Toronto Fire Station #424
1.2 kW PV Installation

Final Report – January 2012

Technology

Monitoring

Best Practices

SolarCity
Partnership

PROJECT SNAPSHOT

Address:	462 Runnymede Road, Toronto, ON
Building Type and Use:	Fire Station $424
Owner:	City of Toronto
Owner contact:	Joel Arthurs
Phone #:	416-392-5177
Email:	jarthur@toronto.ca
System type:	Roof-mounted grid-tied solar photovoltaic system
Array Angle:	40 degrees from horizontal
Azimuth:	10 degrees West of South
String Configuration:	6 modules per string, 1 string
Module Manufacturer:	Sanyo
Module Model:	HIP-200BA3 200 watt
Number of Modules:	6
Inverter Manufacturer:	Xantrex
Inverter Model:	GT2.5-NA-DS-240
Number of Inverters:	1 (2.5 kW)
System Size (kW):	1.2
System Size (sq. meters):	7
Installation Date:	December 2006

PERFORMANCE

3 year average actual performance:	831 kWh/kW
RETScreen using 3 year average local irradiance:	1,166 kWh/kW
RETScreen using 20 year average irradiance:	1,109 kWh/kW

FINANCIAL

Installed Cost (taxes included):	$16,056
External Funding:	$0
Annual Income:	$761
Simple Payback (excluding external funding):	21.1 years
Cost per kW (excluding external funding):	$13,380

Photos provided by Lucio Mesquita

MONITORING

Monitoring equipment installed:	Yes
Overview of the monitoring plan:	WattNote LonWorks AC power measurer. Monitored parameters include AC current (A) and AC power (W) produced by the inverter.
Cost of M&V :	Unknown
Who is analyzing the data?	City of Toronto Energy & Waste Management Office
Is there a dedicated staff person responsible for system operation management?	No

SUMMARY

The City of Toronto's 1.2 kW photovoltaic system at Fire Station #424 was installed in 2006 at a cost of $16,056. Designed to take advantage of Ontario's microFIT program, the system generated an average of 831 kWh/kW/yr over 3 years, which would have resulted in an average annual revenue of $818 for the City. Array yields were almost 30% less than expected because of shading from an adjacent chimney and ground faults that caused the system inverter to shutdown periodically. The system is connected to the grid but is offline and undergoing repairs. Once the repairs are complete, microFIT payments will begin. Model simulations for this system without losses from shading and other factors predict annual long term yield of 1109/kWh/kW, annual revenue of $1091 and a simple payback of 14.7 years. This case study demonstrates the importance of careful installation and maintenance of PV systems.

BACKGROUND

In December 2006, the City of Toronto implemented a 1.2 kW photovoltaic pilot project at Toronto Fire Station #424. The PV system provides energy from a renewable source, which reduces both the financial and environmental costs of operating the fire station. The project demonstrates the City's commitment to renewable energy development and greenhouse gas reduction targets.

Special Site Considerations

Poor system performance and inconsistent data logging (intermittent 0 values for daily total energy production) were observed throughout the monitoring period, mostly during the winter months. A site visit was conducted in November 2011 to establish the cause of these issues.

One major problem at the site was the existence of a ground fault (meaning that current from the array is escaping the circuit and being conducted to ground by other system components). Not only is this a shock hazard, but it also causes a loss in productivity, since the inverter has a built in mechanism to shut itself down once a ground fault is detected. Ground faults can be triggered by moist conditions and then cease when the system dries out, so ground faults may have been causing the inverter to shut down periodically.

A second issue observed at the site was damage to the wire insulation of the array (teeth marks were visible) caused by animals. The location of the wire damage was determined not to be the source of the ground fault, but repairs are nonetheless required.

The data logger display was observed to be flickering. Upon inspection, poor connections were found in the power cord. As well, one of the current transducers was loosely attached to the inverter's power wiring, which may have caused inaccurate readings.

To test for shading of the array, a Solar Pathfinder analysis was conducted. A small amount of shading occurred late in the day. This was evident in hourly production data relative to other non-shaded sites. Although this resulted in reduced energy yield, it was not enough shading to stop production altogether.

It is recommended that the array be removed and reinstalled, correcting the ground faults that are likely near the midpoint on the series string of modules. Array wiring should be covered by a protective sheath, and a barrier should be constructed to keep animals out.

PERFORMANCE ANALYSIS

Actual yield was compared to RETScreen simulations to assess performance of the system and provide a basis for predicting long term energy yield and revenue.

