Earth Rangers
28 kW PV Installation

Final Report – January 2012

Technology

Monitoring

Best Practices

SolarCity
Partnership

PROJECT SNAPSHOT

Address:	9520 Pine Valley Drive, Woodbridge, ON, L4L 1A6
Building Type and Use:	Aviary (A large enclosure designed to house birds, providing shade and space for them to fly).
Owner:	Earth Rangers Centre for Sustainable Technology
Owner Contact:	Andy Schonberger (Director, Earth Rangers Centre)
Phone #:	905-417-3447 ext. 2273
Email:	aschonberger@earthrangers.com
System type:	Roof-mounted grid-tied solar photovoltaic system
Array Angle:	22.62 degrees from horizontal
Azimuth:	Due South
String Configuration:	Each inverter is wired to 4 strings, with 6 modules per string. Total of 6 inverters (24 strings and 144 modules).
Module Manufacturer:	Sanyo
Module Model:	HIP-195BA3 (195 watt)
Number of Modules:	144
Inverter Manufacturer:	SMA
Inverter Model:	Sunny Boy 5000 US with RS485 board (5 kW)
Number of Inverters:	6
System Size (kW):	28.08
System Size (m^2):	170
Installation Date:	July 2008

PERFORMANCE

2008-2011 Actual* Performance:	1,130 kWh/kW/yr
RETScreen using local irradiance:	1,162 kWh/kW/yr
RETScreen using 20 year historical average:	1,127 kWh/kW/yr

*Includes estimations for 97 gaps in the daily yield data.

FINANCIAL

Installed Cost (taxes included):	$344,274
External Funding:	No external funding was received.
Annual Income:	$21,886
Simple Payback (excluding external funding):	15.7
Cost per kW (excluding external funding):	$12,260

MONITORING

Monitoring equipment installed:	Yes.
Overview of the monitoring plan:	Energy production data is accessible through the Sunny Portal web display, which quantifies output at hourly, daily, and monthly intervals.
Cost of M&V :	No external costs. Earth Rangers staff are responsible for monitoring.
Who is analyzing the data?	Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program.
Is there a dedicated staff person responsible for system operation management?	Director of Earth Rangers Centre, Andy Schonberger.

SUMMARY

The Earth Rangers Aviary 28 kW photovoltaic system located at 9520 Pine Valley Drive in Woodbridge, ON, was installed for a cost of $344,274 in July 2008. Over the 3 year monitoring period, the system has produced an average yield of 1,130 kWh/kW/yr. Based on historical weather, the system is projected to generate $21,886 per year in revenue for the Earth Rangers Centre. It is expected that simple payback will be achieved in 15.7 years, which is within the typical range for similar PV systems in the GTA installed between 2006 and 2009.

The Earth Rangers PV system performed slightly below expecations based on local irradiance and temperature data over the three year monitoring period. Since the array is situated within close proximity to tall trees, shading may be contributing to the low system yield.

BACKGROUND

Earth Rangers is a non-profit organization that engages youth in biodiversity conservation and habitat protection initiatives across Canada. The organization is based out of the Earth Rangers Centre for Sustainable Technology, which is certified Gold under LEED® for New Construction. Numerous green technologies are showcased at the Earth Rangers Centre, including two solar photovoltaic systems. A 57.6 kW tracking array is located in the parking lot, and a 28.08 kW array is fixed on the roof of the aviary. The scope of this report is limited to the aviary PV system.

The aviary array was installed in July 2008 at a cost of $344,274. Earth Rangers chose to participate in the Province of Ontario's Feed-In Tariff (FIT) program, which allows the organization to sell electricity to the local utility at a rate of 71.3 cents per kWh. The FIT contract became active late in January 2011. The aviary array, in conjunction with the solar tracking system, provides numerous benefits to the Earth Rangers Centre, including:

- reduction in demand for energy derived from fossil fuels;
- generation of income from the sale of surplus electricity to the Ontario grid;
- diversification of the local energy supply; and
- advancement of knowledge and technical expertise relating to the operation of PV systems in the Greater Toronto Area.

Special Site Considerations

Numerous days in the winter months (a total of 77 days over the 3 year monitoring period) displayed zero or near-zero energy production totals, even under sufficient irradiance conditions. This pattern is characteristic of snow effects, but other possible causes of the low winter productivity, such as shading, should be investigated.

