

## Solar Photovoltaics in Nova Scotia: Report on Costs and Measured Electrical Productivity

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## **Acknowledgments**

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## 1. Introduction

### 1.1. Statement of Purpose

The purpose of this work is to examine the cost trends and the measured electrical productivity of photovoltaic (PV) electricity generation in Nova Scotia, developments in PV technology, and incentive programs in various jurisdictions in the world, with a view to exploring the potential to deploy more PV in Nova Scotia. This report is intended to contribute to an informed discussion about whether and how to promote greater deployment of PV in Nova Scotia. In this work we consider the following elements as they apply to this discussion in Nova Scotia:

- Measured solar electricity productivity in Nova Scotia
- Timing of the solar resource with respect to electricity demand in Nova Scotia
- Prices, trends and projections for PV electricity generation in various Europe, Canada and Nova Scotia
- Trends in feed-in tariff rates and other PV promotion programs in various jurisdictions in Europe and North America
- Available and developing solar energy technologies
- The relationship between development of the PV industry and the solar thermal industry in Nova Scotia.

### 1.2. Background

Photovoltaic electricity systems create electricity directly from sunlight absorbed by semiconductor materials. The use of PV as an electricity supply source is rapidly growing, both globally and in Canada<sup>1,2</sup>.

PV produces electricity from renewable solar radiation with no emissions of pollutants to air or water while in operation. When the emissions from the manufacturing, installation and maintenance of a PV system are included, the total life-cycle emissions of greenhouse gases and air pollutants per kilowatt-hour produced are very low in comparison with fossil-fuel fired electricity generation. Total life-cycle emissions of greenhouse gases from PV are estimated to be between 25 and 50 grams of CO<sub>2</sub>-equivalent per kilowatt-hour (gCO<sub>2eq</sub>/kWh)<sup>3</sup>, compared with about 900 to 1100 gCO<sub>2eq</sub>/kWh for coal-fired electricity<sup>4</sup>.

Because PV generators are modular, scalable, have no moving parts, and generate no noise or emissions when in use, they are well-suited to being installed in a wide variety of locations throughout a region. PV is effective anywhere in Nova Scotia that has sky exposure to the south and that is not subject to shading. Suitable installation sites include rooftops, walls, on ground mounts and over other compatible infrastructure such as car parking lots. A diversity of PV installations could create a distributed pattern of renewable energy generation and potentially reduce the need for transmission upgrades if they are installed near the points of consumption of the electricity they generate.

The Department of Energy is reviewing the state of solar energy in Nova Scotia to examine its potential in the province. Deploying more solar energy could have a variety of social and environmental benefits in terms of renewability, greenhouse gas emission reduction, diversity and

distribution of electricity generation, economic development and community participation. At the same time, since PV-generated electricity is, at present, more expensive in many markets than fossil-fuel-fired electricity, hydroelectricity or wind power, it is important to consider the costs and benefits as well as the appropriate means of developing PV in the Nova Scotia context. Solar PV is also only one of several ways to harvest the solar energy resource, so we will also consider the relationship between solar PV and other solar technologies.

At present in Nova Scotia, solar energy implementation is supported by government and other public agencies through rebates and zero-interest loans for solar water and air heating systems from Efficiency Nova Scotia. There are at present no programs or incentives in place to specifically promote the installation and use of solar PV in Nova Scotia. Solar PV systems currently qualify for the Nova Scotia Power Enhanced Net Metering Program<sup>5</sup>, which offers Nova Scotia Power Inc. (NSPI) customers credit at the retail electricity rate for renewable electricity that they generate on-site.

Another form of renewable energy program, the Nova Scotia Community Feed-In Tariff Program (COMFIT) has been open for applications since September 19, 2011, and has generated considerable interest and numerous renewable energy project applications. The COMFIT offers pre-determined rates for renewable energy generated by eligible facilities owned by eligible entities. The eligible entities are municipalities, First Nations, Community Economic Development Investment Funds (CEDIFs), co-operatives and non-profit organizations<sup>6</sup>. The COMFIT program is currently undergoing its scheduled review, to determine whether any adjustments should be made.

The COMFIT program currently offers tariffs for the following technologies:

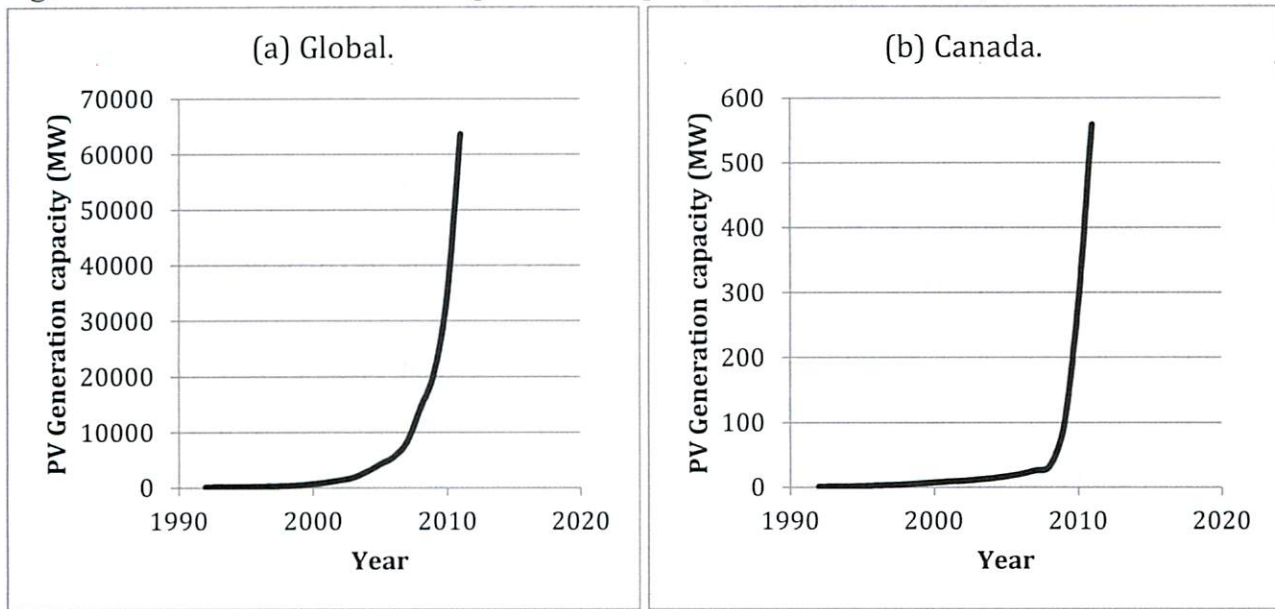
- Small-scale wind energy generators (50kW or less)
- Large-scale wind energy generators (greater than 50kW)
- Small hydroelectric projects
- Biomass Combined Heat and Power projects
- Tidal Electricity projects

Solar energy is not currently included in the COMFIT program. Interest has been expressed by several stakeholders in the idea of expanding the COMFIT program to include solar energy. We include in this report an estimate of the cost of that option.

### **1.3. Growth of Solar PV Generation**

Worldwide, the installed generating capacity of PV is growing quickly. Cumulative installed global PV generating capacity has demonstrated growth rates averaging more than 60% per year for the past 5 years.<sup>7</sup> In Canada over the same period the growth rate of installed PV generation capacity has averaged over 100% per year, including a near tripling in 2009 and more than doubling in 2010.<sup>8</sup> Graphs of the cumulative installed megawatts (MW) of PV generation capacity worldwide and in Canada since 1992 are shown in Figure 1 below.

**Figure 1:** Cumulative installed PV generation capacity (MW), (a) Global, (b) in Canada.<sup>9</sup>



PV generation is used in both on-grid (grid-connected) and off-grid applications. Off-grid PV is typically used where a grid connection is unavailable or is too far away to be cost-effective. The fastest current growth, both globally and in Canada, is in grid-connected systems, although off-grid PV capacity is increasing steadily as well.<sup>10</sup> The vast majority of the growth in Canada is due to the implementation of the Ontario Green Energy and Economy Act, which established favourable feed-in tariff rates to incentivize the solar PV industry in Ontario.

In Nova Scotia, as of December 2012 there are about 50 grid-connected solar PV arrays with a total capacity of less than 0.2 Megawatts (MW)<sup>11</sup>. Solar PV is eligible for the Enhanced Net Metering Program of Nova Scotia Power, in which credit is paid at the retail electricity rate for surplus electricity generated.<sup>12</sup>

#### 1.4. Strengths and Weaknesses of Solar PV in the Nova Scotia Context

The Nova Scotia government has adopted ambitious greenhouse gas reduction targets<sup>13</sup> and renewable electricity targets for 2015 and 2020.<sup>14</sup> Significant progress has been made so far towards meeting these goals through energy efficiency and the deployment of wind energy. Moving forward, solar PV could add a new source to the diversity of renewable electricity supply in Nova Scotia.

**Table 1:** Some strengths and weaknesses of solar PV in the Nova Scotia context.

Strength	Weakness
The price of solar PV is falling rapidly on the global market.	As of 2012, solar PV still has a higher price than several other forms of renewable electricity and energy efficiency.

Solar PV can be widely deployed in a distributed pattern near electrical loads, including in urban areas where wind energy would not be suitable.	Nova Scotia has existing electricity system assets built around a different paradigm – large centralized generation and long-distance transmission.
Solar PV generates in the daytime, when demand is relatively high. PV will not cause surplus generation during conditions of minimum nighttime load.	Solar PV output is higher in the summer months than in the winter months, while highest peak electricity demand in Nova Scotia comes in the winter months.
Solar PV is feasible for property owners to install at their properties all over the province, thus allowing greater participation in and support for renewable energy generation.	The existing solar industry in Nova Scotia has strength in solar thermal systems, which homeowners can also install. Too ambitious a program in solar PV could risk moving business away from solar thermal.
Community economic development and jobs would be created in the solar PV system design, installation, monitoring and maintenance.	Nova Scotian industries currently do not manufacture solar PV equipment or systems.

## 2. Solar Energy Technologies

Unless otherwise indicated, information in section 2 is from the International Renewable Energy Agency.<sup>15</sup>

### 2.1. First Generation PV - Crystalline Photovoltaics (cSi-PV)

Crystalline solar cells (cSi-PV) are the most prevalent form of PV on the world market today, accounting for about 87% of the market in 2010.<sup>16</sup> Formed from wafers of silicon semiconductor, cSi-PV modules that are commercially available typically have a solar energy conversion efficiency of between 14 and 19%.



Crystalline solar PV is a relatively mature technology that has undergone a major increase in the scale of manufacturing. For example, one of the largest manufacturers of PV modules in the world, Canadian Solar Inc., is capable of manufacturing more than 1000 megawatts of cSi-PV modules annually at its production facilities in China.<sup>17</sup>

During 2012 there was an over-capacity of global production of PV modules, including cSi-PV, and prices on the world market were at all-time lows. While this is encouraging continued growth in sales and installations, it is also causing a shakedown and consolidation of the PV production industry. A comprehensive market analysis predicts that overcapacity, low prices and consolidation of PV manufacturing will continue through 2014.<sup>18</sup>

## 2.2. Second Generation PV - Thin Film Photovoltaics (thin-PV)

Thin-film solar cells are made from thin layers of semiconductor successively deposited on a substrate such as glass, plastic or metal. Thin-PV requires much less semiconductor material than crystalline PV, and as such has the potential for lower material and manufacturing costs. These lower costs are partly offset by a generally lower efficiency of solar energy collection.



Another advantage of thin-PV is that the material is more flexible and can therefore be coated onto a variety of curved or oddly-shaped surfaces, facilitating the development of building-integrated photovoltaics (BIPV). Its light weight also allows for innovative applications such as on clothing and backpacks for charging portable electronic equipment.

The three main types of commercially-available thin-film solar modules are:

- Amorphous silicon;
- Cadmium Telluride; and,
- Copper-Indium-Selenide and Copper-Indium-Gallium-Diselenide

**Table 2:** Summary of features of thin film PV types.<sup>19</sup>

Thin film type	Efficiency	Notable features
Amorphous thin film	4 to 8% (12% in lab)	Most common type of thin film product on the market.
Multi-junction amorphous	14 to 15%	Extra junctions absorb more red and infrared light.
Cadmium telluride	15 to 16%	Low production costs, but cadmium is toxic and tellurium is not highly abundant.
Copper-indium-selenium Copper-indium-gallium-selenium	7 to 16% (20% in lab)	Highest efficiency in thin film, in laboratory tests.

