Solar Energy: Part of a Sustainable Future in Nova Scotia

Submission to the Electricity System Review
Solar Nova Scotia – December 2, 2014

Summary

Solar energy is here. Its growth is an inevitable outcome of private and public investment decisions. For economic and environmental reasons, we must plan now for the long-term replacement of all fossil fuel generation with renewables. Our best chance to achieve that is to provide diverse solutions, which should include distributed solar photovoltaics (PV).

The growth rate in solar PV installed capacity in Nova Scotia has averaged 80% per year for the past five years. This represents exponential growth. In a possible future scenario, if a more modest 30% annual growth rate is sustained, installed solar PV capacity would reach 32 megawatts (MW) by 2030, and exceed 500 MW by 2050, or approximately 5% of 2013 electricity production in Nova Scotia.

Depending on one's assumptions about future increases in electricity rates, a solar PV system at 2014 prices can be an investment with an after tax internal rate of return between 2.3% and 6.6%. We calculate the levelized cost of energy (LCOE) for solar PV to be in the range of $0.196 to $0.291 per kWh in Nova Scotia in 2014, not $0.35 per kWh, projected in 2020 as stated in the consultants' Technical Report.

We believe that an independent study of the grid integration needs for distributed solar PV has not been done for Nova Scotia, and it should be done within the next few years in anticipation of the continued growth in solar PV installations.

For every investment in a solar PV system in Nova Scotia, which is largely a private investment, a significant portion stays in Nova Scotia in the form of wages, contracted services, and local fabrication of components. The spin-off economic benefits from this are magnified within the local economy.

Subsidies for solar are only required to the extent that fossil fuel, nuclear, and other forms of energy continue to be subsidized by not paying for their externalized costs of pollution. Solar needs and deserves a level playing field, for example by introducing a carbon tax on fossil fuels.

If there will be opportunities to develop solar PV in Nova Scotia through the new renewables-to-retail legislation, much will depend on the conditions and regulations of the program, and especially on the tariffs established to be paid by renewable electricity generators for the use of transmission and distribution systems to reach their customers.

We detail five recommendations in Section 10.

1. Importance of diverse energy sources

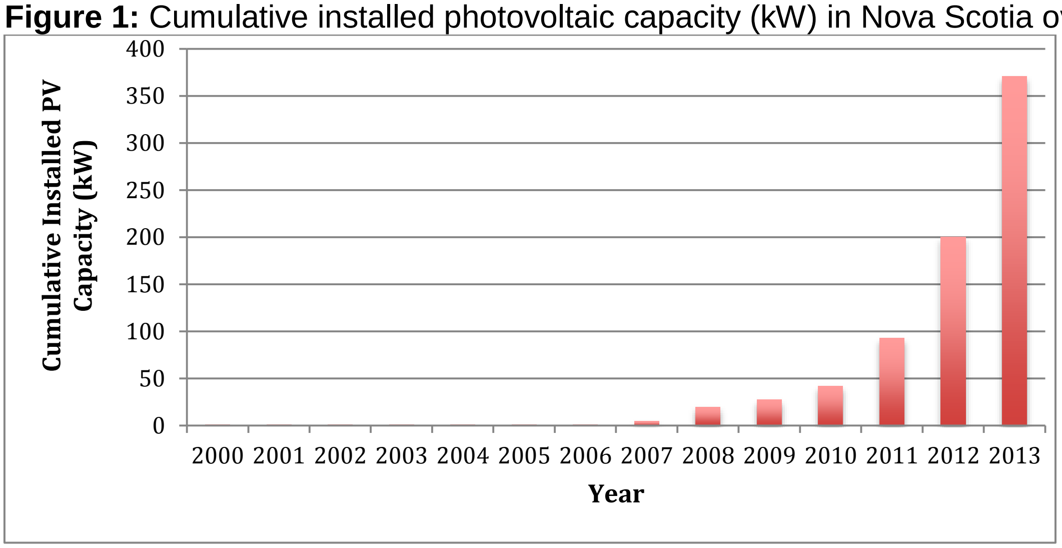
The most recent Intergovernmental Panel on Climate Change (IPCC) report is clear. The world needs to become carbon neutral as soon as possible, and developed countries have a moral duty and the capacity to lead the way. This means that Nova Scotia must eventually wean itself off all fossil fuel produced electricity, the sooner the better. This is technically possible and becoming economically more and more feasible. Eventually, it will become an economic as well as an ethical and environmental imperative.

It is difficult to predict future advances in technology; therefore it is important to plan for maximum diversity of renewable energy sources in the production of our future electricity requirements. With diversity in renewable energy sources come energy security, price stability, grid stability, economic opportunities and overall improved resilience.

