Toronto Water
86.4 kW PV Installation

Final Report – January 2012

Technology

Monitoring

Best Practices

SolarCity
Partnership

PROJECT SNAPSHOT

Address:	201 Copperfield Road, Toronto
Building Type and Use:	F.J. Horgan Water Treatment Plant
Owner:	Toronto Water
Owner Contact:	Bernard Tung, Engineering Technologist Technician
Phone #:	416-392-0961
Email:	btung@toronto.ca
System type:	Building-integrated grid-tied solar photovoltaic system
Array Angle:	0 degrees from horizontal
Azimuth:	10 degrees
String Configuration:	2 modules in series to form a source circuit. Number of parallel strings: 60 source circuits (120 modules total).
Module Manufacturer:	Solar Integrated Technologies (USA)
Module Model:	SI-G1 720 watt
Number of Modules:	120
Inverter Manufacturer:	SatCon Power Systems
Inverter Model:	PVS-100 (480V) (100 kW)
Number of Inverters:	1
System Size (kW):	86.4 kW total
System Size (sq. meters):	1,913 m^2
Installation Date:	October 2009

PERFORMANCE*

December 2010	
Actual Performance:	15.0 kWh/kW
RETScreen using on-site irradiance:	30.6 kWh/kW
RETScreen using 20 year historical average:	26.6 kWh/kW
July 2011	
Actual Performance:	144.0 kWh/kW
RETScreen using on-site irradiance:	147.1 kWh/kW
RETScreen using 20 year historical average:	148.1 kWh/kW

*One complete year of production data was not available, so a seasonal analysis was conducted using data from one winter month and one summer month

Photo by Rob McMonagle

FINANCIAL

Installed Cost (taxes included):	$1,050,000
External Funding:	None
Annual Income*:	$59,332
Simple Payback (excluding external funding):	17.7 years
Cost per kW (excluding external funding):	$12,153

*Based on RETScreen expected yield

MONITORING

Monitoring equipment installed:	Yes
Overview of the monitoring plan:	A web-based performance monitoring system is installed that measures PV system status and power production. A weather station on site records numerous environmental parameters including solar irradiance, wind speed and direction, ambient temperature, rainfall level, humidity/dew point, and barometric pressure.
Cost of M&V :	Unknown
Who is analyzing the data?	Toronto Water
Is there a dedicated staff person responsible for system operation management?	No

SUMMARY

Toronto Water's 86 kW building-integrated photovoltaic system at the F.J. Horgan Water Treatment Plant is expected to generate approximately 967 kWh/kW/yr, once fully operational. 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 $1,050,000. Based on historical weather, the project should achieve a simple payback in 17.7 years.

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 roof and PV system, and provide a reliable revenue stream for the Toronto Water for years after.

BACKGROUND

When the time came for Toronto Water to replace the roof on a building at the F.J. Horgan Water Treatment Plant, numerous types of green initiatives were considered. A vegetated green roof was assessed, but the roof structure was found to be incapable of supporting such a system. A conventional photovoltaic system was also evaluated. Conventional (non-flexible) PV panels are typically mounted at an angle on a rooftop, requiring individual mounting and support brackets. A system of this type would have necessitated structural reinforcement of the roof, greatly increasing the cost of the installation. Conventional PV systems can cost up to 60% more than thin film systems.

Toronto Water therefore chose to install a more cost-effective building-integrated photovoltaic system, which would act as both a roof and a power generator. Installed in October 2009 at a cost of $1,050,000, this project was the first of its kind in Canada, showcasing Toronto Water's commitment to sustainability. It was designed to take advantage of the Ontario Power Authority's Feed-in Tariff (FIT) program, allowing Toronto Water to sell electricity to the grid at a rate of 71.3 cents per kilowatt hour. This enabled Toronto Water to generate a payback for their roof replacement while producing clean electricity.

Special Site Considerations

It should be noted that the total cost of the installation does not account for the costs that would have been incurred for a conventional roof replacement (the cost of the PV itself would have been less than the total reported here).

During a site visit in September 2010, pooling of water was observed on portions of the photovoltaic laminates (PVLs). This is due to the orientation of the strings relative to the pitch of the roof. Since the pitch is so gradual and the strings are in a portrait configuration, water is dammed by the slightly elevated top and bottom ends of the PVLs.