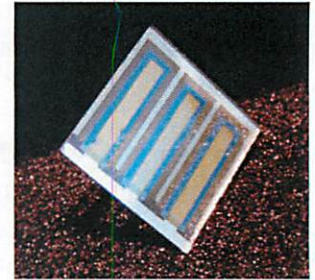
## 2.3. Third Generation PV – Organic PV, Concentrating PV and other novel PV technologies.

Much work is being undertaken in research institutions and companies around the world to develop new ways of generating electricity with photovoltaic materials, including work now happening at Dalhousie University in Halifax. Dr. Ian Hill of the Department of Physics and Dr. Gregory Welch of the Department of Chemistry, both at Dalhousie University, conduct research into organic photovoltaic materials, one of the types of “third generation PV”.

### 2.3.1. Organic PV

Organic solar cells are composed of polymers and/or smaller organic (carbon-containing) molecules. They have considerable potential to provide low-cost PV materials that are light-weight, thin and flexible, using primarily materials such as carbon that are very abundant and readily available. By adapting commonly available ink printing technologies, some kinds of flexible organic PV cells can be produced quickly and cheaply.

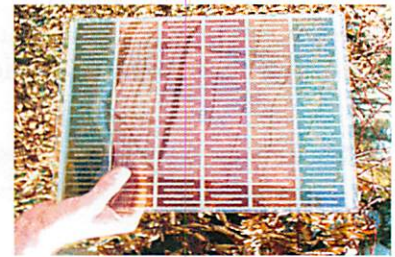
The current disadvantages of organic solar cells are their relatively low efficiencies (4 to 5% commercially and 6 to 8% in the lab), as well as the relative instability of the products. The performance and integrity of organic PV material decreases rapidly with time when exposed to sunlight. Researchers at the Massachusetts Institute of Technology have been working on an organic PV solution that mimics plants by “healing” itself after sun exposure.<sup>20</sup>



### 2.3.2 Dye-Sensitized Solar Cells

Dye-sensitized solar cells (DSSC) contain a photo-sensitized anode (for example titanium dioxide coated with a light-sensitive pigment), in contact with an electrolyte. The process mimics photosynthesis in plants. Its advantages are in the low cost of the materials and simplicity of manufacture.

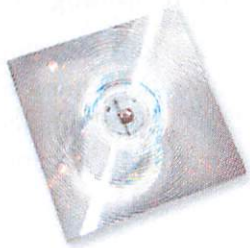
Currently available commercial DSSCs have relatively low efficiencies (4 to 5%), and a tendency to degrade with time in UV light. Laboratory demonstration cells have reached an efficiency of 12%. Research is continuing, with thousands of dyes and anodes tested to find those capable of absorbing a greater portion of the solar spectrum and thus increasing efficiency.



### 2.3.3. Concentrating PV

The idea behind concentrating PV is that if the solar energy from a large area can be concentrated onto a small area of PV material, the cost of PV electricity production will be lower. This idea is based on the fact that highly-efficient, multi-junction PV material is expensive, while the materials needed to concentrate light, such as mirrors or plastic fresnel lenses, are less expensive.

Concentrating PV also has the potential to reach higher efficiencies. By using the highest-efficiency triple-junction PV cells currently available, made from combinations of germanium, indium, gallium, arsenic and phosphorous, the efficiency of concentrating solar cells could theoretically reach 59%. In practice, commercial products currently available are in the range of 20 to 25% efficiency, and laboratory cells have reached 40%.



A Canadian example of technology development in concentrating PV is Morgan Solar, which has developed the Sun Simba collector.<sup>21</sup> The cells in this collector consist of acrylic light guide solar optics, which guide the incident light to a multi-junction PV wafer located at the centre of the cell. They claim that modules made from these cells will produce electricity at efficiencies comparable to crystalline modules widely available on the market today, but at lower cost.

An important characteristic of concentrating PV, and all concentrating solar technologies, is that its performance is strongly direction-dependent. The optical mechanisms that concentrate the light energy can accept sunlight from a specific direction only, not indirect or scattered sunlight. This has two implications: (1) The arrays must be mounted on two-axis trackers to point at the sun at all hours of operation, and; (2) their performance will be higher in regions with more days of clear, sunny sky, because they cannot use the indirect light scattered by clouds and particles in the air.

The type of solar radiation that concentrating PV depends on is called direct normal incident (DNI) radiation. As may be expected, global maps of DNI indicate that this solar resource is particularly abundant in arid, desert regions of the world, where cloud cover is infrequent.<sup>22</sup> Concentrating PV will of course work in Nova Scotia, but its relative advantages are not as pronounced in Nova Scotia as they would be in regions with less frequent cloud cover, such as southern Saskatchewan.

### 2.3.4. Solar Combined Heat and Power

A variant of concentrated solar power, solar combined heat and power technology produces PV electricity and hot water simultaneously. This is an ingenious adaptation to the fact that multi-junction solar cells subjected to solar radiation concentrated to hundreds or thousands of times its ordinary intensity must be cooled to avoid being damaged by high temperatures. The cooling fluid, circulated behind the PV cells, becomes hot and can be used to heat service water and buildings. By combining electricity and useful heat output, the overall efficiency of this system is higher than for PV alone.

Pictured at right is a prototype solar combined heat and power unit being developed at Menova Energy in Ottawa in 2008, photographed by one of the authors. This technology has since evolved significantly and migrated to California.

There is a Nova Scotia company in Amherst named Solartron, which has a solar thermal concentrator in the parabolic dish shape, as shown in the lower photo at right. Solartron is currently working on a combined heat and power unit.



### 2.4. Concentrating solar thermal electricity



Although not technically considered a photovoltaic system, concentrating solar thermal electricity is another method of producing electricity from the sun. This category includes solar troughs, dishes, and power towers. Nova Scotia's own Prometheus dual-stage concentrator, which was developed at the Lunenburg Foundry, could potentially be used to generate solar thermal electricity.

The basic principle of solar thermal electricity is that sunlight, when concentrated from a great area onto a small collection surface, can heat that surface to many hundreds or



even several thousand degrees Celsius. This heat is collected by a fluid, typically a mineral oil capable of being heated to high temperatures, which is then used in a heat exchanger to produce steam to run a turbine that propels a rotary generator to produce electricity.

Solar thermal electricity has some interesting advantages. It can attain electrical generation efficiencies approaching those of other thermal electricity generating stations, on the order of 30%. The overall efficiency can be even higher through combined heat and power if there is a nearby use for the expelled heat from the steam

condenser, such as to heat water or buildings near the generator. Another intriguing possibility, now being demonstrated at several sites in the world, is the ability to store the heated fluid in an insulated container for use during brief cloudy periods and after sunset, thus extending the hours of predictable operation.

Like all concentrating technologies, solar thermal electricity requires dual-axis tracking to ensure that the reflectors to concentrate the sunlight are pointed at the sun. It also depends only on direct normal incident radiation, and therefore has higher performance in regions with less frequent episodes of cloud cover.

## 2.5. Solar thermal

Solar heating, also referred to as solar thermal, is at present the most widely used solar energy harvesting technique in Nova Scotia. This category refers to solar energy systems that do not produce electricity, but rather collect heat directly for various applications, including:

- **Heating domestic and service hot water:** For residential homes, institutions and industries that require hot water, solar water heaters are an effective way to collect a significant fraction of the energy needed to heat water.
- **Heating ventilation air:** Cost-effective systems are installed on institutional, industrial and residential buildings around the world to pre-heat the fresh air being drawn in for ventilation.
- **Heat for buildings:** Passive designs and active systems that collect heat from the sun to supply a portion of the space heating load for buildings are readily available in Nova Scotia.
- **Cooling for buildings:** Heat from solar collectors can be used as the energy supply to absorption chillers that provide cooling for buildings.

As the purpose of this document relates to solar electricity, we will not cover the topic of solar thermal in detail. It is relevant to the discussion of solar PV because solar thermal is a pre-existing solar energy industry in Nova Scotia that offers numerous products and benefits to our province. The solar thermal and solar PV industries relate to each other directly in several ways.

A clear example of a relationship between solar thermal and solar PV is the fact that a solar water heater, when it displaces electricity that would otherwise have been consumed by an electric water heater, is effectively serving a similar function as a solar PV array, namely the reduction of demand

on the electricity grid. The greenhouse gas emission reductions associated with a solar water heater are significant.

Solar thermal systems tend to have higher collection efficiency than PV, on an annual average, because they can absorb a broader portion of the solar spectrum. For a residential household, installing a solar water heater will typically displace more electricity than would be generated by a solar PV array of the same collection surface area. A comparison between a solar water heater and a solar PV array for a household application is shown in Table 3 below. For this comparison we assume that the solar water heater is displacing electricity consumption in an electric back-up water heater. Production data are from RETScreen<sup>23</sup>, and the cost for the solar water heater is estimated from experience in the industry. Costs for solar PV systems are discussed in Section 4.

**Table 3:** Comparison of a solar water heater and PV array for household use in Nova Scotia

	Solar Water Heater	Solar PV System
Usable energy delivered per year	2500 kWh	2500 kWh
Annual GHG emissions avoided <sup>24</sup>	2125 kg	2125 kg
Peak output capacity	3.89 kW	2.27 kW
Collector surface area	5.9 m <sup>2</sup>	14.2 m <sup>2</sup>
Approximate initial capital cost	\$7000	\$10,000
Energy delivered per collector area per year	422 kWh/m <sup>2</sup>	176 kWh/m <sup>2</sup>

In principle, there is no reason a household could not invest in both a solar water heater and a photovoltaic array. Indeed, the two net-zero demonstration homes completed in Nova Scotia in 2011 have both these systems installed<sup>25</sup>. Under the most common circumstances, the upper limit on the size of the solar water heater for a family home is a two-collector system that provides about 60% of the family's annual hot water energy consumption unless an unusually large thermal storage capacity is employed. The upper limit on a solar PV array is either the limit established in the interconnection agreement with Nova Scotia Power or the amount of suitable area available for PV collectors on the property, whichever is less.

In practice, experience in Ontario demonstrates that if there is only a significant incentive for solar PV and no corresponding incentive for solar thermal, the solar thermal industry can suffer a downturn as solar PV receives more exposure.<sup>26,27</sup> The need to treat the solar thermal and solar PV industries equitably has been emphasized by several stakeholders (see section 8 on stakeholder engagement).

### 3. Solar Resource Productivity in Nova Scotia

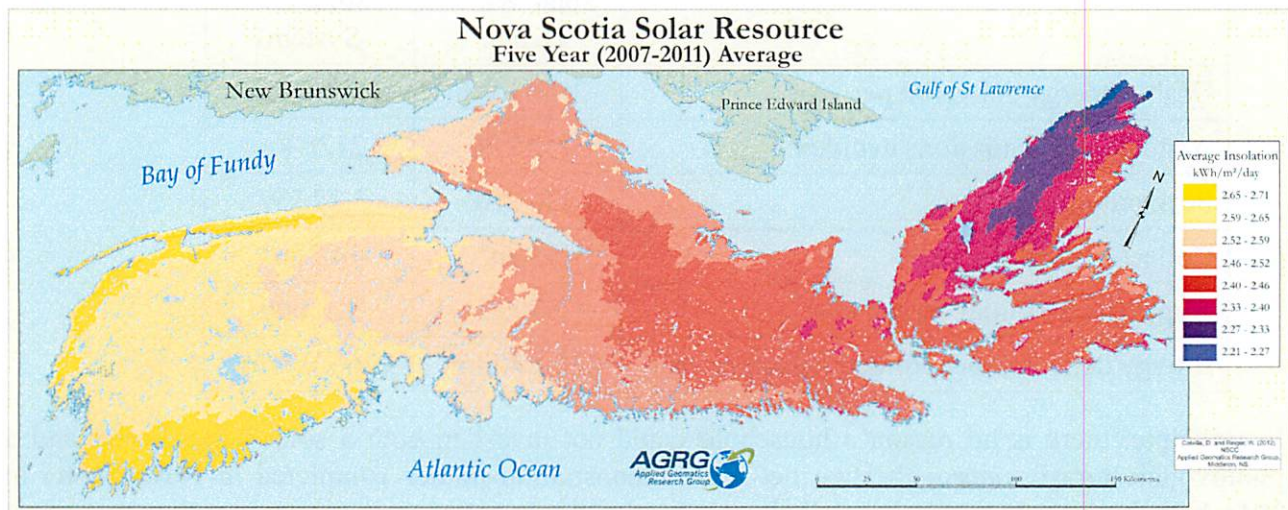
#### 3.1. Modelled solar resource productivity

The approximate incident solar radiation in Nova Scotia has been mapped at coarse resolution by Natural Resources Canada (NRCAN), based on irradiance data and modelling. This interactive map, available online, allows the user to estimate the solar resource potential for broad regions of

Canada on annual average and for each month of the year, for a suite of six different collector tilt angle configurations.<sup>28</sup> The map represents an approximation of the solar resource that is sufficiently precise for general estimates over large regions. Over the course of a month or a year, solar radiation generally varies less from one site to another in Nova Scotia than wind energy does, provided both sites have clear exposure to the sky and are not shaded by nearby objects. Therefore, a broad-scale map can give a reasonable estimate of the solar resource available in Nova Scotia.