There are tall trees growing in the vicinity of the Earth Rangers aviary array, and potential shading effects would be most pronounced in the winter months when the sun is lowest in the sky. It is recommended that a shading analysis be performed at this site.

PERFORMANCE ANALYSIS

RETScreen Model Parameters

RETScreen was used to predict expected yield. Table 1 shows the key parameters in the two RETScreen scenarios. The first uses a 16% loss factor derived from the California Energy Commission guidelines[1] and historic irradiance and temperature data from a Toronto weather station (RET20yr). The second also incorporates a 16% loss factor, but uses local irradiance and temperature data over the same three year period that actual production data were available (RET3yr). Both scenarios assume 1% miscellaneous losses and inverter efficiency of 95.5% (as rated by the California Energy Commission).

Table 1. Key parameters in the different RETScreen scenarios.

RETScreen Input	RET20yr	RET3yr
Annual solar radiation (kWh/m^2 on a horizontal surface)	1,310	1,340
Annual average daily irradiance (kWh/m^2/d)	3.59	3.66
Annual average ambient temperature (C)	7.2	8.1
CEC weighted inverter efficiency	95.5%	95.5%
PV array losses	16%	16%
Miscellaneous power conditioning losses	1%	1%

Actual Performance vs. RETScreen Simulations

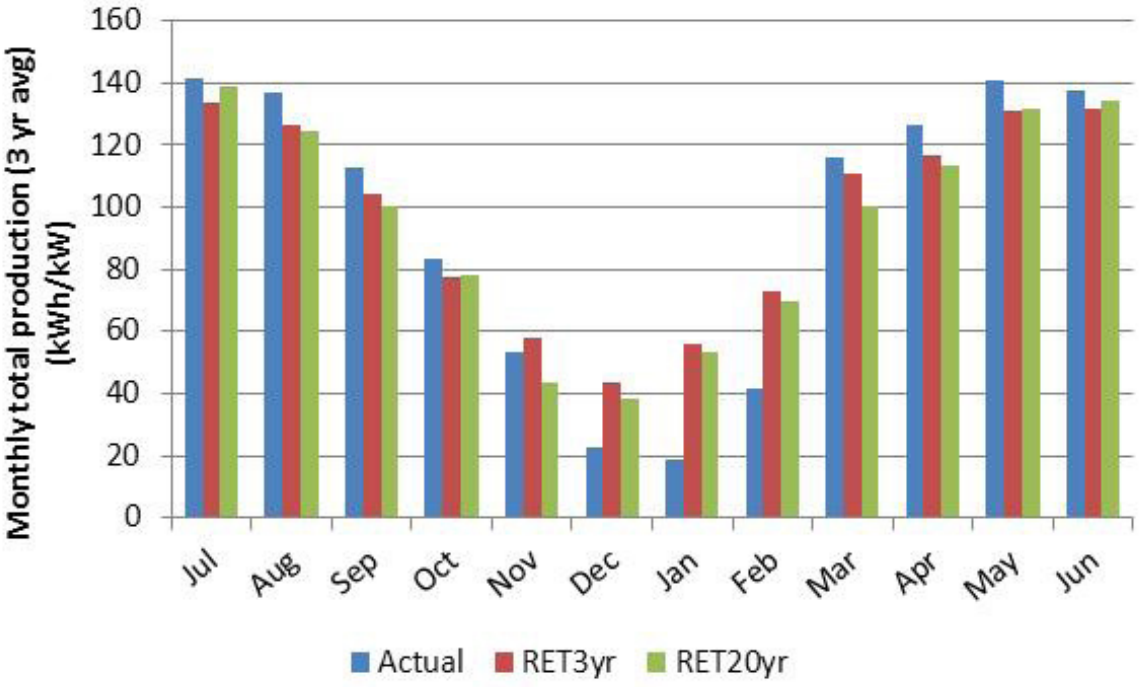
Actual array output is compared to RETScreen estimated production in Figure 1. The RET20yr data scenario best represents actual production at the site. Three year average actual yield (2008-2011) was 31,736 kWh/yr, or 1,130 kWh/kW/yr, which is 0.3% higher than simulated yield derived from historic irradiance. Actual yield was 2.7% lower than simulated yield derived from local irradiance.

1 California Energy Commission, 2001. A Guide to Photovoltaic (PV) System Design and Installation: Consultant Report. The 16% derate only includes loss factors such as STC tolerance, dirt and dust, mismatch and wiring that are relevant to the Earth Rangers site.