This pooled water appears to be trapping dirt and dust, which has resulted in visible soiling of the array. This may eventually cause power degradation and even module failure. At the time of the site visit, construction was occurring, so the building was surrounded by a large amount of exposed earth. When the construction has been completed, soiling may no longer be a concern.

On-site construction at the Horgan Plant required that the PV system be shut down for a large portion of 2010, but energy production and monitoring recommenced in June 2011.

PERFORMANCE ANALYSIS

RETScreen Model Parameters

Since a complete year of energy production data were not available, a seasonal analysis was performed using data from one month in winter and one month in summer (Figure 2). Measured energy yield was 1,298 kWh (15.0 kWh/kW) in December 2010 and 12,438 kWh (144.0 kWh/kW) in July 2011. The month of December is based on data from December 15, 2010 to January 14, 2011, and the month of July is based on data from July 7 to August 6, 2011.

There were seven days in December 2010 with total production less than 1 kWh, which caused the monthly total to be lower than that observed at most other sites in the GTA during the same period. These low production days were likely caused by snow cover on the PV system, which for obvious reasons, accumulates and remains in place for longer than on racked systems (refer to the 'Snow cover analysis' section for details). No days with total production less than 1 kWh were measured in July 2011.

RETScreen was used to predict expected yield. It should be noted that the RETScreen database of PV systems does not contain the Solar Integrated brand installed at Horgan. However, it does contain the Uni Solar PVL model, which is the identical panel used by Solar Integrated. Therefore, the Uni Solar PVL-136W panel was used in the RETScreen analysis. Since the Uni Solar modules are 136W and the Solar Integrated modules are 720W, an increased number of Uni Solar modules were used in the simulation in order to match the capacity of the Horgan PV system (86.4 kW).

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 on-site irradiance and temperature data over the same one year period that actual production data were available (RETOnSite). Both scenarios assume 1% miscellaneous losses and inverter efficiency of 96% (as rated by the California Energy Commission).

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.

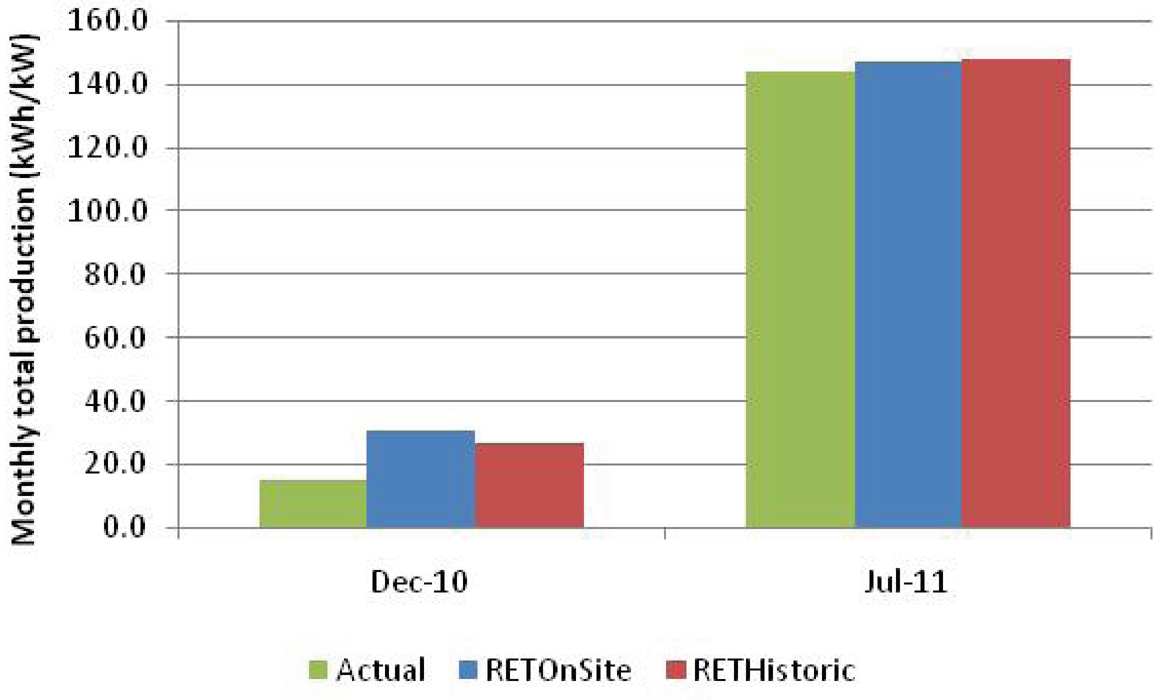
Table 1. Key parameters in the different RETScreen scenarios.