Green Power Labs has developed a higher-resolution solar resource map of Nova Scotia<sup>29</sup>, which is more precise for specific site assessments. This high-resolution map shows generally similar, though on average slightly higher solar radiation levels to the NRCan map. The Nova Scotia Community College (NSCC) has also prepared a high-resolution insolation map of the province, based on 5-year averages from 2007 to 2011 (see Figure 2 below).

**Figure 2: Nova Scotia Solar Resource Map<sup>30</sup>**



While the colours of the map are dramatic, it is important to note that the variation in the solar resource from one end of Nova Scotia to the other is actually relatively small as a proportion of the average insolation. The range from dark blue in Cape Breton to bright yellow on the South Shore is from 2.21 to 2.71 kWh/m<sup>2</sup>/day, which means the range from the median value is only +/- 10%. The solar resource exhibits much less geographic variability than the wind energy resource, which can vary by a factor of nearly 600% from one location in the province to another<sup>31</sup>. The solar map effectively means that all areas in Nova Scotia have similar suitability for solar PV, provided there are no objects in the local area that would cast shadows on a proposed solar array.

According to the NRCan map, for a fixed collector surface oriented to the south and tilted up from the horizontal at the angle of the latitude (around 45 degrees), which is the most likely configuration for installed systems, the range of annual average incident solar radiation in Nova Scotia is between 2.5 and 3.3 kWh per square metre per day (kWh m<sup>-2</sup> d<sup>-1</sup>). The map from Green Power Labs shows a slightly higher range of irradiance levels between 3.3 and 3.6 kWh m<sup>-2</sup> d<sup>-1</sup>. The map from NSCC shows a lower average, but this is because the values are for horizontal surfaces, which receive less solar radiation at our latitude than a typical tilted solar array would receive.

For the purposes of this report we will use the irradiance levels from Green Power Labs, from 3.3 to 3.6 kWh m<sup>-2</sup> d<sup>-1</sup>. These figures are for collectors facing near solar south and inclined 45 degrees from horizontal, and they include direct normal incident radiation and scattered incident radiation.

To estimate the output from a solar PV system, the system efficiency and the surface area are multiplied by the incident energy and the number of days operating in a year. System efficiency consists of module efficiency (typically between 12 and 15% for common monocrystalline PV cells)<sup>32</sup>, times inverter/balance of system efficiency (typically around 90%), for an overall efficiency between 10 and 13%. A case study of system performance in Ireland under real conditions showed an overall system efficiency of 12.6%<sup>33</sup>, which is in the range of predicted efficiencies. For this report we will use 13% as our standard overall PV system efficiency.

Based on the above figures, we estimate that a PV system of 13% efficiency in Nova Scotia will produce an amount of electricity in the range of 156 to 166 kWh per square metre of PV panels per year (kWh m<sup>-2</sup> y<sup>-1</sup>). The size of a PV system is usually identified in terms of generation capacity (kW<sub>p</sub>), which is the output of the PV panels under standard test conditions of 1000 W m<sup>-2</sup> incident radiation at a temperature of 25°C.<sup>34</sup> For a typical monocrystalline PV module on the market, one square metre of module represents about 160 W of capacity.<sup>35 36</sup> Using these figures and the range of output per square metre, we estimate that a PV system in Nova Scotia will produce annually in the range of 975 to 1037 kWh of electricity per installed kW of capacity, with the middle of the range being about 1006 kWh y<sup>-1</sup>. The production of any particular system will depend on its actual location, tilt angle and any obstructions that may shade the collectors.

*Modelled annual PV electricity output in Nova Scotia: 975 to 1006 kWh/kW<sub>p</sub> installed capacity.*

For comparison, the NRCan Atlas of PV potential rates Nova Scotia with between 900 and 1200 kWh/kW<sub>p</sub>, with the bulk of the province in the range of 1000 to 1100 kWh/kW<sub>p</sub>.

### 3.2. Measured solar electricity production in Nova Scotia

From Solar Nova Scotia members we have obtained access to measured production data from three grid-connected PV systems operating in Nova Scotia<sup>37</sup>. These systems are monitored automatically on a continuous basis and their performance data are available to their system owners and operators online in real time. The data shows daily, monthly and annual electricity production.

**Table 4:** Measured electricity production from grid-connected PV arrays in Nova Scotia.

System Location	Rated System Capacity (kW)	1-year production beginning Oct 2011 (kWh)	kWh/kW <sub>p</sub> (annual)
Antigonish County	8.28	9409	1136
Richmond County	5.06	5917	1169
Cape Breton Regional Municipality	6.90	7619	1104
AVERAGE			1137

*Measured annual PV electricity output: 1100 to 1140 kWh/kW<sub>p</sub> installed capacity.*

The measured production, averaging 1137 kWh per installed kW<sub>p</sub> of capacity, is higher than the modelled range of 640 to 1037 kWh/kW<sub>p</sub>. The measured data represent a small sample at a few locations that do not cover the area of the province. The sample size is not large enough to determine a statistically valid average of real production for the province. Also, the sample systems are all using the same inverter technologically and don't represent a variety of inverter types.

However, the incident radiation is one of the significant variable factors, and the reported sites are not unusually sunny. They are located in mid-range solar insolation regions of Nova Scotia, according to the various solar maps mentioned previously. The variation in annual solar radiation across Nova Scotia is about +/- 4.5%. Therefore, as an estimate of average solar PV productivity for Nova Scotia, we will consider average annual production of 1100 +/- 50 kWh/kW<sub>p</sub> as achievable in our province.

*Estimated solar PV productivity for Nova Scotia: 1100 +/- 50 kWh/kW<sub>p</sub> installed capacity.*

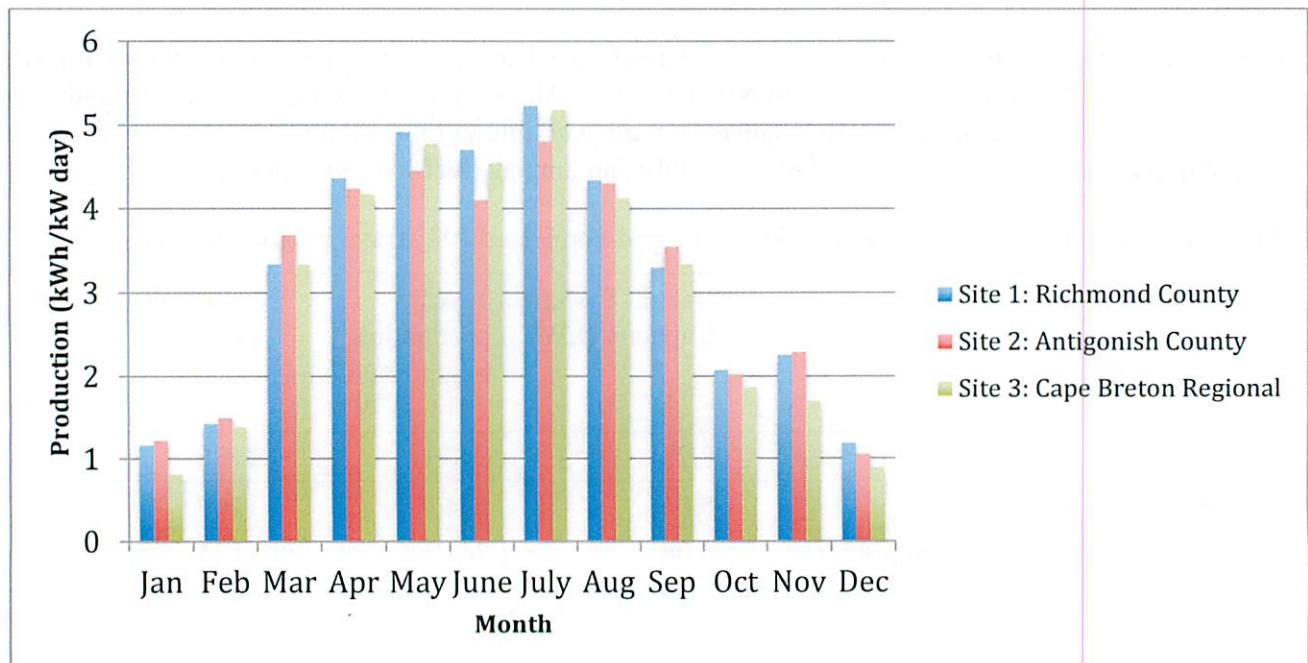
By comparison, Toronto, Ontario rates about 1160 kWh/kW<sub>p</sub>, Los Angeles, California about 1485 kWh/kW<sub>p</sub>, and Berlin, Germany, about 850 kWh/kW<sub>p</sub>.<sup>38</sup>

### 3.3. Timing of production and electrical demand

#### 3.3.1. Seasonal variation (monthly)

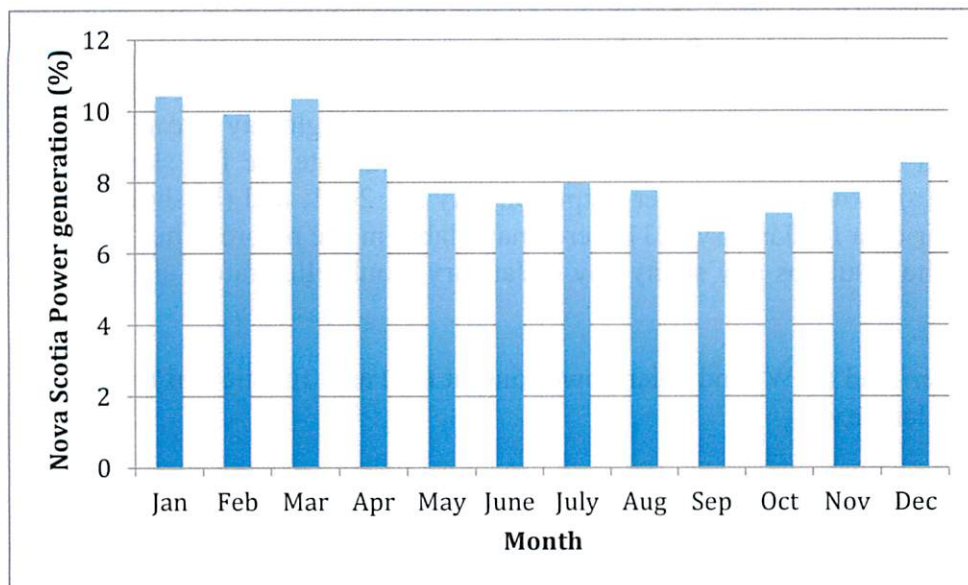
On the timescale of months, incident solar radiation varies fairly consistently in Nova Scotia, with a curve that follows from the angles of the sun and length of day. This variation in solar radiation is observable in the measured output of PV systems, as shown in Figure 3 below.

**Figure 3:** Monthly measured output of three PV systems in Nova Scotia (2011/2012)



The monthly production of solar energy can be compared with the monthly total generation on the Nova Scotia Power system, as reported in the Open Access Same-time Information System (OASIS) – see Figure 4.

**Figure 4:** Monthly total electricity generation by Nova Scotia Power in 2011.<sup>39</sup>



It can be seen from Figures 3 and 4 that on a monthly basis the variations in solar electricity generation and total electricity generation were not well correlated in Nova Scotia in 2011. Neither were they consistently anti-correlated. The very low months for solar electricity output were December, January and February. Of these months, January and February were two of the three highest months for total electricity generation. By March, the second-highest month for total electricity generation, solar output had tripled, reflecting the longer sunshine days of impending springtime.

The period from May to August yielded high solar electricity output, while total load decreased through April, May and June and then increased to a small summer peak in July and August, presumably due to cooling demand. September was the lowest month for total load. October and November saw gradually rising load and decreasing solar output as the days shortened.

