Toronto Parking Authority
21 kW PV Installation

Final Report – January 2012

Technology

Monitoring

Best Practices

SolarCity
Partnership

PROJECT SNAPSHOT

Address:	2 Church Street at Esplanade, Toronto
Building Type and Use:	Parking garage
Owner:	Toronto Parking Authority
Owner contact:	Remy Iamonaco, P.Eng., Vice President, Design, Construction & Maintenance, Toronto Parking Authority
Phone #:	(416) 393-7335
Email:	riamonaco@toronto.ca
System type:	Wall-mounted grid-tied photovoltaic system
Array Angle:	65 degrees from horizontal
Azimuth:	15 degrees East of South
String Configuration:	4 strings of 10 panels per inverter (total of 12 strings)
Module Manufacturer:	Sharp
Module Model:	mono-Si NT-175U1 175 watt
Number of Modules:	120
Inverter Manufacturer:	SMA
Inverter Model:	SB7000US
Number of Inverters:	3, 7 kW
System Size (kW):	21
System Size (sq. meters):	156
Installation Date:	August 2009

PERFORMANCE

2010 Actual Performance:	1,132 kWh/kW
RETScreen using local irradiance:	1,063 kWh/kW
RETScreen using 20 year historical average:	1,018 kWh/kW

FINANCIAL

Installed Cost (taxes included):	$269,740
External Funding:	$50,000 from Toronto Environment Office
Annual Income:	$16,247
Simple Payback (excluding external funding):	16.6 years
Cost per kW (excluding external funding):	$12,845

Photo provided by Carmanah.

MONITORING

Monitoring equipment installed:	Yes
Overview of the monitoring plan:	Fat Spaniel monitoring system. Monitored parameters include on-site radiation, cell and ambient temperature, wind speed and direction. Energy production is monitored via three inverters.
Cost of M&V :	2.3% of total project cost
Who is analyzing the data?	Unknown
Is there a dedicated staff person responsible for system operation management?	No

SUMMARY

The Toronto Parking Authority's 21 kW photovoltaic system at 2 Church Street generated approximately 1,132 kWh/kW in 2010, which was 6.5% higher than simulated yield derived from local irradiance. Designed to take advantage of Ontario's Feed-in Tariff (FIT) program which pays owners for the electricity produced by their system, the system was installed in 2009 for $269,740. Based on historical weather, the project will achieve a simple payback in 16.6 years before external grants and 13.5 years after. Had the site not required a boom lift rental and the creation of an electrical room, the financial case would have been more attractive.

The project experienced extra costs and significant delays in securing a Feed-in Tariff contract due to changes in the contract's grid connection rules. Once finalized in early 2012, the twenty-year FIT contract should pay for the cost of the system and provide a reliable revenue stream for the Toronto Parking Authority for years after.

BACKGROUND

In 2006, Toronto Parking Authority staff participated in the City of Toronto's Renewable Energy Action Plan Working Group established by the City's Executive Environment Committee to advance the development of renewable energy in Toronto. One of the group's initiatives was the Photovoltaic Feasibility Study to identify corporate structures suitable for the installation of a photovoltaic system. The TPA offered six possible garages. St. Lawrence Garage at the foot of Church Street was most favourable, as the rear wall of the building faces due south and is free of obstructions to sun radiation.

In December 2006 the TPA Board authorized funding from the capital budget for the installation of a photovoltaic system at the St Lawrence Garage. The Project would be a 20 kilowatt system with a capacity to generate 20,000 kilowatt hours annually. The intention was to sell the power generated back to the local utility through the Renewable Energy Standard Offer Program (RESOP was replaced by the FIT program in 2009).

After a long period of consultation, a 21 kilowatt system was installed in the summer of 2009 at a cost of $269,740.

Other important objectives of the initiative were to demonstrate the Toronto Parking Authority's commitment to sustainability and to help build capacity for large PV systems in Toronto.

Special Site Considerations

The PV modules were installed on the wall of the parking garage at a steep angle, 65 degrees from horizontal, to alleviate concerns about vandals climbing or sitting on the system. A boom lift was rented to install the panels on the wall.

An electrical room was created to house the system's electrical equipment.