RETScreen Input	RET20yr	RETOnSite
Average daily irradiance in December 2010 (kWh/m²/d)	1.05	1.21
Average daily irradiance in July 2011 (kWh/m²/d)	6.09	6.07
CEC weighted inverter efficiency	96%	96%
PV array losses	16%	16%
Miscellaneous power conditioning losses	1%	1%

Simulation results

In December 2010, the RETHistoric scenario was most accurate, predicting output 76.9% greater than actual yield. In July 2011, the RETOnSite scenario most closely modeled actual production, predicting output 2.2% greater than actual yield. Overall, the most accurate model was RETHistoric, projecting output an average of 39.9% above actual yield (Figure 1).

Figure 1. Actual and simulated energy production of the Horgan PV system in 2010-11.



Since the RETOnSite model is based on local irradiance data, it is used as a benchmark for PV production. Under this scenario, actual production was less than expectations in both months of the monitoring period. Actual yield was less than simulated yield by 50.8% in December 2010 and by 2.1% in July 2011.

At most other study sites in the GTA, the energy output of PV systems has been observed to fall below expectations in the winter, and exceed expectations in the summer. Data from the Horgan PV system do not follow this pattern. Yield remained below expectations in both seasons, especially in December of 2010. Horizontal panels are more susceptible to accumulations of dirt, dust, and other debris if not properly maintained. Since the Horgan PV system was shut down for construction for the majority of 2010, it is possible that the panels were not as frequently maintained that year as they were in summer 2011 when PV production recommenced.

The large difference between simulated and measured energy production in the winter month was likely caused by the presence of snow on the panels. As noted above, the orientation of the panels relative to the pitch of the roof has been observed to cause pooling of water at the downstream end of the strings. In this scenario, snowmelt is less likely to drain effectively from the panels. Since RETScreen does not account for snow cover, this reduces the accuracy of the RETScreen models in December 2010.

ENERGY YIELD OF TWO HORIZONTAL PV SYSTEMS IN THE GTA

Comparison of monthly energy production

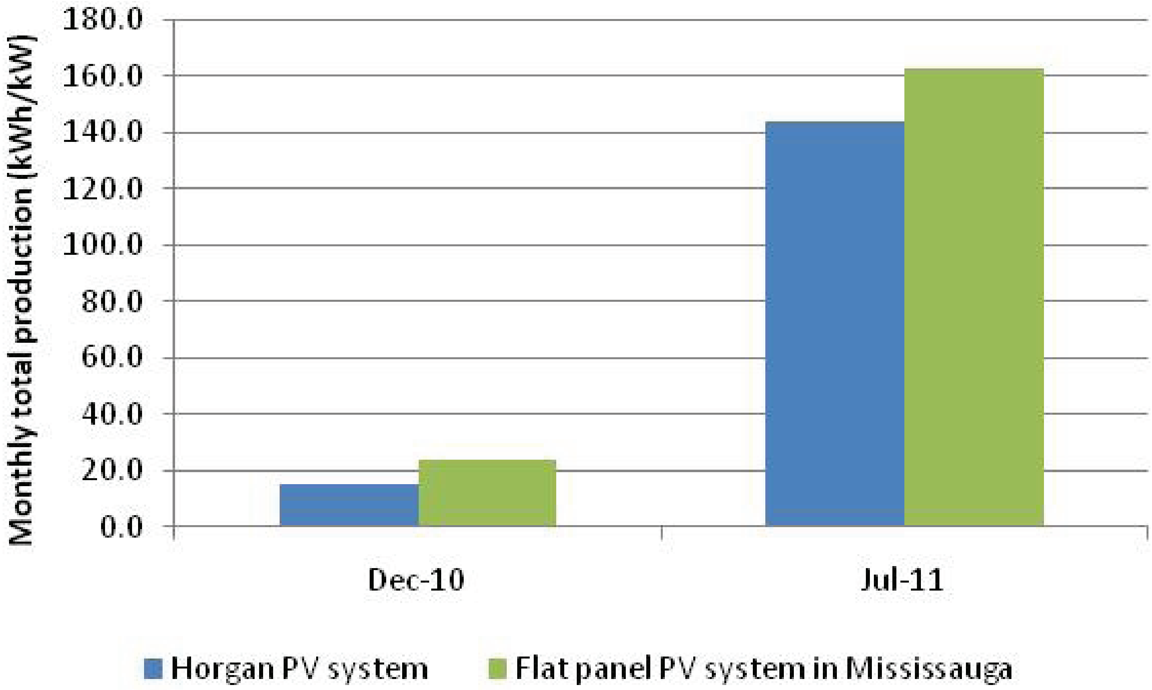
Energy output of the Horgan PV was compared to the output of another horizontal PV system, located in Mississauga (Figure 2). Total output of the Horgan array was 36.4% below that of the flat PV system in Mississauga in December 2010 and 11.6% below in July 2011. Refer to Appendix 1 for plots of daily production totals. Irradiance measurements from the two PV sites and a meteorlogic station in Toronto are compared in Appendix 2.