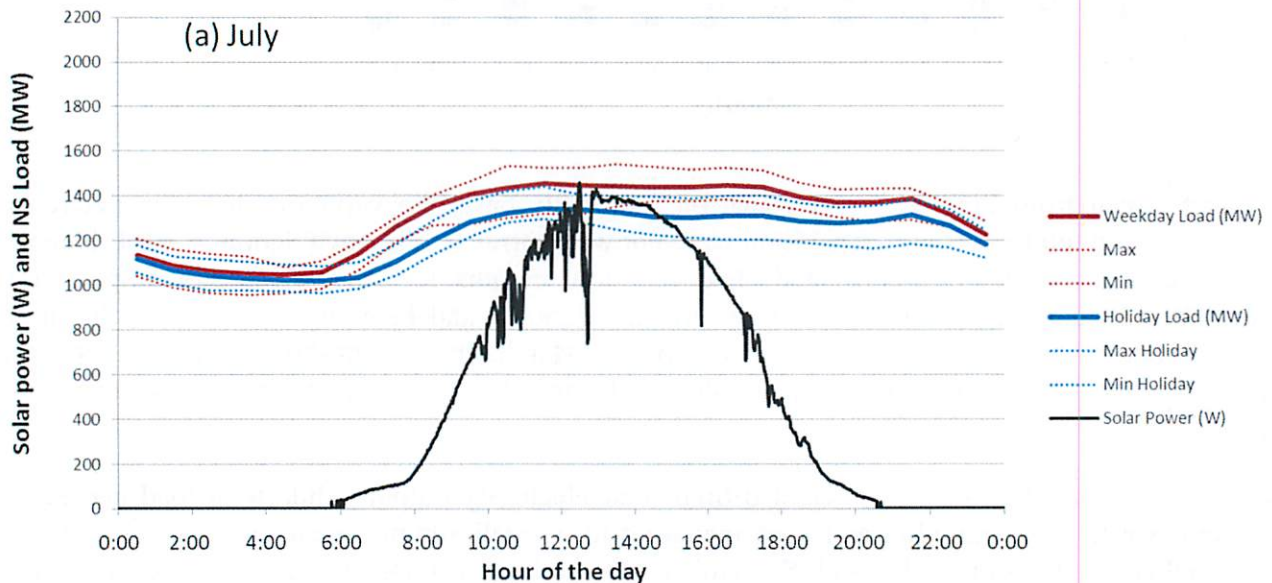
The effect of the lack of monthly correlation between solar output and total generation is that a given amount of solar capacity will provide a larger portion of the total in the spring, summer and autumn and a lower percentage in winter. When the installed solar capacity is small, this will have no tangible impact on the operation of the system. For example, if 100 MW of solar PV capacity were installed in Nova Scotia, it would produce about 1% of our annual electricity. The percentage supplied in the lowest month (January) would be about 0.3%, while the percentage supplied in the highest month (July) would be about 1.7%.

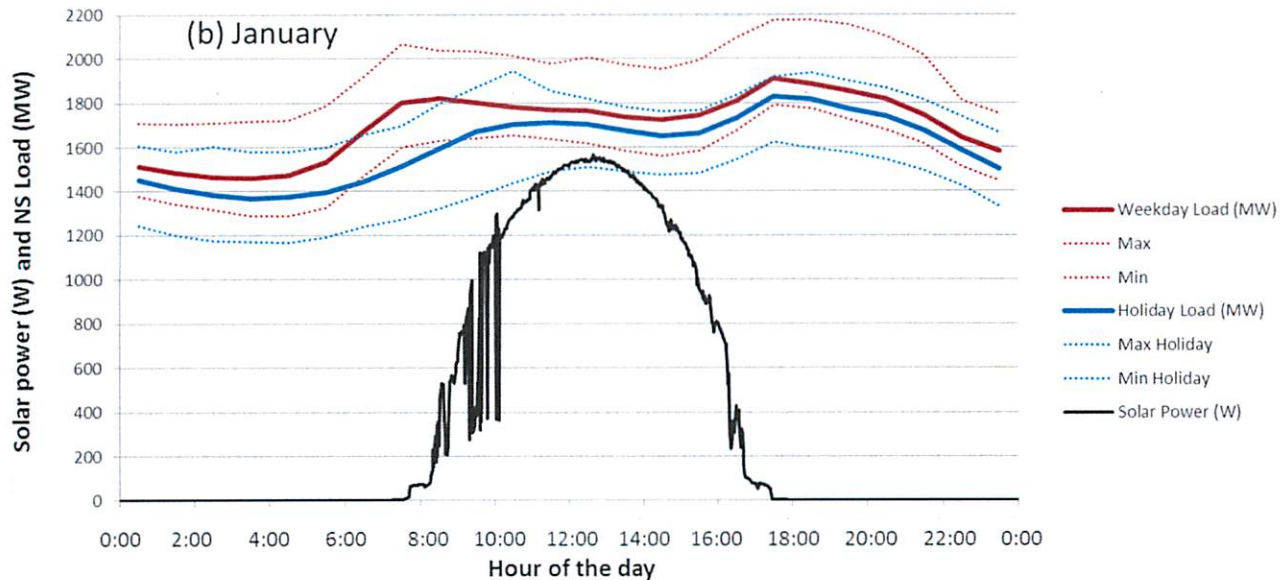
### 3.3.2. Daily variation

The purpose of this section is to compare the production from a solar array to the Nova Scotia electricity demand curve in the course of the day. Solar electricity production, in the absence of an energy storage system, occurs in a direct and nearly instantaneous relationship with the amount of solar radiation available at the generation site at any given moment.

The hourly load characteristics of the Nova Scotia Power grid are shown in Figure 5(a) for July and 5(b) for January, both in 2011.<sup>40</sup> The average, maximum and minimum hourly loads are shown for weekdays (Monday to Friday), and holidays (Saturdays, Sundays and statutory holidays). Figure 5 also shows the measured output of a 1.5 kW PV array at the Nova Scotia Community College (NSCC) Waterfront Campus in Dartmouth, at one minute intervals on a single day in each of those months. We chose data from sunny, high solar production days to illustrate the full shape of the solar output curve. Figure 5(a) shows solar power output on July 20, 2011, and (b) shows output for January 26, 2012, as solar data for January 2011 were unavailable in the record. The difference in the year does not affect the result, as any sunny day in January would illustrate a similar solar profile.

**Figure 5:** Nova Scotia Power load (MW) and solar power output (W) as a function of the hour of the day for; (a) July, and (b) January.





On the sunny July day (a), the morning rise in electricity demand is followed fairly closely by the increase in solar output as the sun rises in the sky. The mid-day peak in electricity demand occurs at a time of high solar output. In the afternoon and on into the evening, as solar output gradually declines, the system power demand stays level until after the sun has set. The observed pattern suggests there is some correlation between solar output and electricity demand. This correlation is strongest for the morning rise. In the evening, electricity demand continues to be high after the solar output has declined.

The downward spikes in solar output represent passing clouds that cast shadows on the array. The downward spikes are often preceded and followed by small upward spikes, as the cloud edge refracts extra radiation onto the collectors. On a day like this, if multiple arrays were installed in various places across a geographic area the size of a city or a municipality, the cloud shadows would cross the separate arrays at different times, leading to a smoother total output curve for multiple arrays than for this example of one array.

On the sunny January day (b), the peak output of the solar array around 13:00 hours is higher than the peak output in July. This is because, (1) the angle of the array is about 45 degrees from the horizontal, resulting in strong production midday in winter due to a direct sun angle, and (2) crystalline photovoltaic cells produce a higher voltage, and therefore more power, at colder temperatures. Despite the high performance around midday, the total electricity generation (the area under the curve) is smaller in January because the effective solar day length is four hours shorter than in July.

Finally, the highest peak load in January occurs around 18:00 hours, after the PV array has ceased production for the day because of sunset. This means that, in the absence of a short-term storage method or time-shifting of the load, PV generation will not be available for the highest peak of the day in winter, which in Nova Scotia is the highest peak of the year. What PV generation will do is contribute to supplying/decreasing the load in the midday hours, primarily between 11:00 and 17:00 hours.

### 3.3.3. Correspondence of photovoltaics with daytime minimum load

Grid-connected solar PV systems most often do not have an integrated storage capacity, and hence their output varies minute-by-minute with the intensity of solar radiation as detailed in 3.3.2 above. Grid-connected solar PV systems therefore represent a variable, non-dispatchable generation source on the grid. Like other variable generation sources, including wind energy, it is important to consider the relationship between distributed PV generation and the load on each substation as well as across the province, if we are considering installing a significant amount of solar PV capacity.

For non-dispatchable variable generators such as wind turbines and PV systems, the approach to coping with variability thus far in Nova Scotia, particularly with respect to connection of generators to the distribution network, has been to limit the total output capacity of variable renewable generators to less than the minimum annual load on the substation to which the generator is connected. This is the general rule in practice for COMFIT projects. The function of this rule is to ensure that all the energy produced by the variable generator is used in its local distribution zone, preventing spill-over of generation through the substation into the transmission network. For COMFIT projects, this rule constitutes a fairly simple and rational method for deciding whether a particular distribution zone can accept another variable generator, such as an additional wind turbine.

If we connect more solar PV generators to distribution lines around the province, the first and simplest assumption would be to apply the same rule, namely that the total of variable generation in the distribution zone should not exceed the minimum annual load. However, there is a fundamental difference between solar PV and other variable renewable generators that is essential to consider, namely that solar PV will only generate in the daytime. A PV system produces at nearly its peak capacity for a period of no more than six hours in the middle of the day, at a time of day when electricity load is observed to be consistently higher than the annual minimum load.

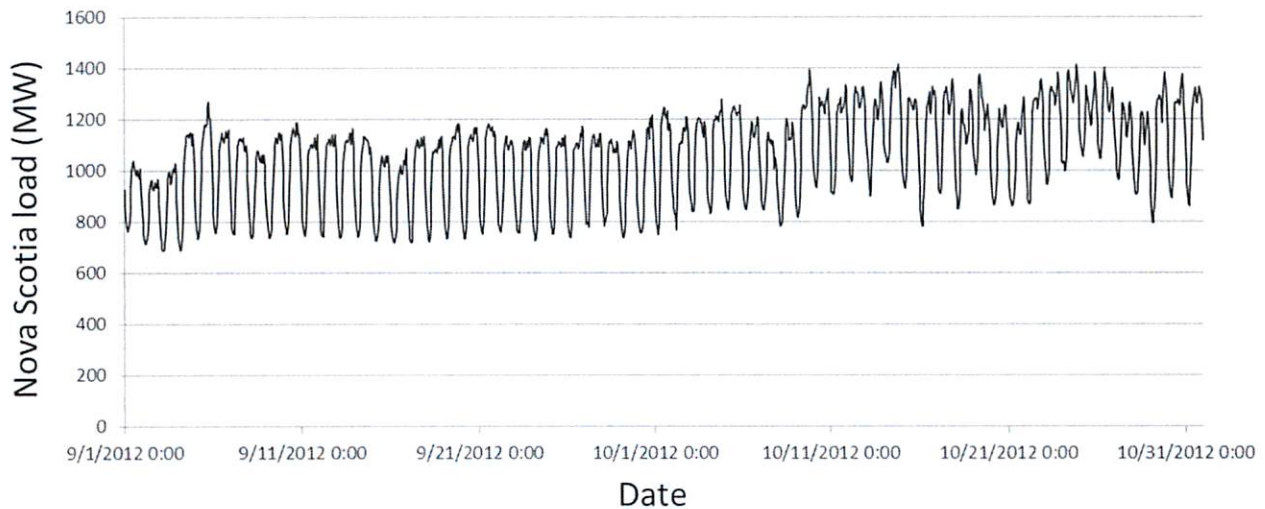
We analysed solar power output data from the NSCC PV system for those months of the year when the minimum load is most likely to occur (September and October) and found that in those periods the peak output from the solar array always happens between 10:00 am and 16:00 hours (100% of the time). Output near peak capacity never occurred outside of those hours in our sample. As this observation is based on the predictable pattern of the sun in the sky, we expect that this will be true of all PV arrays installed in the province, particularly fixed arrays, which do not face the sun early in the morning or late in the afternoon. As the sun angle is similar in

We defined peak power output as a range from 10% below rated capacity to 30% above rated capacity. The output from a PV system can sometimes be higher than the rated capacity. This can be caused by occasional incidents of solar radiation of greater intensity than the standard test conditions of  $1000 \text{ W/m}^2$  due to atmospheric conditions or reflection of light from roofs, water or other surfaces. However the most common cause of elevated power output is a low outdoor temperature, which increases the voltage of solar cells and hence increases power output. In September and October of 2011, the highest peak solar power output from the PV system was 30% above its rated capacity.

The essential question, then, is what is the minimum annual load during the midday period when solar PV could be producing at its peak? This differs from the situation for wind turbines or tidal turbines, which could be generating at night. To answer this question for the Nova Scotia electricity

system as a whole, we analysed load data from the Nova Scotia Power OASIS site for 2010, 2011 and 2012. We found the annual minimum load for all hours of the day and also found the annual minimum load during solar peak hours (10:00 to 16:00 hours) each day. The difference between minimum load and minimum daytime load is illustrated in Figure 6 below. On any given day, and throughout the whole record, the minimum load during the midday period when solar PV may be producing is always higher than the overall minimum load by a significant margin.