Conservation and efficiency improvements offer perhaps the greatest potential to contribute to the goal of sustainable energy. In addition, today's major renewable energy sources include wind, small scale hydro, solar, tidal, and geothermal. The extent to which large scale hydro and biomass contribute to climate change solutions is context specific and very much debated. Solar is already mainstream in most of the world. Tidal is not yet proven to work in the harsh conditions of the Bay of Fundy but has a promising outlook for Nova Scotia. The Summary Report accepts wind, hydro, tidal and biomass as part of a diverse solution but not solar.

In the Technical Report on Emerging Technologies prepared for the electricity system review, ICF as consultants to the Nova Scotia government have almost entirely dismissed solar energy as a resource in Nova Scotia. The only conclusion made with respect to solar energy in the report is that "solar water heating may continue to grow". In fact, solar PV is already growing at a rapid rate in Nova Scotia.

Figure 1: Cumulative installed photovoltaic capacity (kW) in Nova Scotia over time.[1]



Solar PV capacity is following an exponential growth pattern, with an average growth rate of 80% per year over the past five years. As solar PV cumulative capacity grows, the

[1] Nova Scotia Utility and Review Board, Annual Reports on Net Metering from NSPI.

percent growth rate may decrease. However, if a modest 30% annual growth rate in distributed solar PV capacity is sustained, by 2030 this annual growth rate would result in 32 Megawatts of solar PV capacity installed in Nova Scotia, a 100-fold increase from current levels. This is a conservative projection of current trends alone, to say nothing of how those growth rates may change when the price of producing solar electricity falls below the retail rate for electricity in Nova Scotia. Continuing the 30% growth rate, installed solar PV capacity would exceed 500 MW by 2050, or approximately 5% of 2013 electricity production in Nova Scotia.

Solar energy is here. Its growth is an inevitable outcome of private and public investment decisions. It brings with it considerable economic development opportunities in terms of investment and jobs in the design and installation of solar energy systems. Nova Scotia can choose to take advantage of these opportunities.

By 2020, it is mandated that 40% of Nova Scotia’s electricity will come from renewables, aided by hydro-electricity delivered by the Maritime Link. By 2030, coal-fired generation should be largely phased out. It should only be used as a last resort to the extent it is still needed to ensure grid stability and security of supply. For economic and environmental reasons, we must plan now to replace all fossil fuel generation with renewables. Our best chance to achieve that is to provide for maximum diversity of solutions.

The most recent IPCC report, the United Nations Environment Program (UNEP) Emissions Gap report, among many others, make it clear that further reductions in greenhouse gas emissions will be required in Nova Scotia after 2030. It is reasonable to expect that by 2040 there will be considerable pressure on Nova Scotia to be carbon neutral. Even more certain is that by then any remaining GHG emissions will come at a very high price. It is prudent, therefore, for Nova Scotia to start to plan for carbon neutral power generation. A strong solar industry in Nova Scotia can play a significant role in this transition.

2. Diversity of solar technologies

In addition to solar PV, other forms of solar energy, along with smart grid technology, demand side management, energy conservation, and improved efficiency, have the potential to reduce electricity demand from the grid.

Solar water heating is growing significantly in Nova Scotia. Witness the HRM Solar City project, which is facilitating installation of more solar water heaters in HRM in 2014 than were installed in all of Canada in the same year. This program is likely to continue to expand to many other parts of the province, and to start facilitating the financing of solar PV as well. Passing mention of solar water heating was made in the Summary Report of the Review, but no analysis was done on the economic opportunity or the implications for the future planning of the electricity system. The potential for solar water heating to contribute to renewable energy and green economy goals should be investigated more thoroughly.

Solar domestic water heaters that supplement electric back-up water heaters take a load off the electricity distribution system because they store energy in the form of heat, thus decreasing and possibly shifting demand. In that sense, they influence planning of the future electricity system in a positive way, and plans should be made to increase such installations. Even further, solar hot water storage combined with a smart grid control solution to time the electric backup heater to correspond with supply and demand on the grid (as in PowerShift Atlantic), is a great opportunity to reinforce the grid and make it more resilient to swings in supply and demand. Nova Scotia research and development is at work in all these positive areas, and should have continued and increased support.

Passive Solar Homes: Nova Scotia has world-renowned expertise in Passive Solar Home design. As energy-efficient building standards develop, the **Passive House Standard** is emerging and gaining traction. It's a design protocol for buildings that require so little supplemental heat in winter that they need only a tiny back-up heater, similar to R2000 and net-zero homes, but more advanced. Over the coming decades, with the right planning, attention and policies, energy-efficient home design and retrofit could generate significant benefits by reducing future winter peak demand for space heating, thus helping shift the peak demand in Nova Scotia away from the winter. The Nova Scotia government should continue to support development and implementation of advanced energy efficient home design such as the Passive House Standard for new construction and renovation, and develop land use guidelines that promote solar-oriented neighbourhoods.