Comparison of energy production on high yield days

Energy production of the Horgan PV system and that of the flat panel PV system in Mississauga was compared when both systems were functioning well without snow. That is, the yield of the two systems was compared on the top 10 highest productivity days.

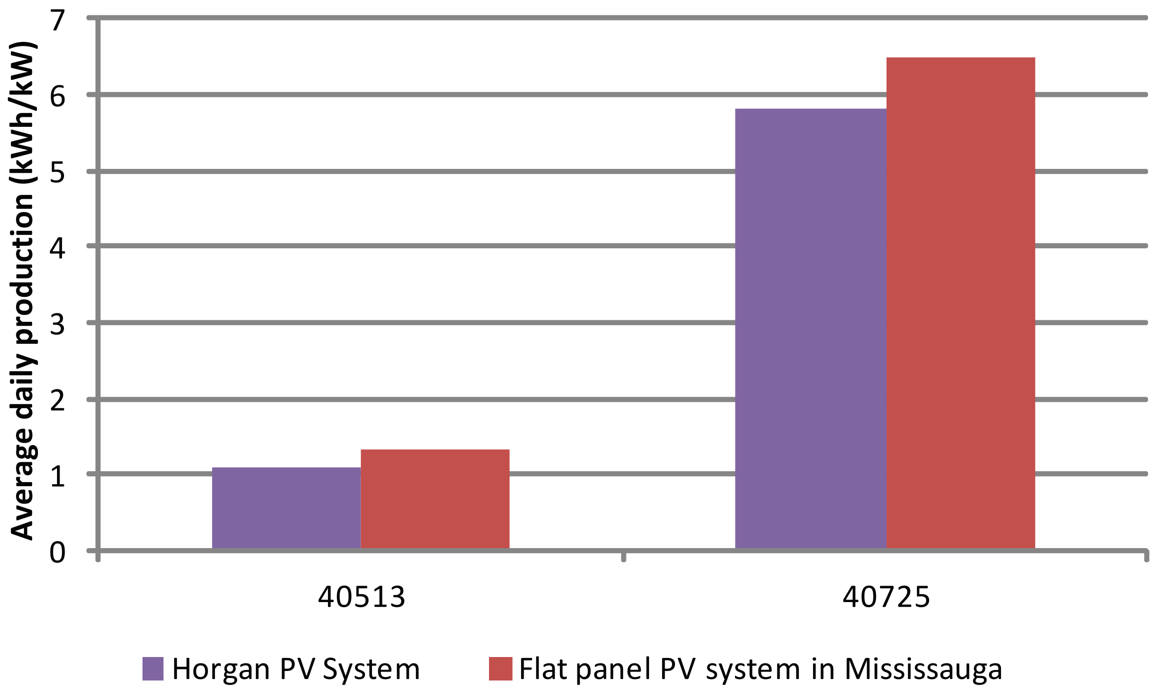
When the yield of each PV on high yield days was averaged for each month, the Horgan system had lower performance than the flat panel system in Mississauga in both months of the monitoring period (Figure 3). The average of high yield days from the Horgan PV was below that from the flat panel PV in Mississauga by 18.1% in December 2010 and by 10.5% in July 2011.