**Figure 6:** Nova Scotia electricity system load (MW) as a function of time in Sept/Oct 2012.



In Table 5 we have extracted from the OASIS data set the minimum overall and minimum daytime load in Nova Scotia for the years 2010, 2011 and 2012.

**Table 5:** Minimum load and minimum daytime load (MW) in Nova Scotia for three years.<sup>41</sup>

<b>Year</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>
Annual minimum load (MW)	1023	741	675
Date of annual minimum load	Dec. 14	Oct. 3	July 1
Time of annual minimum load	03:00	03:00	06:00
Annual <i>daytime</i> minimum load	1360	1040	935
Date of annual minimum daytime load	Dec. 4	Oct. 2	May 20
Time of annual minimum daytime load	15:00	10:00	14:00
<b>Difference (MW)</b>	<b>337</b>	<b>299</b>	<b>260</b>

The conclusion from Table 5 is that the difference between the minimum load and the minimum daytime load has been at least 260 MW in each of the past three years. The implication is that there is room for 200 MW of solar PV power output in Nova Scotia under current conditions without

ever exceeding minimum load, assuming all other variable, non-dispatchable generators are sized below the annual minimum load. This is because PV will only generate in the daytime, which is the time when minimum load is significantly higher. This aspect of the timing of PV generation distinguishes it from either wind energy or tidal energy in our renewable energy mix.

The reason that 260 MW of spare minimum daytime load implies room for 200 MW rather than 260 MW of PV capacity, is that PV systems can routinely produce 30% above their rated capacity under reasonably frequent conditions. Therefore, 200 MW of installed PV capacity could be expected to generate up to 260 MW of solar power at some hours in the year.

The conclusion can be illustrated with a scenario. If in the near future in Nova Scotia we have 500 MW of installed capacity of wind energy, plus 100 MW of capacity of mostly wind energy through the COMFIT program, then there is a possibility of having 600 MW of wind power generated at one time. It is possible, though statistically infrequent, that 600 MW of wind power could be generated at a time when the total load in the province is only around 700 MW. This would result in a very high percentage of wind power on the system for those few hours, which would likely require special grid management to maintain correct voltage and frequency. Managing for this infrequent but possible situation is already a condition of the Nova Scotia electricity system, or will become so in the next few years as the remaining contracted wind energy comes online.

How does this scenario evolve if in addition to the planned wind energy we add 100 MW of solar PV generating capacity to the Nova Scotia electricity system? The maximum power output from solar PV in this scenario could reach 130 MW, but only between the hours of 10:00 am and 16:00, when the minimum load is at least 260 MW higher than the annual minimum, or around 935 MW. It would be very improbable, from a statistical perspective, to encounter an hour when the load is at its annual daytime minimum and both solar PV and wind energy are producing their maximum possible power output. It is beyond the scope of this report to calculate the low statistical frequency of such an event. However, even in this infrequent case, the total combined output from wind and solar power generators in this scenario would be at most 730 MW. This would still be 200 MW below the minimum daytime load, which is the load that matters when considering PV.

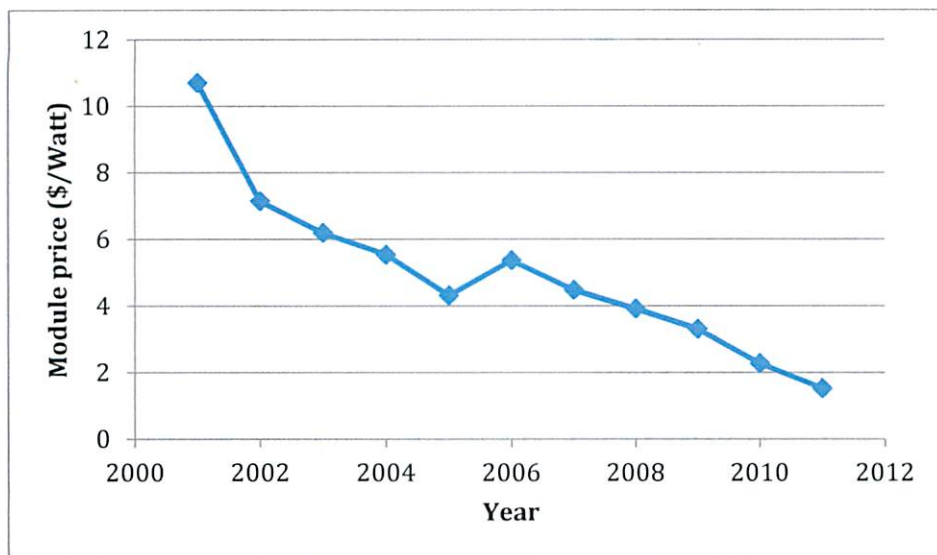
It is also worth noting that installed solar PV capacity of 100 MW would not be added in a single year. Gradual addition of solar PV, starting from less than half a megawatt now, out to a scenario of 100 MW, would take a number of years. It is our estimation that 100 MW of solar PV would integrate well into the Nova Scotia grid of today, for reasons described above. In practice, with an effective incentive program in place to grow the local solar PV industry, it could take three to five years to reach 100 MW of installed PV capacity. During this time, as always, the electricity system will continue to evolve to meet changing conditions. Over time, with advances in smart grid energy management such as PowerShift Atlantic<sup>42</sup>, along with progress in electric vehicles and energy storage technology, the grid of a few years from now will likely be able to accommodate even greater amounts of solar PV and other diverse, renewable sources.

## **4. Prices and costs of solar electricity**

### **4.1. Global cost trends for PV**

Solar PV modules typically account for about 50% of the installed cost of a PV system. The price of solar PV modules decreased significantly between 2001 and 2011, the last year for which annual average data are currently available. Figure 6 shows the trend in module prices in Canada.

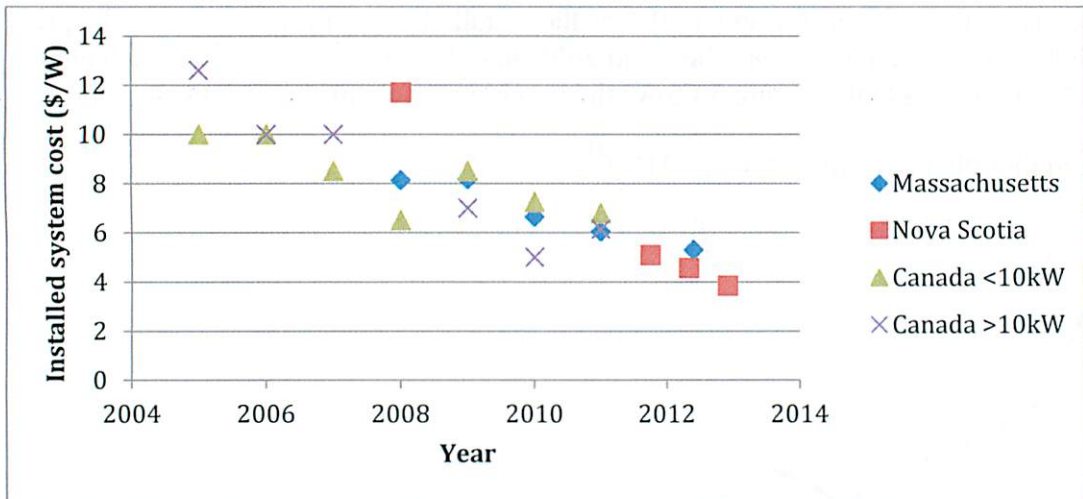
**Figure 6:** Trend in module prices in Canada (CAD\$)<sup>43</sup>



The International Energy Agency (IEA) and the International Renewable Energy Agency (IRENA) have both published global compilations of installed PV system costs. The IEA global report for 2011 states that globally, installed system prices in 2011 averaged US\$3.6/Watt (range 2.6 to 4.4).<sup>44</sup> For the same year, the country report from Canada states turnkey installed system prices of CAD\$6.79/W for systems 10 kW capacity and lower, and \$4.38/W (range 3.50 to 5.27) for systems larger than 10 kW.<sup>45</sup>

The trend in PV system cost for three jurisdictions is shown in Figure 7 below. The prices and the trend are remarkably consistent among the three. The data for Canada is largely influenced by prices in Ontario, as the majority of installations have happened there. The Nova Scotia data is described in greater detail below. The best-fit linear trend in the whole data set is a decrease of \$0.87/W per year.

**Figure 7:** Trend in total installed PV system cost in three jurisdictions.



#### 4.2. Installed costs and trends for PV in Nova Scotia

In response to a request for information to Solar Nova Scotia members, we have received data on actual installed prices of PV systems in Nova Scotia. An example from this data is shown below:

System size (rated capacity)	8.28 kW	
Installation date	September 2011	
Location	Rooftop in Antigonish County	
Total installed cost	\$36,587	(+HST = \$42,075)
Installed total cost per watt	\$4.42/Watt	(+HST = \$5.08/Watt)
PV modules retail price in project	\$2.62/Watt	(+HST = \$3.01/Watt)
PV modules as % of installed cost	59%	

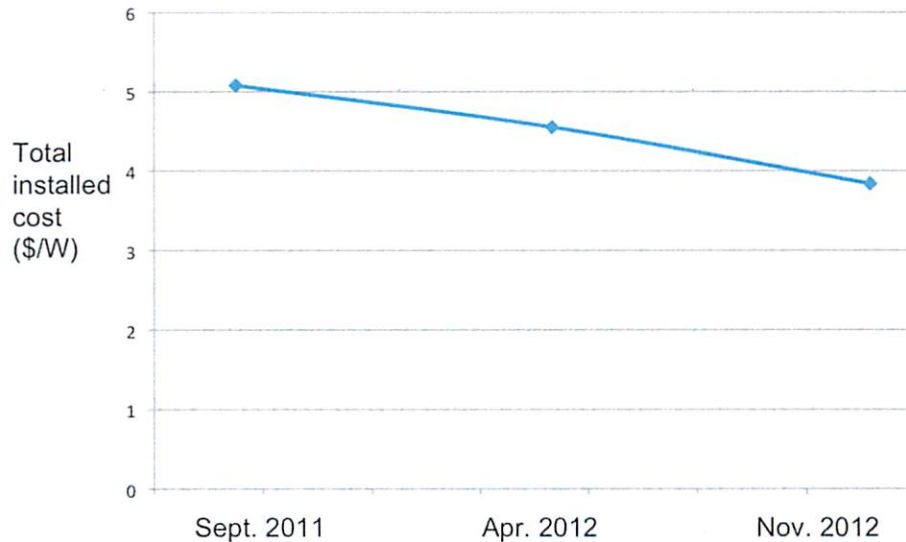
The breakdown of costs for this system is shown in Table 6.

**Table 6:** Cost categories for example PV system installed in Nova Scotia in Sept. 2011.

Modules	Inverters	Roof Mount	Cables & Other	System Monitor	Permits	Labour	Total	HST
59.2%	19.2%	8.9%	4.2%	1.7%	0.8%	6.0%	100.0%	+15.0%

Installers have reported that the cost of PV modules has decreased in 2010, 2011 and again in 2012. The other costs of a system have remained steady. Based on the observed change in module prices, the observed trend in the price of the example system above is shown in Figure 8 below. The trend line represents an average decline of \$1.06 / W per year.

**Figure 8:** Trend in total installed cost in Nova Scotia, including HST:



### 4.3. Estimate of the levelised cost of PV electricity in Nova Scotia

We have created a simple spreadsheet tool to calculate the levelised cost of electricity (LCOE) for PV systems. This tool is available from the authors. We have calculated the LCOE as follows, in the same manner as the International Renewable Energy Agency.<sup>46</sup>

$$LCOE = \frac{\sum_{i=1}^n \frac{I_i + M_i + F_i}{(1+r)^i}}{\sum_{i=1}^n \frac{E_i}{(1+r)^i}}$$

Where:

LCOE = the average lifetime levelised cost of electricity generation;

$I_t$  = investment expenditures in the year  $t$ ;

$M_t$  = operations and maintenance expenditures in the year  $t$ ;

$F_t$  = fuel expenditures in the year  $t$ ;

$E_t$  = electricity generation in the year  $t$ ;

$r$  = discount rate; and

$n$  = economic life of the system.