The RET3yr data scenario should best represent actual production, because it is based on local irradiance and temperature measurements during the monitoring period. Since actual yield was slightly below RET3yr simulated yield, shading of the array may be occurring. Given the system's close proximity to tall trees, further investigation is warranted.

On a monthly basis, using the RET3yr model as a benchmark, actual yield was less than expectations during the late fall and winter (November through February) by an average of 41%. Similar patterns of low winter yield relative to expectations have been observed at other sites with PV systems in the GTA, and are likely due in part to the fact that the RETScreen program does not account for snow cover. During the remaining months of the year, energy yield was an average of 6.7% above expectations. Refer to Appendix 2 for plots of simulated energy production over three years.

Figure 1. Actual* vs. RETScreen simulated performance (2008-2011 averages by month).



*All gaps in the daily production data were estimated using RETScreen (97 days total).

BUSINESS CASE

The Feed-in Tariff (FIT) contract pays a fixed price for energy produced by the Earth Rangers Aviary PV system for the next 20 years. Although this PV project was originally implemented under Ontaro's Renewable Energy Standard Offer Program (which would have provided income at a rate of 42 cents/kWh), it was grandfathered into the FIT program in 2010. This business case assumes FIT income for the entire payback period.

To evaluate the business case, a RETScreen analysis using historical irradiance and ambient temperature data was used to simulate energy production and associated income for the next 20 years. The RET20yr model used in the business case was modified to include a derate factor of 18.5%, which was the derate that best fit the actual production data over the three year monitoring period.

Table 2 presents the business case for the Earth Rangers Aviary PV Project. This analysis predicts an array output of 30,695 kWh/yr (1,093 kWh/kW/yr), which would provide $21,886 of income per year at the current Feed-in Tariff rate of 71.3 cents/kWh. The simple payback for this scenario would be 15.7 years. Assuming that the system continues to function over a minimum 16 year period, Earth Rangers stands to gain significant revenues from the project.

Table 2. Earth Rangers Aviary PV Project: Business Case

	Total cost installed	Array output (kWh/yr)	Annual income from electricity sales	Simple payback (years)
Adjusted feasibility study (using RET20yr model)	$344,274	30,695	$21,886	15.7

Installed System Costs

The total cost of the system, including materials and labour, was $344,274, or $12,260 per kW installed. No external grants were received, so the project was funded entirely by the Earth Rangers Centre.

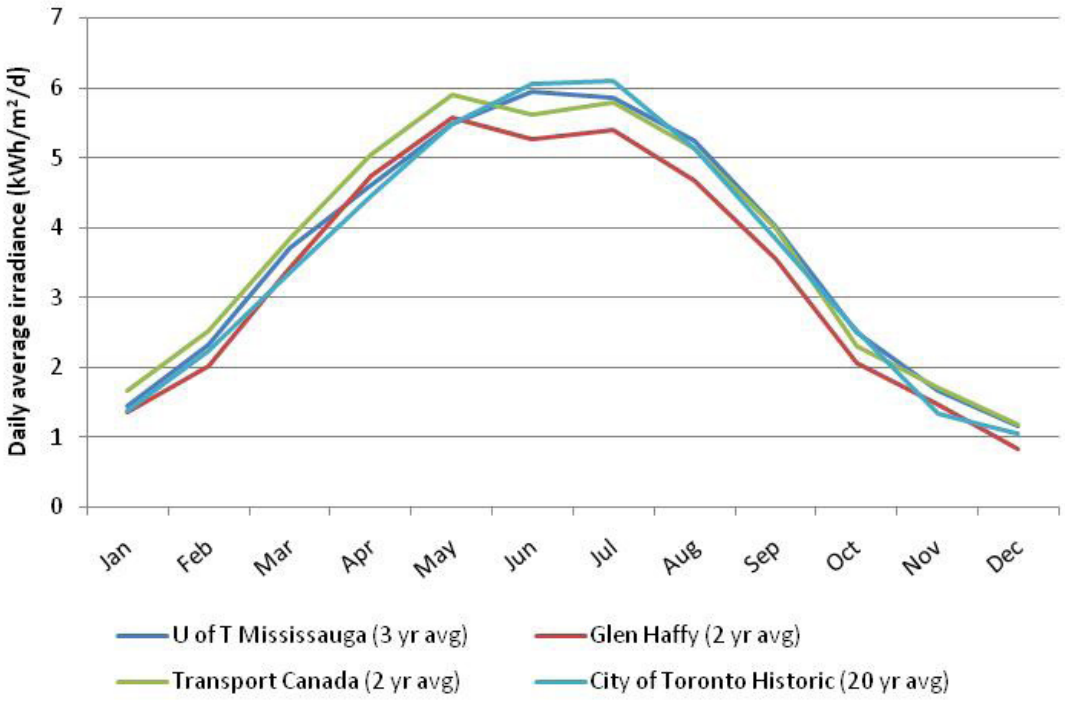
Feed-in Tariff Issues

There were no major challenges in the procurement or implementation of the FIT contract. The process, from the application stage to the commencement of the contract, lasted 14 months.