Figure 2. Measured energy production of two flat PV systems in the GTA.



The difference in productivity between the two flat panel PV systems may be partly explained by the difference in efficiency of the panels installed at each site. The SI-G1 720 modules used on the Horgan roof have an efficiency of 6.3%, while the Sanyo HIP-205 NKHB1 modules used in the flat system in Mississauga have an efficiency of 16.3%.

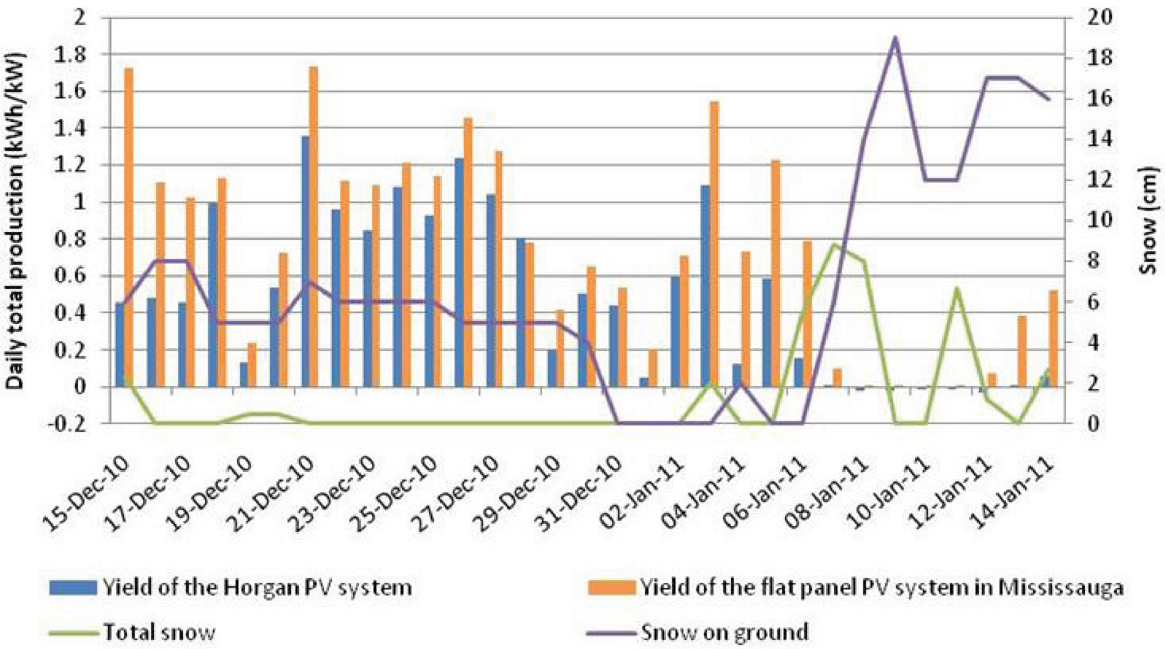
Figure 3. Average daily energy yield on high production days at two flat panel PV systems in the GTA.



Snow cover analysis

Snow cover data were obtained for the winter monitoring period because snow is more likely to build up on horizontal arrays and affect production (Figure 4). When the daily data were analyzed, there was no a statistically significant relationship between either measurement of snow cover and energy production. However, it appears that in general, energy production decreased as snow cover increased. This pattern was most apparent during the period from January 7 to 14, 2011. The flat panels on racks in Mississauga also appear to shed snow more quickly than the building integrated PV (see Jan 12 – 14). This would be expected given their greater exposure to the air and wind, and the obvious fact that building integrated panels have no place to shed snow.

Figure 4. Snow cover measured at a Toronto meteorologic station in winter 2010-11 compared to energy yield of two flat panel PV systems in the GTA. (Note: Snowfall amounts and patterns at the Toronto and Pearson Airport stations were similar but the Toronto station showed higher ground accumulation in December).