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[2] and temperature data over the same one year period that actual production data were available (RET1yr). 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	RET1yr
Annual solar irradiance on horizontal surface (kWh/m2)	1,301	1,360
Annual average daily irradiance (kWh/m2/d)	3.59	3.72
Annual average ambient temperature (°C)	7.2	9.2
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 RET1yr data scenario best represents actual production at the site, as it is based on local irradiance and temperature measurements. Actual yield for 2010 was 23,780 kWh, or 1,132 kWh per kW installed, which is 6.5% higher than simulated yield derived from local irradiance. Actual yield was 11.2% higher than simulated yield derived from historic irradiance. Projected output was lower under the RET20yr scenario because irradiance conditions observed during the monitoring period were slightly more favourable than the historic average (3.59 kWh/m^2/d historically vs. 3.72 in 2010).

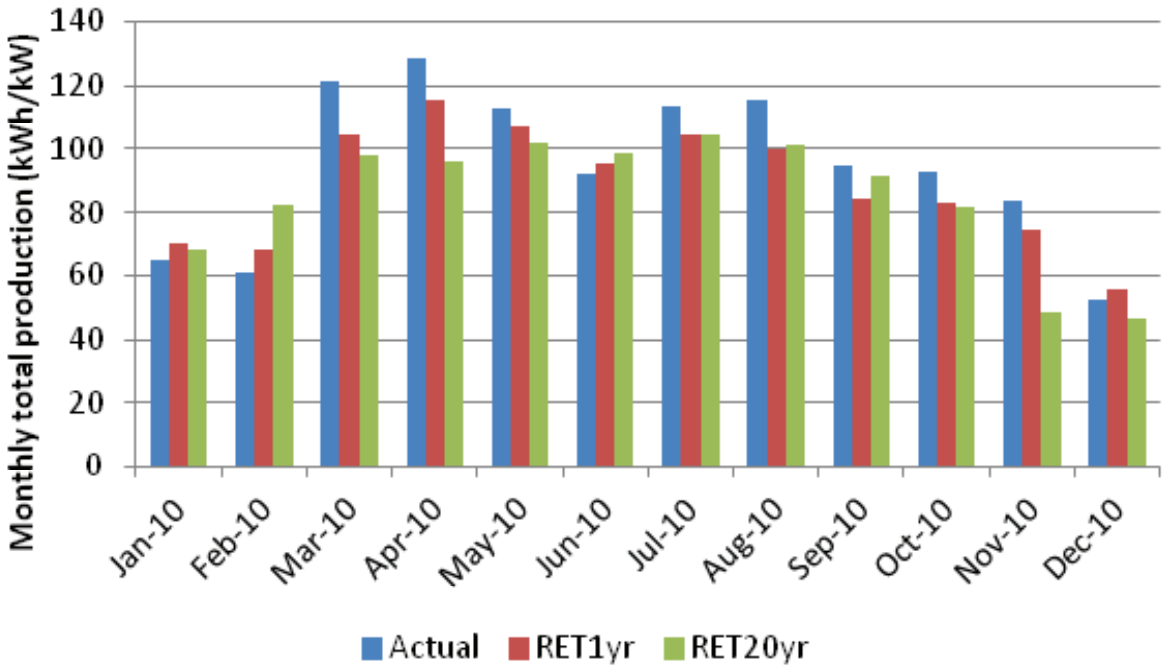
On a monthly basis, using the RET1yr model as a benchmark, actual yield was less than expectated during the winter (December through February) by an average of 8.3% as well as in the month of June by 3.1%. Similar patterns of low winter yield relative to expectations have been observed at other PV systems in the GTA, and are likely due in part to the fact that the RETScreen program does not account for snow cover. The low total for June is likely due to the month being unusually overcast.[3] During the remaining months of the year, measured yield exceeded expectations by an average of 11.6%.

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 Toronto Parking Authority site.

2 Irradiance data from the on-site pyranometer were not used in the RET1yr model because the measurements were unreasonably high. Instead, irradiance and temperature data from the University of Toronto Mississauga meteorological station were incorporated into the local model. Refer to Appendix 1 for details.

3 Based on data from Environment Canada, 2010

Figure 1. 2010 Actual* vs. RETScreen simulated performance



* Missing data from January 1 – 18 were estimated using an average of daily production from Jan 20-31 multiplied by 90 percent. This estimated difference between early- and late-January production is based on the corresponding difference in on-site radiation data.