APPENDIX 1: MONTHLY IRRADIANCE DATA

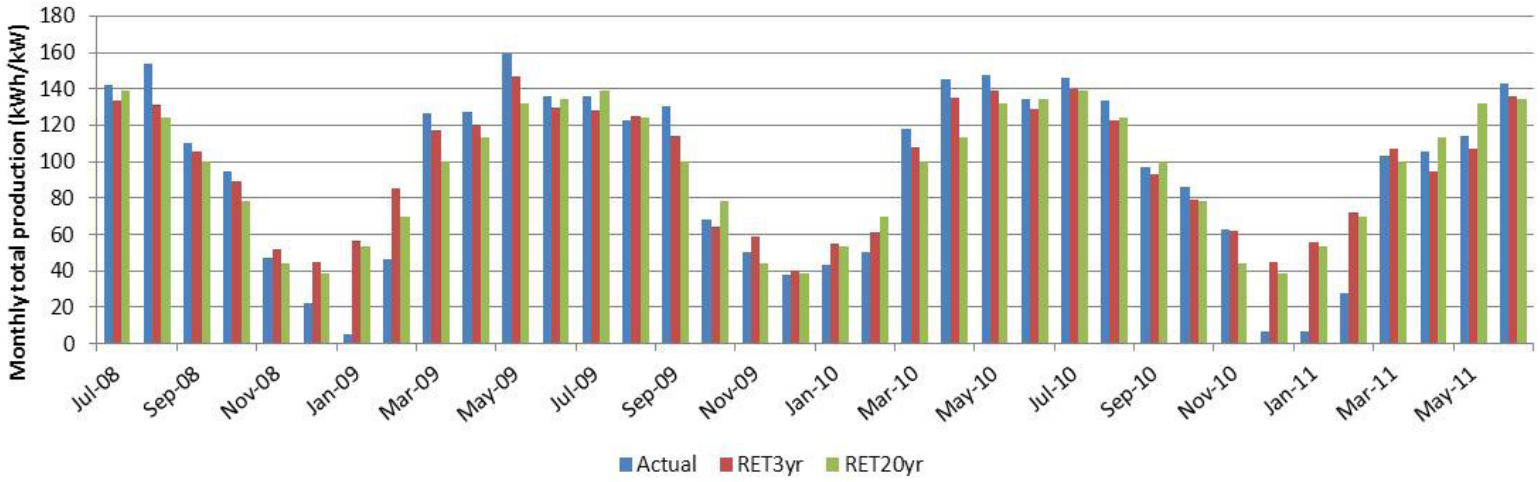
Solar irradiance measured at various sites in the Greater Toronto Area is displayed in Figure A1. Since there were large gaps in the Earth Rangers weather station data (greater than 6 months of gaps over 3 years), irradiance and temperature measurements from the University of Toronto Mississauga Meteorological Station (UTMMS) were used as a proxy in the RET3yr model. In order to evaluate the accuracy of the UTMMS pyranometer, irradiance data measured at this station were compared with data measured at other sites in the GTA and with Environment Canada's 20 year average for the City of Toronto. On an annual basis, irradiance measured at UTMMS was 8.9% above that measured at Glen Haffy, 1.6% below that measured at Transport Canada, and 2.3% above Environment Canada's 20 year average for the City of Toronto.

Figure A1. Average daily irradiance in the Greater Toronto Area (2008-2011).



APPENDIX 2: MONTHLY ENERGY PRODUCTION

Figure A2. Actual* vs. RETScreen simulated performance over the 3 year monitoring period.



*All gaps in the daily production data were estimated using RETScreen (97 days total).