BUSINESS CASE

Table 2 presents the business case for the Horgan Water Treatment Plant PV project. A RETScreen analysis was conducted using Environment Canada's 20 year average irradiance data. A 58.5% derate factor was used in three winter months (December through February), and an 18% derate factor was used during the remainder of the year (March through November). The 58.5% derate factor best fit the production data in December 2010, so it was applied to three months in the winter. The 18% derate factor best fit the production data in July 2011, so it was applied to the remaining months of the year.

The derate factors used in this business case are higher than the conventional 16% derate used in the RETScreen models. Therefore, this scenario represents a conservative estimate of long term yield. The derate factor used here should be reassessed once a full year of data are available.

Toronto Water was responsible for the entire cost of the Horgan PV project (no grants were received). It should be noted that the total cost of the installation does not account for the costs that would have been incurred for a conventional roof replacement (the cost of the PV itself would have been less than the total reported here). This analysis predicts an array output of 83,214 kWh per year, which would provide $59,332 of income per year at the current Feed in Tariff rate of $0.713/kWh. The simple payback for this scenario would be 17.7 years.

Table 2. Horgan Water Treatment Plant PV Project: Business Case.

	Total Cost Installed	Grants	Array Output (kWh/yr)	Income from Electricity Sales	Simple Payback (years)
Adjusted Feasibility Study (using RET20yr model)	$1,050,000	$0	83,214	$59,332	17.7

Feed-in Tariff Issues

Grid connection has been delayed and the project is currently net-metering due to changes in Feed-in Tariff contract grid connection rules. After the system was installed, Toronto Water 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. After consultation with the local distribution company, a modified in-series connection, including two bi-directional meters, was agreed upon. This connection option may not be suitable for other sites to meet the FIT connection rules.

The grid connection change is in the process of being completed with an expected completion in early 2012. The changes will add unexpected costs 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.

APPENDIX 1: DAILY TOTAL ENERGY PRODUCTION OF TWO FLAT PANEL PV SYSTEMS IN THE GTA

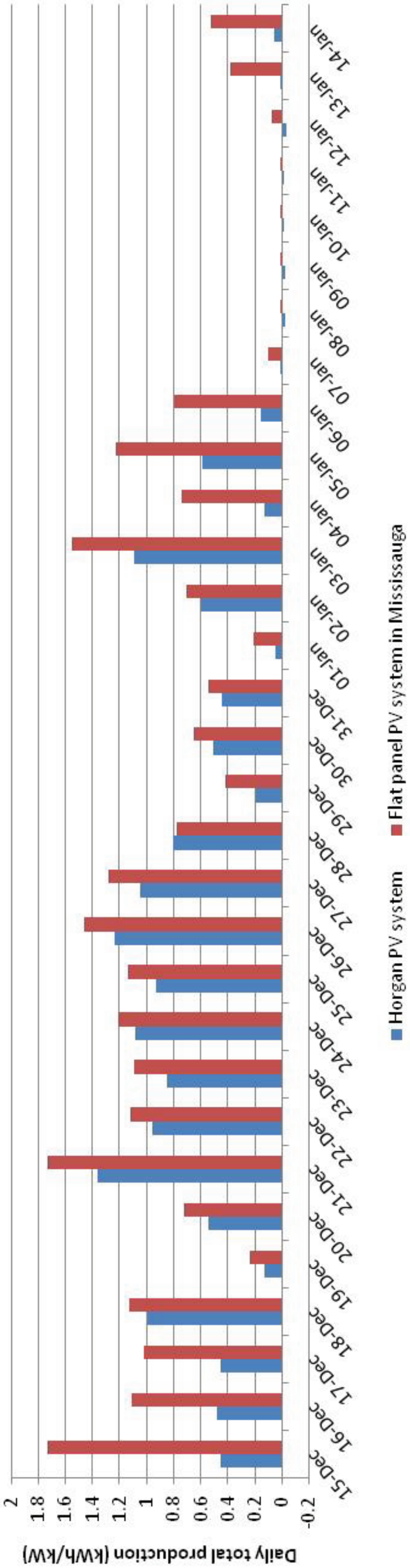


Figure 5. Daily total energy production of two flat panel PV systems in the GTA in winter 2010-11.