3. Financial Viability of Solar PV

Solar Nova Scotia has prepared a calculation of the financial viability for individual property owners to invest in solar PV systems for their properties. It is based on publicly available prices from the winning bids for solar PV projects awarded for Halifax Regional Municipality facilities in 2014, which range from $3.00 to $3.62 per installed Watt, plus Harmonized Sales Tax (HST), for a total of $3.45 to $4.16 per Watt.

A number of assumptions must be made to complete this analysis, including the installed cost, rate of general inflation, and the rate of increase in retail electricity rates. For a range of assumptions, we calculated the following annual internal rate of return (IRR) for investing in a solar PV array at a private or public property, starting in 2014:

Description of case	Installed Cost (/W) incl. HST	General Inflation	Electricity Inflation	IRR (%/y)
Low rate increase	$4.16	2.5%	2.5%	3.8%
Base case	$4.16	2.5%	5.0%	6.3%
Low installed cost	$3.45	2.5%	5.0%	7.4%

The figures above are approximate. What they basically show is that, depending on one's assumptions about future increases in electricity rates, in 2014 a solar PV system can be an investment with a return that many people would find acceptable. In particular, if one believes that electricity retail rates in Nova Scotia will continue to increase at greater than the rate of general inflation, as they have over the past decade, then the investment could be reasonably attractive. It is essentially an investment to pre-purchase electricity at a relatively fixed price, which is a hedge against future electricity price increases. An example image of the spreadsheet for the detailed calculation of IRR is shown in Appendix A.

In our view, the most compelling evidence is that private individuals and organizations are already choosing to invest their financial resources in solar PV systems for their properties in Nova Scotia, as seen by the growth rate in cumulative PV capacity. This is the tangible evidence that the financial case is acceptable to those making this choice. With the general global reduction in solar PV costs, more and more people and organizations will choose to install solar PV in Nova Scotia in the next couple of decades. The government of Nova Scotia should choose to embrace that groundswell and optimize its economic benefits by helping make net metering agreements simpler to obtain, and helping train a network of new installers for the new jobs that are resulting.

4. Levelized Cost of Electricity for Solar PV

The consultants' Technical Report has stated a levelized cost of electricity (LCOE) for solar PV of $0.35 per kWh, projected in 2020. The consultants have used generalized data from the USA and attempted to adjust it for Nova Scotia's solar productivity. Solar Nova Scotia, however, already has current operating examples of residential solar installations in place in 2013 that have lower levelized costs than that (between $0.25 and $0.30). The consultants have not given details of their calculations in the Technical Report. There are many assumptions and parameters that influence an LCOE calculation, such as the discount rate, maintenance costs and inflation rate. Minor adjustments of any of the assumptions influence the result significantly.

The LCOE depends strongly on the installed cost of a solar PV array, which can vary significantly from project to project. As an example, Halifax Regional Municipality issued tenders for two solar PV installations in 2014 for municipal buildings – a 14.75 kW array and a 12.5 kW array. These tenders were awarded at prices of $53,400 and $37,500, respectively, which represents $3.62/W and $3.00/W for these two projects.[2] Based on this information, we consider the installed cost of solar PV in Nova Scotia in 2014 to be in the range from $3.00 to $3.62/W. When more data becomes available, we would gladly refine the price estimate to strengthen its statistical robustness.

Based on these ranges, and a set of reasonable assumptions, we calculate the LCOE of solar PV to be in the range of $0.196 to $0.291 per kWh in Nova Scotia in 2014. The method for calculating LCOE that we have used is in accordance with the International Renewable Energy Agency (IRENA)[3]. The method and example calculations are shown in Appendix A.

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[2] See Nova Scotia Tenders at the Procurement Services website for Nova Scotia, http://www.novascotia.ca/tenders/tenders/ns-tenders.aspx

[3] Renewable Energy Technologies: Cost Analysis Series, Volume 4/5, "Solar Photovoltaics", International Renewable Energy Agency, June 2012.

5. Timing of solar electricity production

As stated in the Technical Report, it is correct to say that solar electricity in Nova Scotia (with no storage capacity) will not produce power at the time of current peak demand, which typically happens at around 7 pm on a cold evening in January or February. There will be no solar PV production at that time of day, therefore no capacity credit can be assumed for solar PV, and none is being asked for.

The reason for the current winter peak is largely about heating and lighting. There are lots of solutions to reduce this (including passive solar, heat storage, efficiency, heat pumps, etc.). It is our position that as long as we have the annual demand peak in the winter, we are not using electricity as wisely as we could be.