APPENDIX 3: VALIDATION OF ESTIMATION METHOD

Estimations were only performed for gaps in the daily energy production data (97 days total). Production data were estimated using the RETScreen program as follows:

1. Using on-site irradiance and temperature data, the RETScreen derate factor that best fit the production data for each month was obtained. If a large number of days (>25%) in a given month had data gaps or production < 1 kWh, the average derate of the month before and the month after was used.

2. For each day on which a data gap occurred, the daily irradiance and temperature data measured on-site and the derate factor obtained in Step 1 were input into RETScreen.

3. Since RETScreen simulates monthly total production, the projected energy output was divided by the number of days in the month in order to obtain the total for that day only.

In order to validate the estimation method, the difference between actual production and the RETScreen models was compared for both estimated and un-estimated data. The un-estimated dataset spans the one year period from August 2008 through July 2009, during which time no data gaps occurred. The estimated dataset represents the 3 year averages over the entire monitoring period (July 2008 through June 2011). This dataset contains estimations for gaps in the daily production data (the estimation method is described in the 'Performance Analysis' section).

The results of this comparison are displayed in Table A1 and Figures A3 and A4. In general, the difference between actual and simulated energy output was similar between the estimated and un-estimated data, with the exception of January and August. The large discrepancy in January can be explained by the particularly low production in 2009 when compared with the 3 year average (71% below average). In August 2008, energy output was 13% greater than the 3 year average. Since the difference between actual and expected output between the two datasets was relatively consistent (within 4%) in all other months, the estimation method was considered to be valid.

Table A1. Estimated and actual monthly production vs. RETScreen simulated yield.

Month	Yield data including estimations (3 year averages)		Yield data excluding estimations (1 year)	
	Energy yield (kWh/kW)	Difference from RET3yr model	Energy yield (kWh/kW)	Difference from RET1yr model
January	18.6	-66.8%	5.4	-90.5%
February	41.5	-42.9%	46.4	-45.5%
March	116.0	4.5%	126.6	7.7%
April	126.1	7.9%	127.2	5.4%
May	140.5	7.3%	159.4	8.2%
June	137.7	4.9%	135.8	4.9%
July	141.5	5.7%	136.1	6.0%
August	136.8	8.1%	154.0	17.2%
September	112.5	7.9%	110.2	4.3%
October	83.1	7.1%	94.7	6.6%
November	53.4	-7.5%	47.0	-9.1%
December	22.6	-47.9%	22.6	-49.9%
Annual total	1,130	-2.7%	1,165	-3.5%

Figure A3. Actual vs. RETScreen simulated performance when no data gaps occurred (2008-2009).