Using the formula above and the spreadsheet tool, for the example PV system given above, we have estimated the LCOE under the following assumptions:

Installed cost: \$4.50 / W (including HST) – represents mid-year 2012 pricing

Economic life of system: 25 years

Annual decrease in energy output: 1% / year Peter Allen asked if this is accurate – check again

Discount rate: 6%

Maintenance costs: \$50 per year, with 2% inflation

Periodic capital investment: \$500 in years 10, 15 and 20 (replacement of electronics)

Under those assumptions, we estimate the LCOE for this example system to be 35 cents/kWh.

The LCOE is fairly constant under changing assumptions. For example, an installed cost of \$4.00/W instead of \$4.50 brings the LCOE down to 31 cents/kWh. A decrease in the discount rate from 6% to 5% (all other factors unchanged) yields an LCOE of 32 cents/kWh. The range of total installed costs from \$4/W to \$5/W yields a range of 32 to 38 cents/kWh.

*Estimate of levelised cost of PV electricity in Nova Scotia (2012): 35 (31 to 38) cents/kWh*

If we project the observed decline in system of about \$1.06/W per year into 2013, we project the LCOE for 2013 to be in the following range:

*Estimate of levelised cost of PV electricity in Nova Scotia (2013): 27 (18 to 34) cents/kWh*

**Note 1:** The cost of financing a PV system, such as interest on a loan for the system, has not explicitly been included in this calculation of LCOE, except to the extent that the discount rate implies a return on the investment. The LCOE would be slightly different if an interest-bearing loan were used to purchase the system. To test sensitivity to the financing method, we also calculated the LCOE under a scenario in which the owner of the system made a 10% down payment and financed the rest with a ten-year loan at 5% interest (comparable with interest rates available for a home renovation loan today). With this financing scenario, the LCOE was 34 cents/kWh, comparable with the first scenario in which the owner pays up-front. The reason there is no significant difference in LCOE with loan financing is the effect of the value of spending later instead of spending now, as expressed by the discount rate.

**Note 2:** All the LCOE estimates calculated above represent the cost to the owner of the PV system. They do not include costs external to that owner, except those that are charged directly to the owner, such as interconnection fees. For example, the estimates do not include any system cost that may be incurred by the electric utility to integrate solar PV electricity into the distribution or transmission system. Initially, if solar PV systems are small in scale, distributed geographically near daytime loads on the distribution system, and moderate in number, we believe the integration cost would be insignificant. Distributed PV systems at a modest scale would be evident on the distribution grid only as modest reductions in load during the midday period on sunny days. If much larger numbers of PV systems are installed, and particularly if large PV farms are installed on the transmission network, system integration costs could become a significant factor for consideration.

## **5. Case studies and prices of solar PV feed-in tariffs in other jurisdictions**

### **5.1. Ontario Feed-in Tariff and micro Feed-in Tariff (FIT and microFit)**

The Ontario Government launched the Renewable Energy Standard Offer Program in November 2006. The program offered \$0.42/kWh for solar electricity. Two years later, solar had the second

largest contract capacity at 515 MW, behind wind energy. However by 2008 only 36 MW of that PV capacity had been commissioned.<sup>47</sup> In the following years, a portion of the contracted capacity was built.

In 2009, as a key program of the Green Energy and Economy Act, Ontario launched its renewable energy feed-in tariff with the goal of creating a clean energy manufacturing base, new jobs and cleaner air. The program offered some of the highest rates for solar PV in the world, which were differentiated by project size and whether the project was ground-mounted or roof-mounted (see Table 1 below). The Ontario FIT program is the primary reason for the large increase in photovoltaic installations in Canada since 2009, as shown in Figure 1.

In October 2011, the Ontario Government launched the two-year review of the FIT program with the goal in part to reduce rates to reflect reduced costs. Reporting in March 2012, the Deputy Minister of Energy recommended a reduction in rates of more than 20% for solar, 15% for wind, and no change for the other energy sources. The new Ontario FIT rates for PV in 2012 are also show in Table 7 below.

**Table 7:** Ontario FIT prices for PV, original prices (2009) and new prices (2012).<sup>48</sup>

Fuel	Project Size Tranche	Original FIT Price (c/kwh)	New FIT Price (c/kwh)	% Change from Original FIT Price	
Solar Rooftop	≤ 10 kW	80.2	54.9	-31.5%	
	> 10 ≤ 100 kW*	71.3	54.8	-23.1%	
	> 100 ≤ 500 kW*	<250kw	63.5	53.9	-15.1%
		>250 ≤ 500kw	53.9	48.7	-9.6%
>500 kW	53.9	48.7	-9.6%		
Solar Groundmount	≤ 10 kW	64.2	44.5	-30.7%	
	> 10 kW ≤ 500kW*	44.3	38.8	-12.4%	
	> 500 kW ≤ 5 MW *	44.3	35.0	-21.0%	
		> 5 MW	34.7	34.7	-21.7%

The Ontario FIT rates also have an “adder” (an additional supplementary rate) if the project is partly or wholly owned by a First Nation or a defined community group such as a co-operative. These adders range from 0.5 to 1.5 cents/kWh, with the range depending on the percentage of community or First Nations equity. The adder applies to all FIT categories except rooftop solar.

## 5.2. Feed-in Tariffs in Germany

Germany introduced its current FIT regime in 2000 through the Renewable Energy Sources Act (EEG). The government reviews the rates on a regular basis. The rates have dropped annually and they are now about one third to one quarter of the year 2000 rates. Depending on the size and type of the PV installation, FIT rates for PV in Germany in late 2012 now range from a low of 16.2 CAD cents/kWh for large ground-mounted arrays to 23.4 CAD cents/kWh for small roof-mounted systems.

The program has been successful in kick starting a massive increase in PV capacity in Germany, from 186 MW in 2001 to over 17,000 MW in 2010 and still growing by about 3,000 MW per year. With the large-scale uptake of the program in Germany, the additional charge to electricity rates for all the FIT payments for all eligible renewable electricity generators is estimated to be 4.6 CAD cents/kWh<sup>49</sup>, on an average retail electricity rate of about 31.9 CAD cents/kWh.

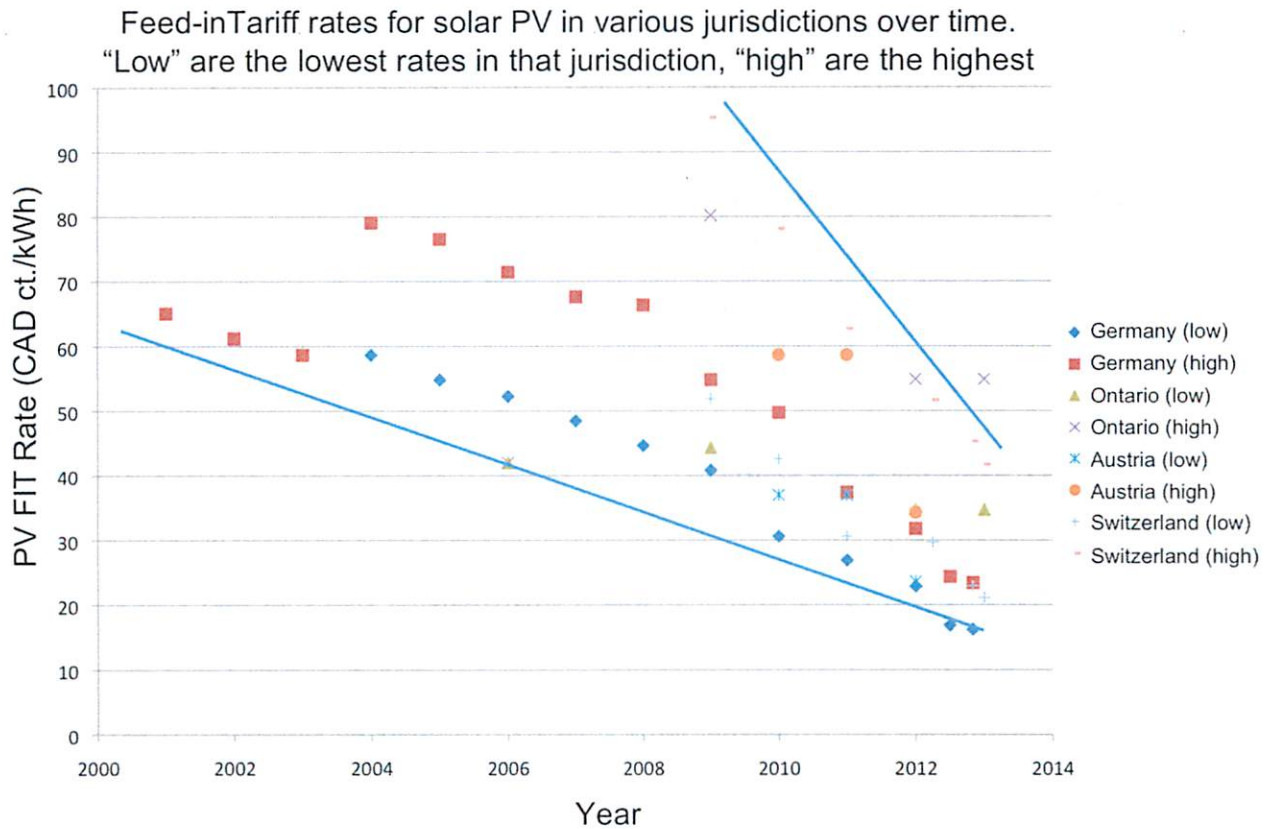
Since 2009 the government offers increasing tariffs if the electricity produced is consumed on site. This is to encourage demand side management and to address the variability of solar energy.

### **5.3. Trends in Feed-in Tariff rates**

Feed-in tariffs are intended to offer higher rates for projects completed in early years and decreasing rates for those installed in later years, as the solar PV industry gains experience in the region and costs decrease. Feed-in tariff rates for PV have been trending downward for the past 3 years in all jurisdictions that we have investigated. Germany provides the best example, where FIT rates for PV have been steadily decreasing since 2004. Several countries, including Germany and Switzerland, have designed their programs with automatic annual or monthly digression rates, specifying the rate of decrease over time. Even so, PV costs have fallen so quickly in 2011 and 2012 that these countries have decreased their FIT rates even faster than originally planned.

Trends in PV FIT rates in a set of jurisdictions in Europe and Canada since 2001 are shown in Figure 9 below. The graph shows the highest and lowest rates in each jurisdiction. The clear downward trend is evident. The general pattern is that a jurisdiction will start an effective FIT program at a relatively high rate, usually higher than in other jurisdictions with longer experience in PV FITs. After a few years gaining experience, the rates tend to fall dramatically and to converge with those of other jurisdictions.

**Figure 9:** Trends in PV FIT rates in one Canadian and three European jurisdictions



Taken together, this set of trends suggests that PV FIT rates in Northern European and Canadian jurisdictions with FIT experience are tending in 2012/2013 towards the range between 17 CAD cents/kWh for large ground-mounted arrays and 45 CAD cents/kWh for small rooftop arrays. Within programs in individual jurisdictions, the difference in FIT rate between large and small systems is decreasing over time.

The data suggest that jurisdictions starting a new FIT program for PV often start with rates approximately equal to what they were 3 to 4 years prior in the most experienced jurisdiction (Germany). By this approximate measure, if Nova Scotia were to add PV to the list of eligible technologies in the COMFIT in 2013, it would be consistent with the trend in the data to choose COMFIT rates in the range that they were in Germany in about 2010, namely from 30 cents/kWh for large ground-mounted installations (>100 kW) to 50 cents/kWh for small roof-mounted installations ( $\leq 10$  kW). At the beginning, to allow time for the local industry to organize, the starting rates could be in effect for 2013 and 2014.

In this scenario, it would also be common practice to have an automatic digression of the tariff in each year, so that the contracted rate for projects to be installed in 2015, 2016 and subsequent years would be lower by an amount pre-determined in the regulations. The slope of the trendline in Germany since 2004, by least-squares regression, is a decrease of about 6.6 CAD cents/year, however since 2008 the slope has been steeper, at about 8.8 cents/year. It would therefore be consistent with this sample of the experiences of other jurisdictions if Nova Scotia were to implement a COMFIT rate ranging between 30 and 50 cents/kWh for contracts signed in 2013/14

and decreasing automatically by about 9 cents/kWh annually in 2015 and 2016. It would be normal practice to expect to change the formula after 2016, based on the market conditions at that time. These rates are summarized in Table 5 below.

**Table 8:** Approximate COMFIT rates (¢/kWh) for PV in Nova Scotia that would correspond with observed patterns in Northern Europe and Ontario.

Size category	Contract Year		
	2013/2014	2015	2016
≤ 10 kW	50	41	32
> 100 kW	30	21	12

## 6. FIT or COMFIT rates for Nova Scotia

### 6.1. Factors in choosing a rate

If the Province of Nova Scotia chooses to set a FIT or COMFIT rate for solar PV, we expect that the Nova Scotia Utility and Review Board would be tasked with ruling on the appropriate rates. It is not our intention to propose or set feed-in tariff rates in this report. However, the purpose of this report includes estimating the cost of incentivizing solar PV. To make an estimate it is necessary to construct a scenario that includes plausible rates. In this section we consider the factors in setting these rates.