RETScreen Model Parameters

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 three year period that actual production data were available (RET3yr). Both scenarios assume 1% miscellaneous losses and inverter efficiency of 94% (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 horizontal surface)	1,301	1,357
Annual average daily irradiance (kWh/m^2/d)	3.59	3.71
Annual average ambient temperature (°C)	7.2	8.0
CEC weighted inverter efficiency	94%	94%
PV array losses	16%	16%
Miscellaneous power conditioning losses	1%	1%

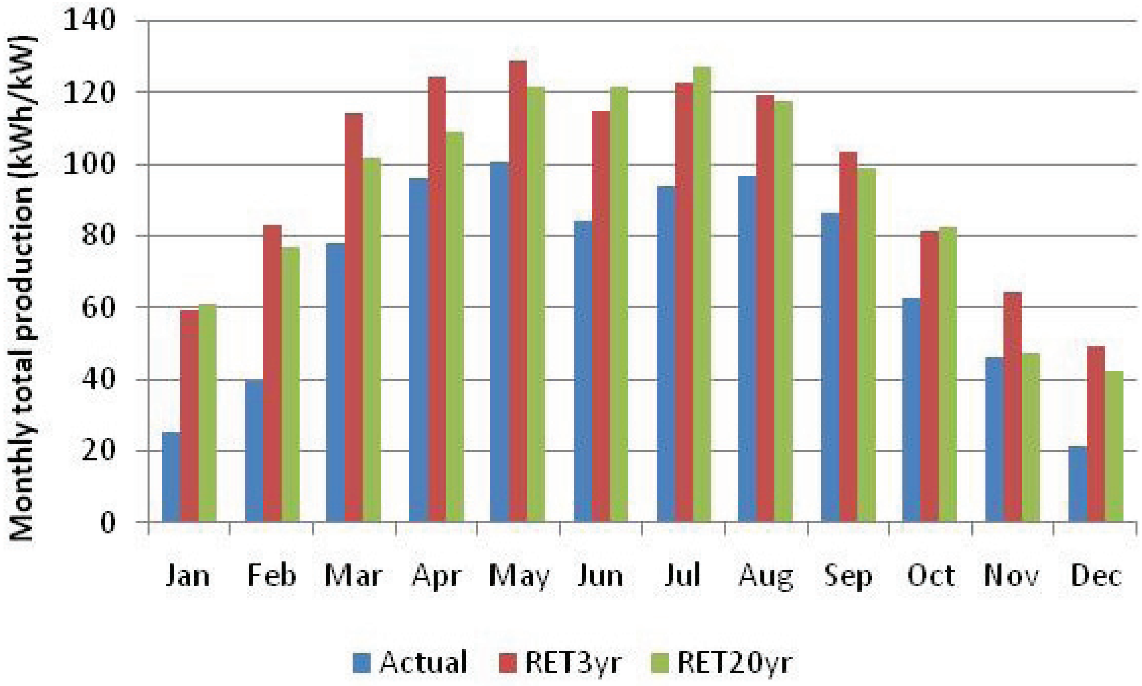
1 California Energy Commission, 2001. A Guide to Photovoltaic (PV) System Design and Installation: Consultant Report. The 16% derate only includes loss factors such as STC tolerance, dirt and dust, mismatch and wiring that are relevant to the Fire Hall #424 site.

2 Since an on-site pyanometer was not installed at Fire Station #424, irradiance and temperature data from the University of Toronto Mississauga meteorological station were incorporated into the RET3yr model. Refer to Appendix 1 for details.

Actual Performance vs. RETScreen Simulations

Three year average actual array output is compared to RETScreen estimated production in Figure 1 and Table 2 (Refer to Appendix 2 for plots of actual production by year). The RET3yr data scenario should best represent actual production at the site, as it is based on local irradiance and temperature measurements during the monitoring period. Actual yield averaged over three years was 997 kWh, or 831 kWh per kW installed, which is 28.8% lower than simulated yield derived from 3 years of local irradiance.

Figure 1: Actual* vs. RETScreen simulated performance (3 year averages)



*Actual yield was 25.1% lower than simulated yield derived from 20 years of 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. 3.71 from 2008-11).

On a monthly basis, using the RET3yr model as a benchmark, actual yield was consistently less than expectations over all 3 years, and became progressively worse with time. In the winter months (December through February), actual yield was an average of 55.4% less than expectations. In winter 2010-11, performance was particularly poor; the system apparently was not producing energy for 63 of the 90 days from December through February. During the remaining 9 months of the year (March through November), actual yield was less than simulated yield by an average of 23.7%.