Some evidence of shading was found in the hourly data spanning January to July 2010 (hourly data was not provided for the latter half of the year). The shading seems to appear in late May, occurring for about an hour around 1PM. The hour over which shading occurs migrates to a later part of the day as the dates progress towards peak summer, arriving at 4PM or 5PM in July. Comparison of data from the three inverters shows less than 0.5% difference in output between any two sets of the three 7 kW arrays. Thus losses to shading can be considered negligible.

BUSINESS CASE

The Feed-in Tariff contract pays a fixed price for energy produced by the Toronto Parking Authority's PV system for the next 20 years. 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 10.5%, which was the derate factor that best fit the actual production data over the one year monitoring period.

Table 2 presents the business case for the Toronto Parking Authority PV Project. This analysis predicts an array output of 22,787 kWh/yr (1,085 kWh/kW/yr), which would provide $16,247 of income per year at the current Feed-in Tariff rate of 71.3 cents/kWh. The simple payback for this scenario would be 16.6 years before grants and 13.5 years after. Assuming that the system continues to function over a minimum 14 year period, the Toronto Parking Authority stands to gain significant revenues from the project.

Table 2. Parking Authority PV Project: Business Case

	Total Cost Installed	Grants	Array Output (kWh/yr)	Income from Electricity Sales	Simple Payback (years)	Payback after grants (years)
Adjusted Feasibility Study (using modified RET20yr model)	$269,740	$50,000	22,787	$16,247	16.6	13.5

Installed System Costs

The breakdown of installed system costs are shown in Table 3. The total cost of the system was $269,740, or $12,845 per kW installed. Materials and construction accounted for approximately 70% of the total cost. Some expenses unique to this site included the rental of a lift truck to install the wall mounted panels, and construction of an electrical room. Toronto Environment Office provided $50,000 for the project, bringing the final project cost down to $219,740, or $10,464 per kW installed.

Feed-in Tariff Issues

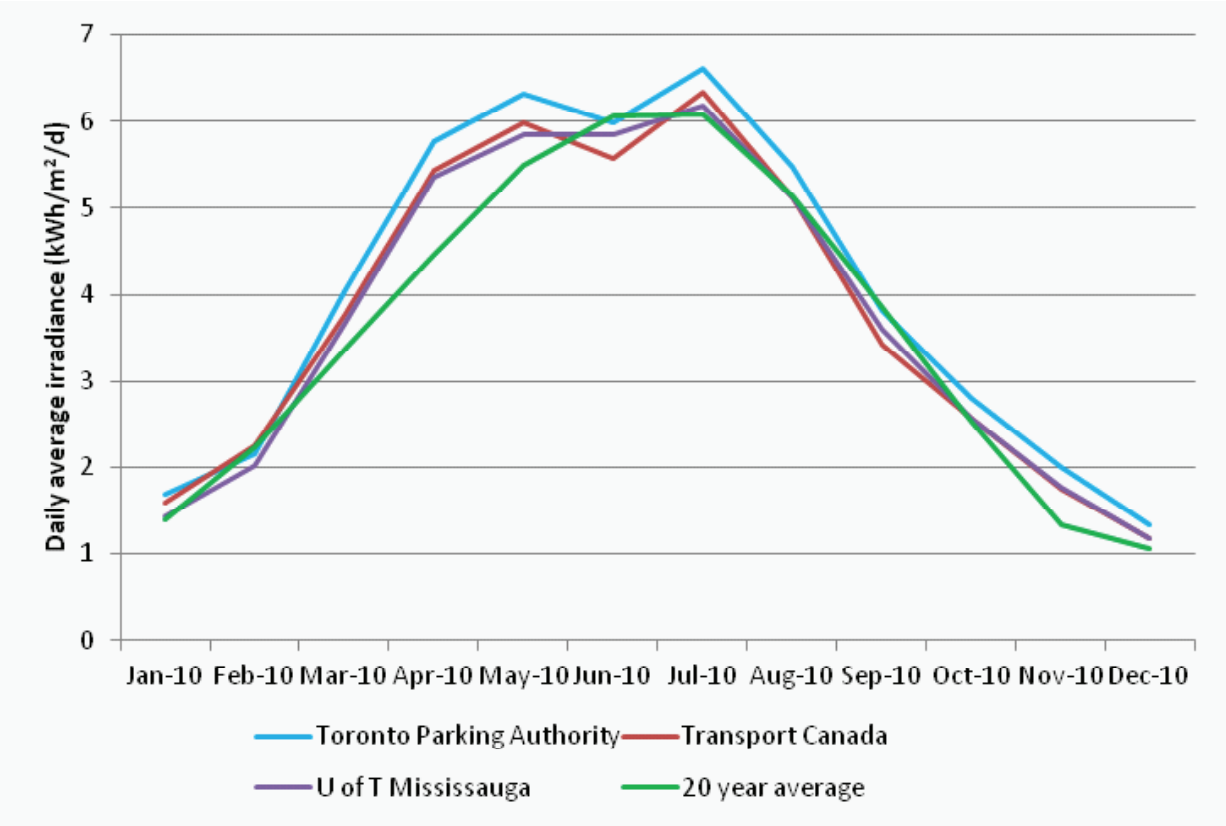
The project experienced significant delays in securing a Feed-in Tariff contract due to changes in the contract's grid connection rules. After the system was installed, the Toronto Parking Authority was informed that inorder to qualify for a FIT contract, the system had to be connected to the grid in parallel – a significant change from the previous in series connection requirement. The grid connection change added unexpected costs, which are still to be confirmed but projected to be less than $10,000, and delayed the start date of the Feed-in Tariff contract and associated revenue. Even considering the delays and extra costs, the project will achieve a payback within the life of the Feed-in Tariff contract and continue to produce clean electricity for many years after.