In section 4.3 we estimated the levelised cost of electricity (LCOE) from solar PV in Nova Scotia, at mid-2012 module prices, to be in the range of 31 to 38 cents/kWh. This estimate is for a residential roof-top system with a capacity of about 8 kW, which would be in the small category (<10 kW) in most FIT programs. The calculation assumes a discount rate, essentially the return on the owner’s investment, of between 5 and 6%. As module prices have continued to decrease in 2012, the LCOE would be lower for systems commissioned in 2013. If we assume a linear decline, the range in LCOE for a small system (<10 kW) would be 18 to 34 cents/kWh.

In Table 5 we have shown estimates of FIT rates that would correspond with normal observed practice for jurisdictions like Nova Scotia that do not yet have a highly developed solar PV industry. We observe that FIT rates for solar PV are normally higher when they are first introduced in a new jurisdiction than in jurisdictions that have had a solar PV FIT for a long time.

It should also be noted that in several jurisdictions that recently started with a high FIT rate, Switzerland and Ontario in particular, there was a glut of applications that could not all be processed in a timely way, due to the high level of interest in the program. If in Nova Scotia we choose a more moderate approach to have a more gradual uptake, lower rates than the observed practice may be considered appropriate.

If the province were to choose rates based on the estimated LCOE, with three size categories, and with an automatic 20% annual digression in price, a plausible set of FIT or COMFIT rates for Nova Scotia would be as shown in Table 9 below.

**Table 9:** Scenario for FIT or COMFIT rates (¢/kWh) for PV in Nova Scotia according to LCOE.

Size category	Contract Year		
	2013/2014	2015	2016
≤ 10 kW	30	24	19
10 to 100 kW	26	21	17
100 to 250 kW	22	18	14
250 kW to 1000 kW	20	16	13

In choosing the size categories we have given the scenario a maximum allowable project size of 1000 kW. This corresponds with the current maximum for self-generation projects to connect to the Nova Scotia Power system under the Enhanced Net Metering Program.<sup>50</sup>

## 6.2. Scenario – Cost of Program to Ratepayers

The total cost to ratepayers of having a solar PV FIT or COMFIT offering in Nova Scotia would depend on the FIT rates chosen and the total capacity installed. Capacity could be limited by setting a cap on total installed capacity, or by setting lower rates to moderate uptake. Alternatively, capacity could be moderated simply by the ability of the distribution network to accept proposed projects, as is the current practice for COMFIT projects, except that the decision to allow a project should be based on minimum daytime load, when PV will produce, instead of overall minimum load.

We have constructed a hypothetical scenario in order to estimate the cost to ratepayers. If the rates given in Table 6 were used, and if a program cap of 1% of total Nova Scotia electricity generation were set, and if the program were fully subscribed by 2016, the totals would be as follows:

*Total installed PV capacity:* 100 MW (rounded down from 104 MW for simplicity)

*Total solar PV production:* 110 GWh/year

It may not be necessary to define a total program cap or a project size cap for PV installations on the distribution grid. The decisions about which installations to allow could be made based on the minimum load on the distribution zone, as they are for COMFIT projects today, except that for solar PV the appropriate basis would be the daytime minimum load, between the hours of 10:00 am and 16:00. As discussed in Section 3.3.3 above, the daytime minimum load is higher than the overall minimum load, and PV arrays will only produce near their peak capacity in the middle of the day.

To estimate the cost to ratepayers, it is necessary to construct a scenario with respect to the percentage of the total capacity installed in each size category and year. The scenario is not a prediction, but serves as a basis for estimating the cost. We have assumed based on the experience in Ontario that a large number of small systems will be implemented, and relatively few large systems. For the timing, we have assumed that the majority of the contracts would be signed in 2015, allowing time for the local industry to ramp up. Table 10 details the deployment scenario we have constructed.

**Table 10:** Scenario of the portion of projects in each size category and year.

Size category	Contract Year		
	2013/2014	2015	2016
≤ 10 kW	10% (10 MW)	35% (35 MW)	15% (15 MW)
10 to 100 kW	8% (5 MW)	10% (15 MW)	9% (5 MW)
100 to 250 kW	2% (5MW)	4% (15 MW)	4% (5 MW)
250 to 1000 kW	0% (0 MW)	1% (1 MW)	2% (2 MW)

When calculating the cost to ratepayers, it is necessary to subtract the avoided cost from other generators which otherwise would have supplied the electricity. For the purpose of this calculation we assume an average avoided cost of 6 cents/kWh. Note that while this is higher than the average cost of electricity production in Nova Scotia, solar power is daytime power only, which has a higher than average value.

Under the set of assumptions made above, by the end of the third year the total net cost of solar electricity sales to the grid would amount to \$17.7 million per year. When spread across the total electricity generation in Nova Scotia (11,400 GWh in 2011), this amounts to a net cost of about \$0.0015 / kWh system-wide for all ratepayers.

***Estimated cost of solar PV feed-in-tariff to ratepayers: \$0.0015 / kWh***

Assuming 20 year contracts, the annual payments would remain constant for 20 years, while the avoided cost would increase due to inflation and fuel price increases. As a result, the net cost as a percentage of the going electricity rate would decrease over time.

**Note:** This estimated cost to ratepayers does not include any system integration costs for solar PV. As stated earlier in this report in section 4.3, we believe that for the first 100 MW of distributed solar PV the integration costs will be insignificant. To consider the possible impact of grid integration, if we assume that integration costs an extra 1 cent/kWh of solar PV generation, this would add \$1.1 million to the total system-wide cost, making the cost of the solar PV feed-in-tariff \$0.0016 / kWh in this scenario.

#### **5.4. Examples of other PV incentive programs in North America**

##### **5.4.1. Alberta**

###### ***Alberta Agriculture***

Alberta Agriculture and Rural Development, a provincial government department, through its “Growing Forward” partnership with the federal government, offered a “Solar PV Equipment Pilot” capital rebate program for eligible registered farms in 2011 and 2012.<sup>51</sup> The goal of the pilot project is to collect data on installation cost and energy productivity of solar PV systems on farms in Alberta. Grants of between \$1.50 and \$2.50/W were offered to cover a portion of the installed

cost, up to a maximum of \$19,500. The incentive was tiered by system size, with the first 3000W receiving \$2.50/W, the next 3000W receiving \$2.00/W, and any portion above 6000W receiving \$1.50/W. The minimum project size was 2.2 kW. There was no maximum project size, although the maximum project grant set an effective cap of 10 kW for a single project, above which no further grant was available.

The farmers who installed the systems applied to interconnect under the Alberta Micro-Generation Regulation<sup>52</sup> and are therefore eligible for payment for surplus generation from their PV array at the retail electricity rate, which in Alberta in 2012 ranged between 8 and 10 cents/kWh.<sup>53</sup> Distribution fees are not counted in the credit.

The pilot program was quickly oversubscribed and closed to further applications, due to “tremendous interest”.<sup>54</sup> Forty-six projects were approved, for a total installed capacity of 352 kW.<sup>55</sup> The pilot program ends March 31, 2013, though it is effectively closed now due to being fully subscribed. The Government of Alberta has expressed interest in continuing and expanding the program in 2013 if it is deemed successful.<sup>56</sup>

### ***ENMAX Generate Choice Program***<sup>57</sup>

A private electrical utility company based in Calgary, ENMAX is offering to lease PV systems to residential customers. The duration of the lease is 15 years, after which the customer can choose to purchase the system for an additional \$350 or pay \$950 to have it removed. Each PV system is sized at 1.3 kW, and there are three payment options, as shown in Table 3 below. Parts and labour are warranted for the duration of the lease.

Over the lifetime of the system, the levelized cost the lessee is paying for the electricity can be estimated based on the up-front fee, the monthly fees, buy-out fee and electricity production. A 1.3 kW PV array can be expected to produce about 1690 kWh annually in southern Alberta. The lease is for 15 years, however if the user elects to buy the system for \$350 at the end of 15 years, they can expect ten more years of useful production after the end of the lease. The estimated levelized cost of solar electricity in these systems is also shown in Table 8.

**Table 11:** Payment plans for 1.3 kW PV systems in the ENMAX Generate Choice program

<b>Fees</b>	<b>Zero Down</b>	<b>Standard</b>	<b>Low Monthly</b>
<b>Initial Fee</b>	\$ 0	\$1500	\$3500
<b>Monthly Fee</b>	\$59.99	\$39.99	\$16.99
<b>LCOE*</b>	38 ¢/kWh	33 ¢/kWh	29 ¢/kWh
<b>Net cost to lessee</b>	28 ¢/kWh	23 ¢/kWh	19 ¢/kWh

\*Levelised Cost of Electricity (estimated from the fees under a set of assumptions). The net cost to the user of the solar electricity is about 10 ¢/kWh less than the LCOE, because they will receive credit at the retail rate for all the electricity they generate.

ENMAX received a grant of \$14.5 million from the Climate Change and Emissions Management Corporation (CCEMC) to support offering this program as an immediate way to reduce greenhouse gas emissions and build capacity in the distributed renewable sector. The program goal is to install 9000 distributed renewable energy systems, 8300 of them solar PV and the other 700 being micro wind turbines, for a total generation capacity of 12,470 kW. If all of the systems are installed, the grant represents a subsidy of approximately \$1.16/W across the whole program.

As of November 2012, the program has facilitated the installation of over 450 kW of renewable capacity, including both wind and solar. The ratio of solar to wind in the installations was not specified. If the ratio installed is equal to the ratio of the program targets, the solar portion would represent about 92%, or 414 kW.

### *Alberta Municipal Solar Showcase*

Twenty municipalities across Alberta are demonstrating highly visible grid-connected solar PV projects at public buildings. Each participating municipality installed a grid-connected PV system of at least 1 kW of capacity. Real-time output for the 20 projects is available on the project website. Funding for the project comes from the municipalities, Alberta's Climate Change Central and the Federation of Canadian Municipalities' Green Municipal Fund. The purpose is to raise awareness amongst the public, the trades, governments and industry.<sup>58</sup>

### **5.4.2. Saskatchewan Net Metering Demonstration Program<sup>59</sup>**

From 2006 to 2012 the Saskatchewan Research Council (SRC) offered a 35% rebate incentive up to \$35,000 per project for environmentally preferable customer-installed electricity generation systems with capacity under 100 kW. In exchange, the customer/generator agreed to provide production data from their system for 10 years. Wind energy and PV systems were both eligible for the same incentive. The program was originally intended to run for five years and was extended for one year. Registrations were accepted up to January 2012.

The program resulted in 250 systems being installed in the first five years and an additional 179 systems in the extended year. Among these there were 190 PV systems for a total of 1530 kW of installed PV capacity. Data collected in the project so far has found that the PV systems are producing 29% more electricity than that predicted by RETScreen<sup>60</sup> software modelling. The lifetime cost of electricity production by the PV systems in the study (after the rebate) is estimated at 13 ¢/kWh.<sup>61</sup> At current prices of \$4 to \$5/W installed, the 35% rebate represents an incentive of \$1.40 to \$1.75/W.

### **5.4.3. Efficiency New Brunswick – Net zero homes incentive and PV**

Efficiency New Brunswick's Residential Energy Efficiency Program offers incentives to improve the energy efficiency of residential buildings, and it includes an optional bonus incentive for net zero retrofits, in cases where the building owner agrees to make the building site produce as much energy as it uses. The idea is that the owner will first upgrade energy efficiency as much as practicable and then install a renewable energy system to produce annually as much energy as the building uses. This in effect is an incentive available for PV systems, because installing PV is one of the more common ways to bring a building to a net zero energy position.

For a single family home, the Net Zero Bonus is \$4000, and for a multi-unit building it ranges from \$4000 to \$20,000. To estimate the value of this as an incentive for PV, consider a scenario in which a single family home has been retrofitted with upgraded insulation and a heat pump, bringing its total energy consumption down to 7000 kWh per year (all electric). In New Brunswick, a 6 kW PV array would produce about this much electricity annually, with a small surplus, and would cost between \$24,000 and \$30,000. An incentive of \$4000 then represents approximately a 13 to 17% capital cost rebate, or about \$0.67/W.