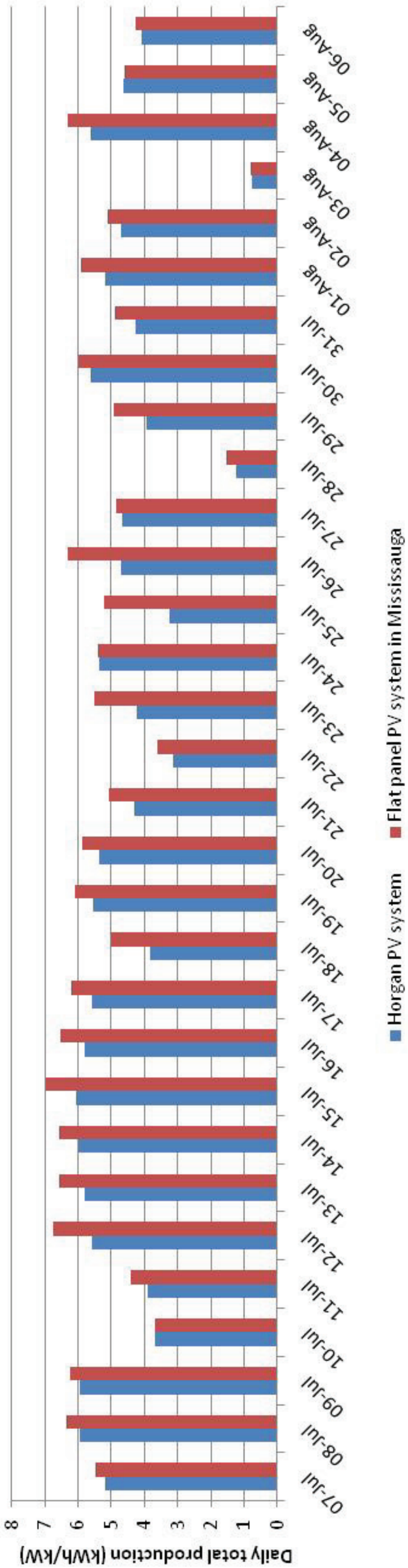


Figure 6. Daily total energy production of two flat panel PV systems in the GTA in summer 2011.

APPENDIX 2: DAILY TOTAL IRRADIANCE IN THE GTA

In order to assess the accuracy of the pyranometer at the Horgan Water Treatment Plant, irradiance data from Horgan were compared with data from pyranometers at the University of Toronto Mississauga campus and at a flat panel PV system in Mississauga. In December 2010, daily total irradiance measured at Horgan was an average of 5.4% above that measured at U of T Mississauga and 21.9% above that measured at the Mississauga flat PV system (Figure 7). In July 2011, daily total irradiance measured at Horgan was an average of 4.8% below that measured at U of T Mississauga and 7.3% above that measured at the Mississauga flat PV system (Figure 8).

Figure 7. Daily total irradiance measured at three sites in the GTA in winter 2010-11.