Acknowledging that we currently do have a winter demand peak, we nevertheless believe that a key point about the timing of solar electricity is being ignored in the Electricity System Review. The Summary clarifies the Department's view of solar energy when it states that solar PV "produces the most when we need it the least." This is not correct and is at best an oversimplification. Solar PV produces some amount of electricity each day between the hours of 10 am and 3 pm. On a sunny day it will produce much more than on a cloudy day, but it will always produce the most through the mid-day hours.

The time when we need the LEAST electricity is during the night following a mild evening in spring (typically May), or autumn (typically September). We have analysed Nova Scotia load records to determine that spring and autumn nights have been the characteristic time of minimum load in each of the past three years. That period of several hours of very low demand in the night can be a challenge for the system operator to manage. However, solar PV will not add to that problem, because the minimum happens at night, when solar PV will not be producing.

Between the hours of 10 am and 3 pm, there is always significant demand for electricity, in every season, and always significantly higher demand than there is at night. In addition, there is a small seasonal secondary peak in daytime electricity consumption in Nova Scotia in the summer months of July and August, due to the modest amount of air conditioning we use. This secondary peak is smaller than the winter peak, but it is nonetheless present, and will likely increase with climate change. Lowest demand is not on a summer's day, but during the night in spring and fall.

It follows that there is significant daytime demand that can absorb a modest amount of growth in distributed solar PV in Nova Scotia. To take an example, consider Burnside industrial park in Dartmouth. The Nova Scotia Power COMFIT generation capacity map[4] shows a total of 18 MW of available COMFIT capacity across the four substations that

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[4] Available COMFIT Generation Capacity (Map), Nova Scotia Power, Inc., https://www.nspower.ca/en/home/community/community-feed-in-tariff-comfit-/available-comfit-generation-capacity.aspx, accessed Nov. 14, 2014.

serve the Burnside area. Not only that, but the daytime electrical demand in Burnside (when solar PV would be producing) is much higher than 18MW, likely twice as high in the daytime as at night.

It is exceedingly unlikely that 18 MW of new wind energy generation would be proposed or approved in Burnside. However, it is very likely that at least that much solar PV, and likely twice that much, could be readily installed in Burnside. Solar PV there would produce clean electricity and economic benefits while never exceeding the demand for electricity within the local distribution zone. The operation of 18 MW of solar PV in Burnside (a likely future scenario even considering current trends alone) would simply mean a reduced demand for electricity in that high-demand zone, in the middle of the day on every sunny day of the year. That is not a disaster for the power grid, and in fact would bring a lot of economic benefits. This scenario can be applied to all other densely populated, high-daytime-demand areas of the province.

We fully recognize that the one problem this scenario poses is to Nova Scotia Power as a business, which currently depends on those electricity sales as part of its business model, and which would lose some sales volume in the middle of the day due to self-generation with PV. But this is not very different from losing sales due to energy efficiency, and we are embracing energy efficiency, as we should. Solar PV is another tool in the toolbox to maximize the efficiency of a built property, and as such should be facilitated.

6. Grid Integration

The Summary Report states in the Solar section [p. 21] that integration costs for the first 500 MW of renewable capacity were assessed to be fairly reasonable, but that going beyond 500 MW (which we already will have in wind energy alone) could increase costs. We believe the 500 MW figure is based on the wind integration studies by Hatch and GE, but this threshold is now being applied to the sum total of solar PV and wind.

However, to the best of our knowledge, there has never been a transmission impact study or grid integration study to consider solar PV in Nova Scotia. Solar PV and wind energy have different characteristics, and to some extent will complement each other. The wind energy integration study is not applicable to solar PV integration.

For example, as detailed in Section 5 above, solar PV produces only in the daytime, when load is higher. Also, the weather patterns that affect solar PV and wind energy are not the same, therefore the varying power output of the two sources are not additive. A sudden drop in wind speed across the province, which can be a challenge for the Nova Scotia System Operator, is unlikely to correspond in time with a sudden change in availability of sunshine. Detailed study of weather patterns may reveal synergies between the two sources.

Furthermore, the addition of hydro-electricity access through the Maritime Link project should increase the ability of Nova Scotia to integrate various forms of local renewable generation, including solar PV. It is our understanding that the electric power supply from the Maritime Link will be dispatchable, and thus able to help smooth variations in supply and demand from all sources. This needs to be clarified and taken into account when considering the future room for solar PV on the grid.

We believe that an independent study of the grid integration requirements for distributed solar PV has not been done, and it should be done, by an independent third party, in anticipation of the continued growth in solar PV installations. This study is not immediately necessary, because in 2014 there is still not enough solar PV on the system to warrant it. But we predict that by the time the installed capacity of solar PV hits 10 MW in Nova Scotia (which is ten times what is installed now and could arrive sooner than we all think) it will be beneficial to have a grid integration study done for solar PV.