#### **5.4.4. Massachusetts, USA – Solar Renewable Energy Certificates**

Since 2010 the state government of the Commonwealth of Massachusetts has established a Renewable Portfolio Standard (RPS) with targets for renewable electricity supply, and within the RPS solar PV has a specific “carve-out”. The goal for Massachusetts is 400 MW of installed capacity of PV, with distributed projects of a variety of sizes up to 6 MW each.<sup>62</sup>

To facilitate growth in solar PV capacity there is a legislated requirement that all retail utilities selling electricity in the state source a percentage of their electricity from a certified solar energy source. The required percentage is adjusted year-by-year to achieve growth. The utilities may install PV systems of their own or purchase Solar Renewable Energy Certificates (SRECs), which are promissory instruments or contracts with an independent power producer (IPP) to supply the specified amount of solar electricity.

The sale of SRECs is the primary revenue source for IPPs, on which they can base their business and financing plans for new solar PV installations. The solar electricity itself is sold primarily through net metering, power purchase agreements or spot pricing, at between 6 and 10 US¢/kWh. On the other hand, the SRECs are sold to electricity retailers on an open market, with the price floating within a range of 28.5 and 50.0 US¢/kWh set by the government. Individuals with small residential systems typically participate in this market by pooling their SRECs through an aggregator company. The government has set up an auction clearinghouse to facilitate the sale of any unsold SRECs, but in 2011 no SRECs were deposited in the auction, suggesting that all who wanted to sell their SRECs were able to do so without needing to put them up for auction.

The combined value of solar electricity in this scenario, including the sale of the energy and the SRECs, is between 34.5 and 60 US¢/kWh, which is comparable with feed-in-tariff prices in Ontario and other jurisdictions. The US dollar has traded within +/- 5 cents of par with the Canadian dollar for all of 2012<sup>63</sup>; therefore in this context US currency is equivalent to Canadian currency.

Interestingly, the retail utilities have an alternative of paying a “compliance fee” if they do not obtain the necessary SRECs. The compliance fee is 55 US¢/kWh in 2012 for the solar portion that they fail to obtain, to decline gradually over the next 10 years to 34.7 US¢/kWh. Given the recent drop in installed solar PV costs, it seems likely that utilities will spend significantly less if they purchase SRECs or install PV systems rather than paying the compliance fee.

The legislated market for SRECs makes commercial solar electricity development very attractive in Massachusetts at this time. SRECs can be sold by anyone, including individuals who install solar

PV systems on their own properties and interconnect them with the grid. The Massachusetts SREC system has a similar effect as having a FIT or COMFIT rate of between 30 and 60 CAD¢/kWh.

Since 2008, over 3700 solar PV projects under 6 MW have been installed in Massachusetts, for a current installed PV capacity of 138 MW. In the year 2012 alone, up to the end of October, over 2000 PV systems were installed, for a total of 86 MW of capacity. If that rate were to continue year-over-year, the 400MW goal would be reached in 3 more years. Being well on track towards meeting the current target soon, the state government is beginning considerations in 2013 about whether to increase the goal.<sup>64</sup>

## **8. Relationship between solar PV and solar thermal**

As mentioned previously in Section 2.5, solar thermal technologies such as solar water heaters are also represent economic development opportunities and an effective means of harvesting renewable energy and reducing greenhouse gas emissions. In Nova Scotia, where the solar industry includes significant activity in solar thermal, the question of the relationship between solar thermal and solar PV technologies is worthy of consideration.

The government of the UK has taken an interesting approach by offering two incentives – a feed-in tariff for solar electricity and a renewable heat incentive for solar thermal systems. The renewable heat incentive is now open in Phase 1 to commercial, institutional and non-profit agency solar thermal installations and offers payments of 8.9 pence (13.8 CAD cents) per kWh of heat energy produced by a solar thermal array<sup>65</sup>. Payments are based on the real measured heat output of the system, and are made every three months for as long as the system produces, or 20 years, whichever comes first. The payments are an additional benefit on top of the savings in energy that accrue to the system owner.

For the small solar water heater described in Section 2.5 of this report, which produces 2500 kWh annually, the UK renewable heat incentive would pay the equivalent of CAD\$345 annually. This would be in addition to the approximately \$350 that the owner would save on electricity bills, for an annual return of nearly \$700 on the investment in a solar water heater, or about 28 cents/kWh. By comparison, the solar PV feed-in-tariff in the UK is structured such that the value of solar electricity is about 45 cents/kWh<sup>66</sup>. The ratio of the value of solar electricity to solar thermal energy in this comparison is 1.6:1, which is similar to the difference in capital cost between the solar heater and the solar PV system described in Section 2.5, which is a ratio of 1.4:1.

The Province of Nova Scotia could consider a similar approach to the UK government, by offering both a renewable heat incentive based on measured production, and a feed-in tariff for solar electricity production. The rates may differ here, but the concept would allow for equitable treatment of solar technologies.

An interesting aspect of the UK system is that in order to be eligible for either of the incentives, a homeowner must demonstrate that their home meets a defined standard for energy efficiency. This prioritizes energy efficiency in the hierarchy of actions to reduce greenhouse gas emissions.

## **9. Results of Stakeholder Review**

In partnership with the Nova Scotia Department of Energy and the Nova Scotia Community College, we held a stakeholder meeting on January 24, 2013 with invited representatives of the solar energy industry in Nova Scotia and Canada. The 27 participants are listed in Table 11 below.

Table 11: Participants in the solar PV stakeholder meeting, January 24, 2013.

Name	Organization
20 (1)	Municipality of Digby
	Dalhousie University Faculty of Law
	WHW Architects
	KMKNO (Mi'kmaq Rights Initiative)
	Dalhousie University Dep't of Chemistry
	Efficiency Nova Scotia
	Nova Scotia Power
	SAGE Energy
	Appleseed Energy
	Appleseed Energy
	Green Power Labs
	My Generation
	Solar Nova Scotia
	Canadian Solar Industries Association (by phone)
	Canadian Solar Industries Association (by phone)
Al Joseph	Nova Scotia Community College
Evan MacDonald	Nova Scotia Department of Energy
Scott McCoombs	Nova Scotia Department of Energy
Sandra Farwell	Nova Scotia Department of Energy
Greg Decker	Nova Scotia Department of Energy
Jonah Bernstein	Nova Scotia Department of Energy
Sheila Paterson	Nova Scotia Department of Energy
Karen Daniels	Nova Scotia Department of Energy
Wayne Groszko	Ecology Action Centre
Mark Butler	Ecology Action Centre
20 (1)	Ecology Action Centre

During the meeting we presented a summary of the key findings of this report and asked for feedback. We also sought feedback from several other people who were not present at the meeting, including 20 (1) of Thermo Dynamics Ltd., and 20 (1) of Encom Group Inc.

We incorporated the feedback into the report to the extent possible within the scope of the project.

The main messages we heard were the following:

- Some participants felt we had underestimated the potential for Nova Scotia industries to develop, manufacture and assemble innovative solar electricity components for the solar electricity industry, both for local use and for export. It was suggested that there is job growth potential in Nova Scotia in this industry and that a strategy for developing that potential is needed. In particular, participants pointed to third generation solar PV materials, the Solartron concentrator manufactured in Amherst, and the capacity to build other system

components, as three examples of local industrial development opportunities. We note this here for further consideration, as it is outside the scope of this particular report.

- It was expressed by several participants that as a province we should define our goals with respect to solar energy, and that this would inform our path forward.
- It was noted by some participants that there could be our estimates of levelised cost of PV could be low, considering the following factors:
  - o The trend in decreasing module prices may not continue.
  - o United States import tariffs on equipment manufactured in China may increase module prices in Canada.
  - o The cost of permitting for PV systems in Nova Scotia may increase, especially with the new Canadian Electrical Code including specific sections of grid-connected renewables.
  - o Building permits may be higher in some counties than in others.

With respect to the point above, we agree that there is a risk that solar PV could cost more than we project in 2013 and subsequent years. We have based the projections on trends over the past decade, which are not always a good indicator of future behaviour. With more information on the possible changes in the market and costs, we could increase the range of uncertainty in costs in the upward direction. We have not attempted to do this, but note that there is uncertainty in the cost estimates.

- A participant asked whether we have calculated the cost of solar PV in a different way, to account for its environmental and social values. We have not done so in the research for this report, because this would expand the scope of work beyond the project budget. We note this here for consideration in the wider discourse about deploying solar PV.
- Several participants asked whether the community eligibility requirements of the COMFIT program are appropriate when considering solar PV, since solar PV can be readily installed at individual homes in urban and rural areas. With a wide range of possible participants, the question was raised as to whether individuals should be eligible for a feed-in tariff for solar PV generation. This question is for the Nova Scotia Department of Energy to consider in its deliberations about the COMFIT review.
- At least two stakeholders we spoke with stated that they believe that solar PV and solar thermal incentives should offer similar returns to participants. They were concerned that any new incentives for solar PV be matched with incentives for solar thermal energy, to raise the profile and opportunities in both of these solar industry sectors.

## 10. Summary

The main points we found in our research can be summarized as follows:

- The solar resource in Nova Scotia is fairly uniform across the province and amounts to about 1100 kWh of annual electricity production per installed kilowatt of PV generation capacity. This is about normal for Canada and intermediate on the global scale.
- On a seasonal basis, solar PV output in Nova Scotia corresponds well with the secondary peak in electricity demand that occurs during July for cooling load, but it does not correspond well with the maximum winter peak demand in January associated with heating.

- On a daily basis, in summer (July) the peak output from solar PV on sunny days will occur during the typical daily demand peak. However in winter (January), PV will not be available at the time of the typical daily demand peak, which occurs after sunset.
- A key difference between solar PV and other variable renewable electricity generators is that peak generation from solar PV always occurs in the daytime, and particularly near the middle of the day. Daytime minimum load in Nova Scotia is higher than the overall minimum load by a significant margin. This means there is a distinct and quantifiable demand on the grid that can specifically absorb solar PV. This distinct demand is in addition to other variable renewable sources such as wind and tidal energy, which will also produce at night and therefore require a different rule about minimum load. We estimate this available demand for solar to be equivalent to about 200 MW of PV capacity in Nova Scotia.
- We find that the capital cost of installed solar PV systems has decreased steadily over the past decade, at about \$0.87/W per year, and the installed prices in Nova Scotia show the same pattern. Installed prices in Nova Scotia in 2012 were in the range from \$4.00 to \$5.00/W.
- Under a chosen set of assumptions, we estimate the levelised cost of solar PV electricity in Nova Scotia to be about 35 (31 to 38) cents/kWh for 2012 prices, and about 27 (18 to 34) cents/kWh for projected 2013 prices. We acknowledge that there are several factors that could make the actual levelised cost higher than this, as stakeholders pointed out.
- Feed-in tariffs have been used in many jurisdictions to effectively encourage deployment of solar PV systems. FIT rates in Ontario and in northern European jurisdictions have declined steadily and dramatically over the past three years, and now range from 17 to 55 cents/kWh, depending on the jurisdiction and the size of the system.
- We constructed a scenario to consider the cost to ratepayers if Nova Scotia offered a FIT or COMFIT rate for solar PV. The scenario we used was based on the levelised cost of solar PV electricity that we have estimated, ranging from 20 to 30 cents/kWh in 2013/2014 and digressing automatically by 20% each year for the subsequent two years. If 100 MW of solar PV capacity were installed under this scenario, we estimate that the cost to ratepayers would amount to about \$0.0015 per kWh on all electricity bills in the province.
- There are several other kinds of incentive programs that have been implemented for solar PV in other jurisdictions, including grants, rebates, leasing programs and tradable Solar Renewable Energy Certificates.
- We have found an example from the UK of a system that encourages both solar thermal and solar PV in a relatively equitable manner, with a renewable heat incentive and a feed-in tariff.

## 11. Conclusion

In conclusion, solar photovoltaic electricity has significant potential to add to the diversity of the renewable electricity supply in Nova Scotia. There are also economic development opportunities in the growing global market for solar electricity technology. This report outlines several options the Province can consider to encourage the solar electricity industry and the solar thermal industry together.

## ENDNOTES

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<sup>58</sup> Alberta Solar Municipal Showcase, accessed on Dec. 7, 2012 at: <http://www.lassothesun.ca/index.htm>

<sup>59</sup> Kelly Winder, Saskatchewan Research Council, presentation to SolarWest 2012, CanSIA conference, Nov. 1, 2012.

<sup>60</sup> Renewable Energy Technology Screening (RETScreen) software, available from Natural Resources Canada.

<sup>61</sup> Kelly Winder, Saskatchewan Research Council, presentation to SolarWest 2012, CanSIA conference, Nov. 1, 2012.

<sup>62</sup> Executive Office of Energy and Environmental Affairs, Commonwealth of Massachusetts, Solar Carve-Out / SRECs information page, accessed Dec. 7, 2012 at: <http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/rps-solar-carve-out/>

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