Table 2: Actual vs. RETScreen simulated performance by year

Year	Energy yield (kWh/kW)		
	Actual	RET3yr	RET20yr
2008	929	1,156	1,109
2009	892	1,178	
Apr 2010 – Mar 2011*	672	1,166	
3 year average	**831**	**1,166**	**1,109**

*The complete month of March 2011 yield data was not available, so March 2011 actually consists of data from March 1-27, 2011 and March 28-31, 2010. Average daily irradiance in March 2010 was within 2% of that in March 2011, so this was considered to be a reasonable substitution.

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. However, in this the case, the numerous technical issues identified at the site were also an important factor affecting system performance not only during the winter, but throughout the year (see operation and maintenance section below).

BUSINESS CASE

The Feed-in Tariff contract pays a fixed price for energy produced by Toronto Fire Station #424'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 an array loss factor factor of 40.1%, which was the factor that best fit the actual production data over the three year monitoring period (Adjusted Feasibility Study A).

The 40.1% loss factor is very high because it represents the PV system when it was not operating at optimal capacity. A second analysis was performed using a 16% array loss factor (Adjusted Feasibility Study B), which was same as that used in the early modeling scenario. Comparative data from other rooftop solar arrays in the GTA indicate that this loss factor is conservative when systems are functioning well and there is no shading. This scenario would likely be a better representation of the system once the on-site technical issues have been addressed.

Table 3 presents the business case for the Toronto Fire Station #424 PV project. Based on Adjusted Feasibility Study A, this analysis predicts an array output of 949 kWh/yr (791 kWh/kW/yr), which would provide $761 of income per year at the current microFIT rate of 80.2 cents/kWh. The simple payback for this scenario would be 21.1 years, which is much longer than usual. If the system were repaired and functioning according to design, a shorter payback and annual revenue of $1091 would be more likely (scenario B in Table 3). The business case should be reassessed once the recommended repairs have been made to the system.

Table 3: Fire Station #424 PV Project Business Case

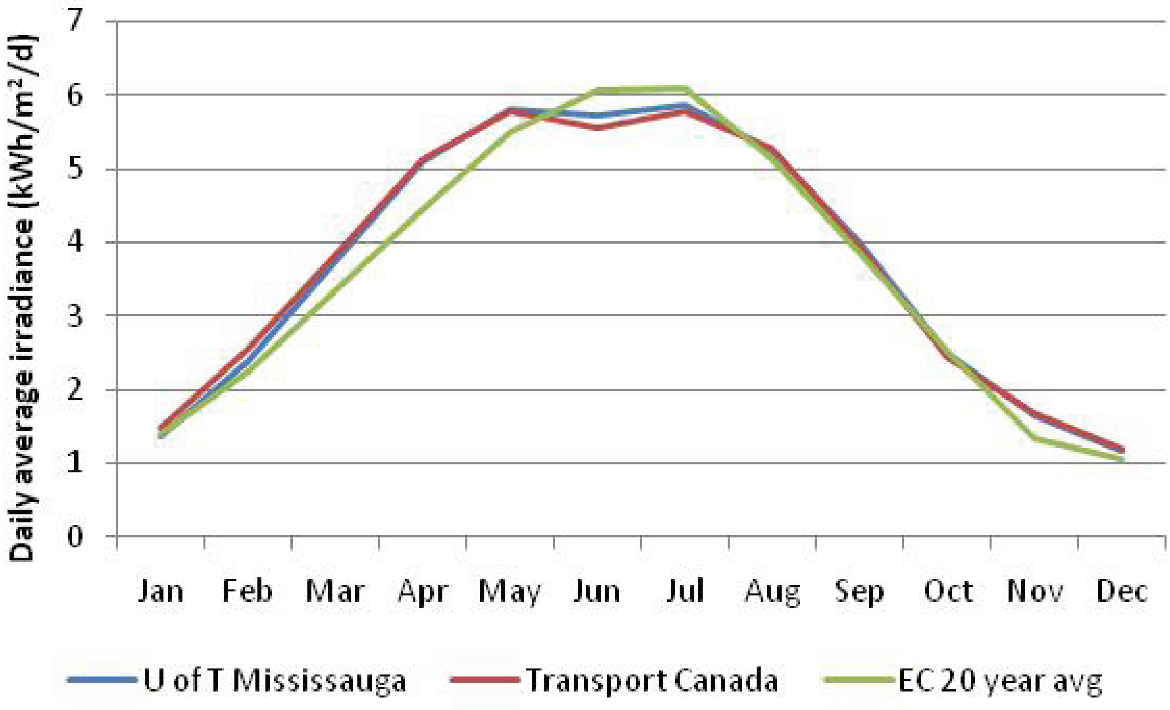
	Total Cost Installed	Grants	Array Output (kWh/yr)	Annual Income from Electricity Sales	Simple Payback (years)
Adjusted Feasibility Study A (40.1% array loss factor)	$16,056	$0	949	$761	21.1
Adjusted Feasibility Study B (16% array loss factor)	$16,056	$0	1,331	$1,091	14.7