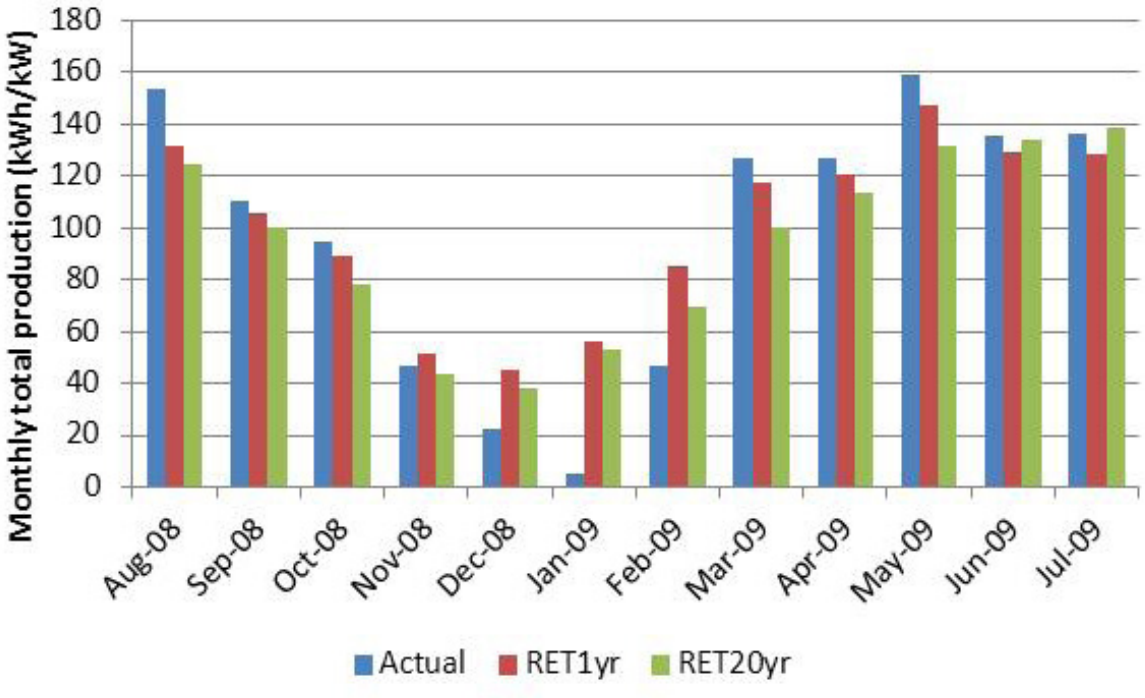
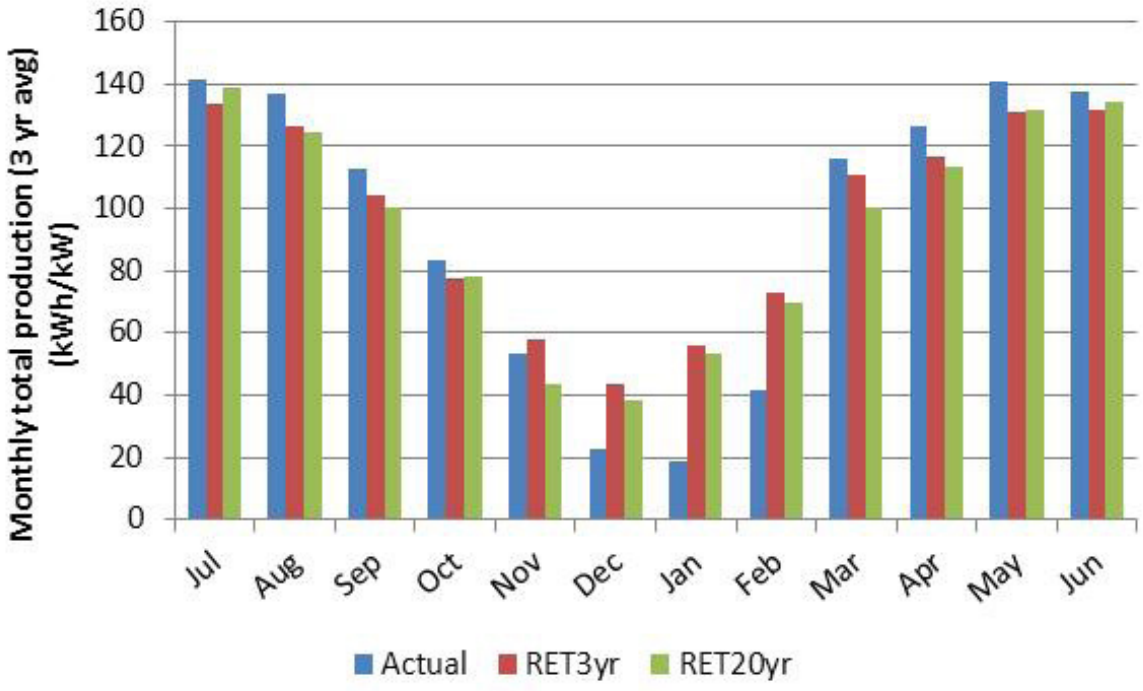


Figure A4 (Figure 1). Actual* vs. RETScreen simulated performance (2008-2011 averages by month).



*All gaps in the daily production data were estimated using RETScreen (97 days total).

About the SolarCity Partnership

The SolarCity Partnership was developed to provide third party monitoring of large urban solar installations and develop best practice recommendations based on independent project evaluations. The Partnership is an information-sharing hub for both public and private organizations involved in deploying solar power. Our SolarCityPartnership.ca website provides case studies, research, and solar radiation data to help with the effective use of zero emissions energy from the sun.

Supporting Partners

The SolarCity Partnership was founded in 2008 by the Toronto Atmospheric Fund, the City of Toronto Energy and Waste Management Office, and the Toronto and Region Conservation Authority, with support from the Federation of Canadian Municipalities Green Municipal Fund. Phase 2 of the Partnership, co-ordinated by the Toronto and Region Conservation Authority, has expanded to include solar facility assessments across the Greater Toronto Area with funding support from the Region of Peel and York Region, and in-kind contributions from various site partners.

We want to hear from you!

If you have further best practice recommendations, insights into system design, deployment or maintenance or a project to profile, please get involved with the SolarCity Partnership! Contact us at:

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