7. Solar PV in Community and Economic Development

Solar PV is the one renewable electricity generation technology that the most property owners can implement, because it has much less site-specific requirements for feasibility than wind energy. As we move through this transition to renewable energy, solar PV is an important tool for gaining participation and community support for the transition. One of the key benefits of the COMFIT program from the beginning has been the encouragement of community members to get involved in the sustainable energy transition. If the COMFIT included solar PV, it would be even more effective at engaging more community groups and leveraging private investment. If it were extended so that it encouraged individual property owners to install solar PV, all these benefits would be even more enhanced.

For every investment in a solar PV system in Nova Scotia, which is largely a private investment, a significant portion stays in Nova Scotia in the form of wages for the designers and installers, contracted services in the construction sector, and local fabrication of accessory components. The spin-off economic benefits from this are magnified within the local economy. Although the solar PV panels are not currently manufactured in Nova Scotia, they only represent about 1/3 of the installed cost, leaving a substantial portion of the other 2/3 of the investment as potentially available to the local economy.

Solar Nova Scotia would like to invite the provincial government to work together on an economic potential study to better understand the opportunities, benefits, barriers, and industrial strategies associated with the growing solar PV market in the Maritime region. We ask the question – what would it look like to have a robust solar PV industry in Atlantic Canada, led by Nova Scotian companies?

8. Subsidies

We are not asking for special treatment for solar. Subsidies for solar are only required to the extent that fossil fuel, nuclear, and other forms of energy continue to be subsidized. Solar needs and deserves a level playing field. That means if solar causes fewer externalities than another form of energy, it deserves a higher price. It means that if the production of another form of energy is subsidized, solar deserves the same subsidy. It also means that if all subsidies for fossil fuels are eliminated, and fossil fuels are required to internalize all externalities (such as air pollution, GHG emissions and resource depletion), solar will not need any subsidies.

One very positive way to start the process of internalizing the cost of producing energy from fossil fuels would be to implement pollution taxes as recommended in the recent Broten Report on Tax Reform.[5] Such an approach would help to stimulate economic development in Nova Scotia in low GHG industry sectors including solar. These are generally high employment industries, creating opportunities for net job creation. As indicated by Broten in her report, the revenues generated can be used to offset other taxes that currently stand in the way of economic development in Nova Scotia.

9. Renewables-to-Retail

Solar Nova Scotia recognizes that the new “Renewables-to-Retail” legislation from the provincial government, which allows companies to sell renewable electricity directly to customers, may present opportunities for further solar PV development in the province. However, we see the “Renewables-to-Retail” market as likely to be focused on relatively large generation projects (greater than 1 MW), while we see the major opportunities in solar PV being in the wide distribution of large numbers of relatively small projects (5 to 100 kW), supplying electricity on-site to property owners directly.

If there will be opportunities to develop solar PV in Nova Scotia through renewables-to-retail, much will depend on the conditions and regulations of the program, and especially on the tariffs established to be paid by renewable electricity generators for the use of transmission and distribution systems to reach their customers.

A related question is how the development of community solar gardens can be facilitated and encouraged. Community solar gardens are collectively-owned solar PV arrays, for which the multiple owners (individuals in the community) receive credit on their power bills. They are an extension of the net metering arrangement, for those who may not have appropriate space on their own property for a solar PV array, and who would like to pool their resources into a common array. Legislation to enable community solar gardens has passed in some US states, including Minnesota. We believe that the NS Department of Energy is currently thinking that “Renewables-to-Retail” will facilitate the development of community solar projects in Nova Scotia, but it may or may not. The community solar gardens program and “renewables-to-retail” are different in their structure and implementation. We would like to gain more clarity on how the provincial government plans to facilitate community-owned solar PV projects going forward.

As an organization, Solar Nova Scotia is interested to learn more about how the renewables-to-retail process will work, and to contribute to the discussion around its implementation.

[5] Broten, Laurel. Charting a Path for Growth: Nova Scotia Tax and Regulatory Review. November 2014.

10. Recommendations

(i) Improve and facilitate access to enhanced net metering interconnection agreements.

Solar Nova Scotia members are reporting unnecessary delays in getting interconnection agreements processed and signed by the system operator and inspectors for net-metered solar PV systems. The government needs to take action to facilitate access, by setting up or requiring NSPI to set up a simplified and standardized approval process with standard timelines to ensure that solar PV systems that meet the regulations are approved in an easier and timelier manner. The government should develop this by organizing meetings involving industry stakeholders and customers to determine the best way to facilitate solar PV interconnection agreements.