Installed System Costs

The total cost of the system was $16,056, or $13,380 per kW installed. The City of Toronto was responsible for the entire cost (no grants were received).

APPENDIX 1: IRRADIANCE DATA

Figure 2: Three year average daily irradiance in the Greater Toronto Area (2008, 2009, Apr 2010 – Mar 2011)



Solar irradiance measured at various sites in the GTA is displayed in Figure 2. Since a weather station was not installed at Fire Station #424, data from a reliable station located at the University of Toronto Mississauga were used in the RET3yr model.

Over the 3 year monitoring period (2008, 2009, and April 2010 through March 2011), average daily irradiance measured at U of T Mississauga was 3.71 kWh/m^2/d. This is 0.2% lower than irradiance measured at Transport Canada (3.72 kWh/m^2/d) and 3.5% higher than Environment Canada's 20 year average for the City of Toronto (3.59 kWh/m2/d).

APPENDIX 2: ENERGY PRODUCTION

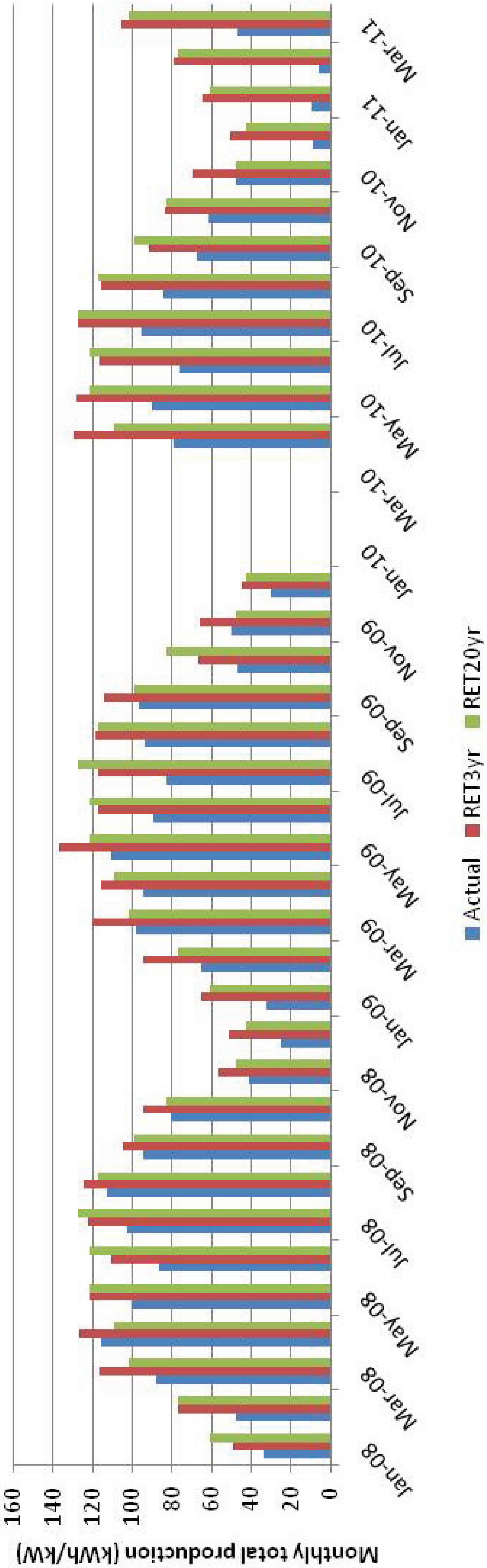


Figure 3: Actual* vs. RETScreen simulated performance over the 3 year monitoring period

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.

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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