additional years would not further offset installation costs

Internal Rate of Return: 6.1% annual
This is an estimate of the annual return on the investment, if a private entity owned and operated the project and held 30% of the project cost as equity, while financing the rest with a loan. To achieve this rate of return, the private owner would have to sell the solar electricity at a fixed price

---

11

of $0.208 / kWh for 25 years, as estimated below in Table 2. At this rate, there is a significant positive return, however there are several factors that must be considered for a project of this type that would affect its feasibility:

(1) ***Financing:*** The amount, interest rate, and terms of financing will affect the rate of return.
(2) ***Grants:*** Due to the environmental and social benefits of this project, infrastructure grants, partnership grants, and in-kind contributions of labour and expertise from partners may be possible, to help make the project more financially viable.
(3) ***Electricity Price:*** The selling price for the solar electricity is not known at this point, but would need to be set at $0.208 / kWh to make this rate of return.

Average Unit Cost of Electricity Production:

We have estimated the cost of electricity production from a solar PV array on the site. The range of costs is wide, from $177/MWh to $274/MWh, depending on the conditions and assumptions used in the calculation. Estimates are shown in Table 2 below in ascending order and with the mid-range estimate shown in bold print. More details about these estimates follow below the table.

Table 2: Summary cost-of-production results.

Scenario	**Cost of production ($/MWh)**
Estimate for a municipality	$ 177 / MWh
Estimate for a community or private entity	$ 208 / MWh
High estimate	$ 274 / MWh

Estimate for a municipality: $177/MWh

If this project were undertaken by a municipality, there are several distinctive attributes. First and foremost, the municipality may be able to borrow funds at a significantly lower interest rate. Secondly, the municipality is not obligated to pay a dividend to its shareholders. In calculating the cost of electricity production in this scenario, we assumed that the municipality:

1. Would be able to secure a grant for 15% of the cost of the project from the Federation of Canadian Municipalities (FCM) (FCM staff, personal communication, May 2016).

2. The remaining 85% would be obtained in a loan from FCM at 2.6% interest for 20 years (FCM staff, personal communication, May 2016).

3. The municipality would break even, plus collect 10% above annual operating costs for a reserve fund in case of unexpected costs, or to contribute to community development.

4. The municipality would not be able to capitalize on GHG credits.

Estimate for a private/community entity: $208/MWh

This estimate is based on a private or community-owned entity doing the project using a combination of shareholder equity (30%), and a loan from a financial institution for the rest, at an interest rate of 6%. This estimate assumes that the entity operating the project will pay back both the loan and the equity, plus interest, and dividends of 4% annually to its shareholders, during the 25-year operating life. Also assumed in this estimate is that the entity can obtain a credit of $30 per tonne for the greenhouse gas that it is preventing from entering the atmosphere (GHG credits). The assumed installed cost in this scenario is $2.40/Watt.

High end estimate: $274/MWh

This estimate is the same as the private/community entity estimate, except at a higher installed cost ($3.00/W), and with the assumption that the entity cannot obtain any financial credit for the GHG emissions it is preventing with this system. This represents a worst-case scenario.

Retail Electricity Prices:

For reference, the average retail cost of electricity in Nova Scotia in 2016 is around $147/MWh for residential customers. For larger-scale customers such as a municipality, it is between $110 and $170 / MWh, depending on the additional demand charges.

Our calculations indicate that a municipality, with access to some grants and low-interest financing, could produce electricity from this proposed project as a cost of approximately $177 / MWh. This price would remain fixed for 25 years, during which time the price of electricity on the retail market can reasonably be expected to increase significantly.

Conclusion

In conclusion, it appears that a solar photovoltaic (PV) array at this site is technically feasible and could be sized to at least 3.87 MW of capacity. The financial viability of a PV generating station depends on many factors, including the type of ownership, installed cost, availability of grants, and interest rates on borrowing.

Based on this work, we consider the possibility of a solar generating station at this site to be a worthy of serious consideration and further discussion with potential community, government, and business partners. Potential partners include:

1. Department of National Defence (potential user of electricity generated, for their nearby Camp Aldershot facility).
2. Nova Scotia Health Authority (potential user of electricity generated, for Valley Regional Hospital).
3. Municipality of the County of Kings (owner of the closed landfill site).
4. Meadowview Community Development Association (for whom this feasibility study was produced).
5. Nova Scotia Community College Faculty in the Energy Sustainability Engineering Technology (ESET) and the Electrical Engineering Technology (EET) programs.
6. Private investors.
7. Business Community.

Projects of this type, at this time, should be of great interest to the broader community as well as all levels of government.

Most notably, the Government of Canada, in partnership with the provinces, is seeking green energy projects as part of an effective climate change action plan aimed at meeting our nation's international commitments. It is the hope of the Meadowview Community Development Association and the authors that their effort to bring this project forward will lead to further action in the months and years immediately ahead.

References

Commonwealth of Massachusetts, “The Guide to Developing Solar Photovoltaics at Massachusetts Landfills”, 2012. Accessed Aug. 2015 at: http://www.mass.gov/eea/docs/doer/green-communities/pubs-reports/pvlandfillguide.pdf

Groszko, W. & M. Butler, “Solar Photovoltaics in Nova Scotia: Report on Costs and Measured Electrical Productivity”, commissioned by the Province of Nova Scotia, 2014.

Tighe & Bond, Inc., Major Modification (Landfills) Permit Application, Town of Boxford, Massachusetts, Dec. 2014.

US National Renewable Energy Laboratory (NREL), “Distributed Generation Renewable Energy Estimate of Costs, updated August 2013. Accessed Feb. 2016 at: http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html

United States Environmental Protection Agency (USEPA), “Best Practices for Siting Solar Photovoltaics on Municipal Solid Waste Landfills, February, 2013. Accessed Jan. 2016 at: http://www.epa.gov/re-powering/best-practices-siting-solar-photovoltaics-municipal-solid-waste-landfills