In the future, as net-metered solar PV installations grow in number and capacity, there will be debate about whether to limit net metering or impose extra fees on net metering customers to account for their use of the grid as a holding place for net-metered electricity. This debate is already occurring in several US states where net-metered solar PV is more prevalent. In Nova Scotia we are not yet at the point to need this debate, but we might as well be prepared for it. In a few years, when net-metered solar PV has reached a larger portion of the marketplace, we will want to have considered our policies around sharing the cost of using the grid. One policy we see that seems to hold promise today is the concept of a modest “minimum monthly bill” to cover the share of grid infrastructure that the customer uses for net metering.

Further to this, we recommend that the Province consider enacting legislation to allow community solar gardens, which are net-metered solar electricity installations that are co-owned by community members and located at a common site in the neighbourhood. Development of community solar gardens is being led by the State of Minnesota, which gives a good example of how this model is great for community economic development.

Consider also an award system that allows people who have reduced or shifted their winter peak demand to install and net meter a larger solar PV array. That will put the incentive on improving grid performance.

(ii) Start including plausible projections of solar electricity growth (and solar energy growth generally, including solar hot water and Passive Houses) in the models and planning processes for the electricity system.

Ignoring the growth of solar energy; (a) won’t make it go away, and; (b) would cause our province to miss the opportunity to take our part in this growing industry. Start planning for solar now.

Related to planning, we refer the provincial government to the QUEST report from 2013 on Planning for Solar Energy in Halifax Regional Municipality[6]. This research work considers issues such as land-use planning to optimize solar gain, right-to-light legislation to protect people's investments in solar energy systems, and heritage property considerations. Moving forward, we believe this work has great value in planning for increasing levels of solar energy usage.

Implementation of the recommendations in the QUEST report should not be left to municipalities; they should be implemented at a provincial level so that all municipalities can benefit from them. This is an area that requires regulations rather than voluntary measures because decisions about subdivision design and home construction are made by individuals who will not have to live with those choices for most of the life cycle of the subdivision or home.

(iii) Pay careful attention to the opportunities and conditions for medium-scale solar PV developments in the Renewables-to-Retail regulations and transmission tariffs that are being developed.

Ensure that conditions of transmission access are fair to proponents of medium-scale solar farms for retail sale direct to customers.

(iv) Support a comprehensive research project to study the regional economic opportunities presented by solar energy to Nova Scotia.

The province as a whole would benefit from having a clearer picture of the solar energy industry and its potential to create community economic development opportunities and jobs in Nova Scotia.

(v) Commission an independent study of grid integration needs for solar electricity.

Engage an independent third-party consultant to study the timing and productivity of distributed solar electricity in Nova Scotia and make recommendations on the process and costs of integrating growing amounts of solar electricity at the distribution level. This study is not urgently needed, because there is not yet enough solar electricity generation installed to have a significant impact on transmission needs. The occurrence of this study could be timed to coincide with when the amount of distributed solar PV on the Nova Scotia system reaches about 10 MW of capacity, in a few years time.

(vi) Enhance education of solar energy workers in Nova Scotia.

Work with Solar Nova Scotia, private industry partners, community organizations, the Nova Scotia Community College, and universities, to develop a province-wide, comprehensive education strategy to give workers the skills to work on solar energy projects. The main focus of this should be professional development for existing trades contractors, so that they can add solar energy to their list of offerings to customers.

[6] Planning for Solar Energy: Halifax Regional Municipality, Quality Urban Energy Systems of Tomorrow (QUEST), 2013.

Having a more effectively trained workforce and contractors will reduce the costs and increase the benefits of using solar energy in Nova Scotia. Make effective use of existing training support programs, charge for the training on a cost-recovery basis, and train on a flexible, “as-needed” basis.

11. Conclusion

We believe that solar energy, the largest source of readily accessible and zero-emission energy on the planet, has a significant role to play in the development of the green economy and a truly sustainable energy for Nova Scotia. We look forward to working in partnership with the Nova Scotia government to facilitate the dawn of that future.