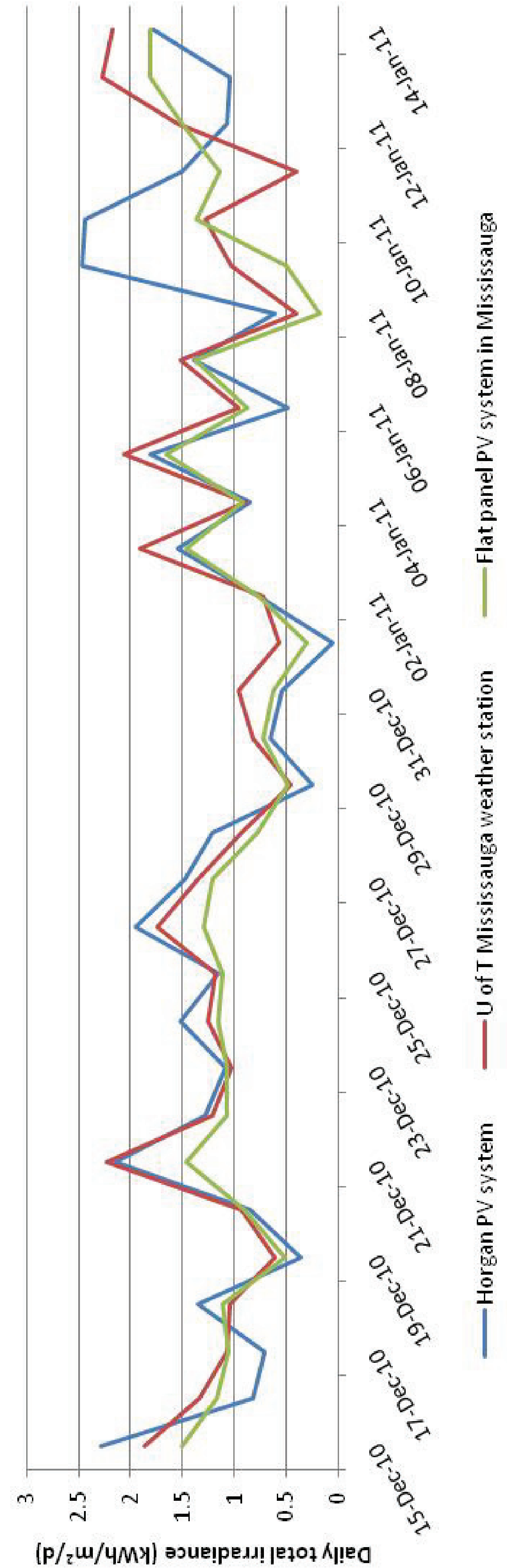
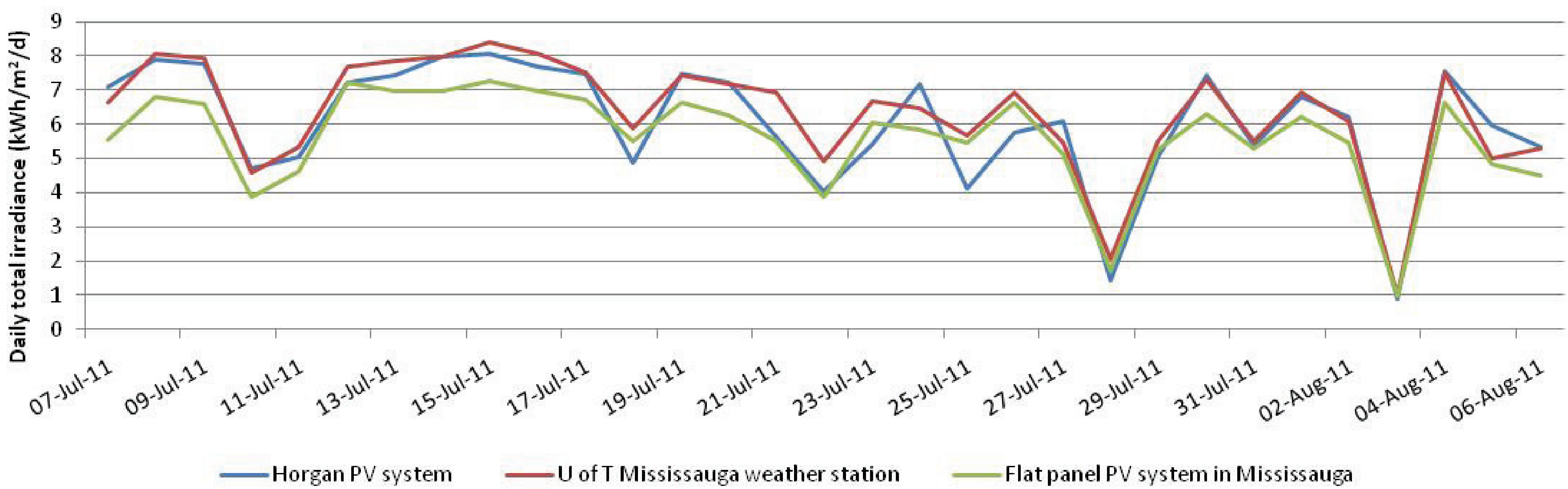


Figure 8. Daily total irradiance measured at three sites in the GTA in summer 2011.



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:

info@solarcitypartnership.ca

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