Table 3. As-Built Cost Breakdown

Cost Items	Component Costs	Percent of Total Cost
General Requirements		
Performance bonds	$5,250	1.9
Shop drawings	$1,000	0.4
Building Permits/Approvals	$1,400	0.5
Structural Work		
Design/Engineering/Approvals	$7,500	2.8
Materials and construction	$57,880	21.5
Electrical Work		
Design engineering approvals	$11,500	4.3
Supply/installation of conduit/wiring/boxes/ painting	$3,160	1.2
Photovoltaic System		
PV modules	$119,523	44.3
Balance of system	$6,976	2.6
Commissioning of PV Systems	$2,500	0.9
Monitoring System		
Supply, installation and commissioning of monitoring	$6,116	2.3
General		
Final commissioning of system	$2,500	0.9
Start-up and acceptance test	$1,250	0.5
On-site training for complete system	$1,250	0.5
Warranty	$5,000	1.9
Freight	$7,535	2.8
Project Management		
Project management	$2,400	0.9
Consulting costs	$27,000	10.0
Total Cost (tax included)	**$269,740**	
External funding	$50,000	
FINAL TOTAL	**$219,740**	

APPENDIX 1: IRRADIANCE DATA

Figure 3. Average daily irradiance in the Greater Toronto Area (2010).



Solar irradiance measured at various sites in the GTA is displayed in Figure 3. Over the 2010 monitoring period, average daily irradiance measured at the Toronto Parking Authority was 4.00 kWh/m2/d. This is 6.4% higher than at Transport Canada (3.76 kWh/m2/d), 7.3% higher than at the University of Toronto Mississauga (3.72 kWh/m2/d), and 11.3% higher than Environment Canada's 20 year average for the City of Toronto (3.59 kWh/m2/d).

The Toronto Parking Authority array is located near the waterfront, and therefore may receive slightly elevated levels of solar radiation due to reflection from Lake Ontario. However, when compared with other sites, a difference in irradiance of more than 5% was considered to be unreasonably large, and may indicate a problem with the pyranometer. Therefore, irradiance data measured using a reliable instrument located at U of T Mississauga were used in the RET1yr model.

About the SolarCity Partnership

The SolarCity Partnership is a joint initiative of the Toronto Atmospheric Fund, Toronto and Region Conservation Authority and the City of Toronto designed to promote best practices and careful monitoring of large solar installations. SolarCity 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 weather data to help with the effective use of zero emissions energy from the sun.

Toronto Atmospheric Fund

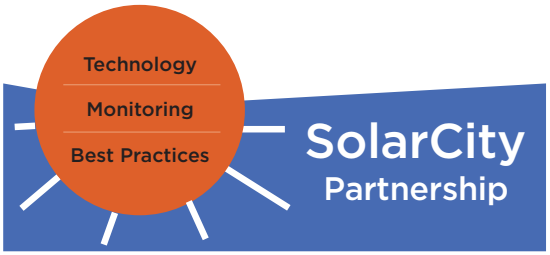
Toronto and Region Conservation for The Living City

Toronto

FCM | Green Municipal Fund / Fonds municipal vert

We want to hear from you!

If you have further best practices 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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