Appendix A: Example Calculation of Internal Rate of Return (IRR)

Cost per watt	$3.62	Wh/yr/W	1150	Inflation:	
Cost/W incl HST	$4.16	Degradation/ yr	0.90%	Revenue	5.00%
Installed watts	5000	$/KWh now	$0.157	Expense	2.50%
Investment	$20,815	Maintenance			
		provision	0.50%	IRR	6.35%
Year				Sum NPV	0.00

Year	KWhr produced	% original productivity	$/KWh	Value of electricity production	Investment	Provision for maintenance	Net cash flow	Cumulative net cash flow
0					(20,815.00)		(20,815.00)	(20,815.00)
1	5,750.00	100.0%	$0.157	902.75		(104.08)	798.68	(20,016.33)
2	5,698.25	99.1%	$0.165	939.36		(106.68)	832.68	(19,183.65)
3	5,646.97	98.2%	$0.173	977.45		(109.34)	868.10	(18,315.54)
4	5,596.14	97.3%	$0.182	1,017.08		(112.08)	905.01	(17,410.54)
5	5,545.78	96.4%	$0.191	1,058.33		(114.88)	943.45	(16,467.09)
6	5,495.87	95.6%	$0.200	1,101.24		(117.75)	983.49	(15,483.60)
7	5,446.40	94.7%	$0.210	1,145.90		(120.70)	1,025.20	(14,458.40)
8	5,397.39	93.9%	$0.221	1,192.36		(123.71)	1,068.65	(13,389.75)
9	5,348.81	93.0%	$0.232	1,240.71		(126.81)	1,113.91	(12,275.84)
10	5,300.67	92.2%	$0.244	1,291.02		(129.98)	1,161.05	(11,114.79)
11	5,252.96	91.4%	$0.256	1,343.37		(133.22)	1,210.15	(9,904.65)
12	5,205.69	90.5%	$0.269	1,397.85		(136.56)	1,261.29	(8,643.35)
13	5,158.84	89.7%	$0.282	1,454.53		(139.97)	1,314.56	(7,328.79)
14	5,112.41	88.9%	$0.296	1,513.51		(143.47)	1,370.04	(5,958.75)
15	5,066.39	88.1%	$0.311	1,574.89		(147.06)	1,427.83	(4,530.92)
16	5,020.80	87.3%	$0.326	1,638.75		(150.73)	1,488.01	(3,042.90)
17	4,975.61	86.5%	$0.343	1,705.20		(154.50)	1,550.70	(1,492.21)
18	4,930.83	85.8%	$0.360	1,774.34		(158.36)	1,615.98	123.78
19	4,886.45	85.0%	$0.378	1,846.29		(162.32)	1,683.97	1,807.75
20	4,842.47	84.2%	$0.397	1,921.16		(166.38)	1,754.78	3,562.53
21	4,798.89	83.5%	$0.417	1,999.06		(170.54)	1,828.52	5,391.05

22	4,755.70	82.7%	$0.437	2,080.13		(174.80)	1,905.32	7,296.38
23	4,712.90	82.0%	$0.459	2,164.47		(179.17)	1,985.30	9,281.68
24	4,670.48	81.2%	$0.482	2,252.24		(183.65)	2,068.59	11,350.27
25	4,628.45	80.5%	$0.506	2,343.57		(188.24)	2,155.33	13,505.60
26	4,586.79	79.8%	$0.532	2,438.60		(192.95)	2,245.66	15,751.25
27	4,545.51	79.1%	$0.558	2,537.49		(197.77)	2,339.72	18,090.97
28	4,504.60	78.3%	$0.586	2,640.38		(202.72)	2,437.67	20,528.64
29	4,464.06	77.6%	$0.615	2,747.45		(207.79)	2,539.67	23,068.31
30	4,423.88	76.9%	$0.646	2,858.86		(212.98)	2,645.88	25,714.19
31	4,384.07	76.2%	$0.679	2,974.79		(218.30)	2,756.48	28,470.67
32	4,344.61	75.6%	$0.712	3,095.42		(223.76)	2,871.65	31,342.33
33	4,305.51	74.9%	$0.748	3,220.94		(229.36)	2,991.58	34,333.91
34	4,266.76	74.2%	$0.786	3,351.54		(235.09)	3,116.45	37,450.36
35	4,228.36	73.5%	$0.825	3,487.45		(240.97)	3,246.48	40,696.84
36	4,190.31	72.9%	$0.866	3,628.87		(246.99)	3,381.87	44,078.72
37	4,152.59	72.2%	$0.909	3,776.02		(253.17)	3,522.85	47,601.57
38	4,115.22	71.6%	$0.955	3,929.13		(259.50)	3,669.64	51,271.20
39	4,078.18	70.9%	$1.003	4,088.46		(265.98)	3,822.48	55,093.68
40	4,041.48	70.3%	$1.053	4,254.25		(272.63)	3,981.61	59,075.30
				86,905.22	(20,815.00)	(7,014.92)	59,075.30	

Appendix B: Levelized Cost of Electricity (LCOE) Calculations

LCOE is calculated according to the following formula, from the International Renewable Energy Agency (IRENA)[7]

$$\text{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

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.

[7] Renewable Energy Technologies: Cost Analysis Series, Volume 4/5, “Solar Photovoltaics”, International Renewable Energy Agency, June 2012.

Using the formula above, the following table is an excerpt from a spreadsheet in which we calculated the LCOE for solar PV, based on the high end of our cost assumptions ($3.62/W installed, and an 8% discount rate). The result is an LCOE of $0.291/kWh.

Spreadsheet example calculation:

		Installed			Annual	5-year
Installed	Annual	cost	Maintanance	Discount	Maintenance	Repair
Capac. (kW)	output		inflation	rate	Factor ($/kW)	Factor ($/kW)
14.75	decrease	$/W				
PV potential	0.007	3.62	0.025	0.08	5	100
1200						
kWh/kW year						
	Energy	Investment	Maintenance	Time value	Numerator	Denominator
Year	E(t) (kWh)	I(t)	M(t)	(1+r)^t	($)	(kWh)
1	17700	53395	73.75	1.00	53468.75	17700
2	17576.1	0	75.59	1.08	69.99	16274
3	17452.2	0	77.48	1.17	66.43	14962
4	17328.3	0	79.42	1.26	63.05	13756
5	17204.4	0	81.41	1.36	59.84	12646
6	17080.5	0	83.44	1.47	56.79	11625
7	16956.6	0	85.53	1.59	53.90	10686
8	16832.7	0	87.67	1.71	51.15	9822
9	16708.8	0	89.86	1.85	48.55	9027
10	16584.9	1475	92.10	2.00	783.94	8297
11	16461	0	94.41	2.16	43.73	7625
12	16337.1	0	96.77	2.33	41.50	7007
13	16213.2	0	99.19	2.52	39.39	6438
14	16089.3	0	101.67	2.72	37.38	5916
15	15965.4	1475	104.21	2.94	537.66	5436
16	15841.5	0	106.81	3.17	33.67	4994
17	15717.6	0	109.48	3.43	31.96	4588
18	15593.7	0	112.22	3.70	30.33	4214
19	15469.8	0	115.02	4.00	28.78	3871
20	15345.9	1475	117.90	4.32	369.09	3556
21	15222	0	120.85	4.66	25.93	3266
22	15098.1	0	123.87	5.03	24.61	2999
23	14974.2	0	126.97	5.44	23.35	2754
24	14850.3	0	130.14	5.87	22.16	2529
25	14726.4	0	133.39	6.34	21.04	2322
					56032.97	192310
					LCOE	
					($/kWh)	
					0.291	

The low end case is shown in the following table ($3.00/W installed, and a 5% discount rate). In this case the project owner is willing to count future benefits at a value of 5% per year, rather than 8%, and has obtained the best currently available (2014) price. The result is an LCOE of $0.196/kWh

Spreadsheet example calculation:

		Installed			Annual	5-year
Installed	Annual	cost	Maintanance	Discount	Maintenance	Repair
Capac. (kW)	output		inflation	rate	Factor ($/kW)	Factor ($/kW)
14.75	decrease	$/W				
PV potential	0.007	3	0.025	0.05	5	100
1200						
kWh/kW year						
	Energy	Investment	Maintenance	Time value	Numerator	Denominator
Year	E(t) (kWh)	I(t)	M(t)	(1+r)^t	($)	(kWh)
1	17700	44250	73.75	1.00	44323.75	17700
2	17576.1	0	75.59	1.05	71.99	16739
3	17452.2	0	77.48	1.10	70.28	15830
4	17328.3	0	79.42	1.16	68.61	14969
5	17204.4	0	81.41	1.22	66.97	14154
6	17080.5	0	83.44	1.28	65.38	13383
7	16956.6	0	85.53	1.34	63.82	12653
8	16832.7	0	87.67	1.41	62.30	11963
9	16708.8	0	89.86	1.48	60.82	11309
10	16584.9	1475	92.10	1.55	1010.17	10691
11	16461	0	94.41	1.63	57.96	10106
12	16337.1	0	96.77	1.71	56.58	9552
13	16213.2	0	99.19	1.80	55.23	9028
14	16089.3	0	101.67	1.89	53.92	8532
15	15965.4	1475	104.21	1.98	797.61	8064
16	15841.5	0	106.81	2.08	51.38	7620
17	15717.6	0	109.48	2.18	50.16	7200
18	15593.7	0	112.22	2.29	48.96	6803
19	15469.8	0	115.02	2.41	47.80	6428
20	15345.9	1475	117.90	2.53	630.36	6073
21	15222	0	120.85	2.65	45.55	5737
22	15098.1	0	123.87	2.79	44.46	5419
23	14974.2	0	126.97	2.93	43.40	5119
24	14850.3	0	130.14	3.07	42.37	4835
25	14726.4	0	133.39	3.23	41.36	4566
					47931.18	244474
					LCOE	
					($/kWh)	
					0.196	