Performance Review of Rooftop Solar Photovoltaic Projects in the Greater Toronto Area

January 2012

Technology

Monitoring

Best Practices

SolarCity Partnership

SUMMARY

The SolarCity Partnership was established in 2008 to undertake third party monitoring and performance verification of large solar installations. Results are used to help optimize the performance of solar facilities and establish best practices and tools needed to continuously improve standards for use of solar energy in an urban context. While the initial phase of this project funded by Federation of Canadian Municipalities focused on installations on City of Toronto facilities only, the project has expanded to consider private and public installations across the GTA and data from all of these various sites are included in this analysis to provide a more robust project data set for comparison.

Twelve rooftop solar photovoltaic (PV) arrays of various sizes and design located at eight separate sites were evaluated. Of these eight sites, five are owned by the City of Toronto and three are privately owned and operated. The location of each site is presented in Table 2. ***Of the 12 arrays studies, eight performed within the expected range of productivity relative to the system design, mounting configurations and irradiance conditions occurring over the study period.*** Energy yields ranged between 1,048 kWh/kW/yr for a flat panel system to 1,245 kWh/kW/yr for a system installed at a 35 degree angle. Irradiance during the one year study period was approximately one percent lower than the 20 year Toronto average.

RETScreen model software was used to assess PV performance at the different sites. This model utilizes rated inverter efficiencies and various user defined array loss factors to account for losses from dust and dirt, snow, ageing, stand test condition (STC) tolerance, and other factors. ***Uncertainties in the effect of these factors on yield resulted in overly optimistic predictions of performance at some sites.*** To help identify a 'reasonable' loss factor for use in pre-feasibility studies, the RETScreen was used to determine the derate factor that best fit the actual yield at each site. For the 8 arrays that did not experience site specific losses from shading or other variables, the best fit array loss factor was 11.1%, with a range between 6.5% and 16.4%. As a conservative estimate of PV yield, it is recommended that a 16% array loss factor be used in pre-feasibility studies.

The photovoltaic projects evaluated encountered some technical challenges, but once the projects were up and running, most required relatively little maintenance to keep the systems operating. The key challenges occurred in establishing the initial FIT contract for the system, overcoming site specific challenges relating to roof loads and other considerations, and ensuring the system was operating at optimal capacity once the system became fully operational. Two of the 12 arrays experienced yield reductions of up to 20% due to shading. Two other arrays suffered from unexpected production losses caused by night time power use from the inverters.

Photo provided by Carmanah.

Installation costs per kW installed ranged from approximately $8,943 to $12,845. ***Simple paybacks varied between 13 and 18 years at prices offered under the Province of Ontario's Feed in Tariff program.*** These costs represent the first generation of rooftop solar installations, most of which were purchased between 2006 and 2009. With the considerable reduction in the costs for materials and installation since 2008, it is expected that new projects will cost significantly less than documented in this study.

BACKGROUND

Since the initiation of the Province of Ontario's *Renewable Energy Standard Offer Program* in 2006, later replaced by the *Feed in Tariff* program 2009, hundreds of rooftop solar photovoltaic installations have sprung up across Ontario. In order to document how these have performed over time and determine whether improvements may be needed, the SolarCity Partnership evaluated twelve rooftop solar PV systems at eight study sites across the Greater Toronto Area. Results were presented in case studies for each facility on a publically accessible website – see solarcitypartnership.ca. In addition to overall performance, various site specific issues such as shading, data collection, and construction and operational challenges were also addressed as part of the study. The following provides a comparative review of the eight study sites, with the aim of supporting knowledge sharing and refining best practices for urban PV systems.

STUDY SITES

Site Locations

The case studies assessed a total of 12 PV arrays located at 8 sites in the GTA. Of these 8 sites, 5 are owned by the City of Toronto and 3 are privately owned and operated. The location of each site is presented in Table 1.

Table 1: Solar City Partnership case study sites

Site Name	Address
Earth Rangers Aviary (private)	9520 Pine Valley Drive, Woodbridge, ON
F.J. Horgan Water Treatment Plant (Toronto)	201 Copperfield Road, Toronto, ON
Horse Palace, Exhibition Place (Toronto)	200 Princes' Boulevard, Toronto, ON
Loyalty One Customer Care Centre (private)	6696 Financial Drive, Mississauga, ON
Neighbourhood Unitarian Universalist Congregation (private)	79 Hiawatha Road, Toronto, ON
Toronto Fire Station #334 (Toronto)	339 Queen's Quay West, Toronto, ON
Toronto Parking Authority (Toronto)	Carpark 43 (St. Lawrence Garage) 2 Church Street at Esplanade, Toronto, ON
Toronto Police Traffic Services (Toronto)	9 Hanna Avenue, Toronto, ON

System Specifications

Of the 12 arrays monitored, all but two are installed on the roof. One is a wall mount system, the other is mounted on the ground in the parking lot adjacent to the building. They range in size from 3.2 to 147 kW and are mounted at angles varying between 0 and 65 degrees from horizontal. All but one of the installations face east of south, with azimuths ranging from 0 to 29 degrees east of south. Refer to Appendix 1 for detailed specifications of each PV system.

SOLAR IRRADIANCE

Although the majority of sites were equipped with a pyranometer to measure solar irradiance received at the site, the quality of the instruments was variable. Inaccurate irradiance readings and large data gaps (spanning days or months) were commonly observed. An accurate irradiance dataset is crucial for simulation modeling and performance assessment. In several cases when the quality of the on-site irradiance data was uncertain, data from a reliable weather station (located at the University of Toronto Mississauga) were used as a proxy in the RETScreen model.

Irradiance data measured at various sites in the GTA are presented in Table 2 and Figure 1. Average daily irradiance at the majority of sites was within 5% of that measured at the University of Toronto Mississauga. Measurement uncertainties for calibrated pyranometers are typically between 3 and 5% on a monthly basis.[1] The low irradiance measured at the Glen Haffy and Loyalty One stations warrants further investigation, as these stations recorded annual irradiance levels of more than 10% below U of T Mississauga. Irradiance data from the Horse Palace and Toronto Parking Authority pyranometers were not available over the study comparison period, and are therefore not included in Table 2. However, in both cases, measurements in earlier years differed considerably from the University of Toronto Mississauga and Transport Canada stations.

All sites recorded a prominent dip in irradiance in April and May 2011. This was caused by increased cloud cover and precipitation in these months. Total precipitation in April and May 2011 was 237.4 mm, while the historic average (1971 to 2000) was 140.9 mm[2].

1 Thevenard D, Driesse A, Pelland S, Turcotte D, Poissant Y. Uncertainty in long-term photovoltaic yield predictions, report # 2010-122 (RP-TEC), CanmetENERGY, Varennes Research Center, Natural Resources Canada, March 31 2010, 52 pp.

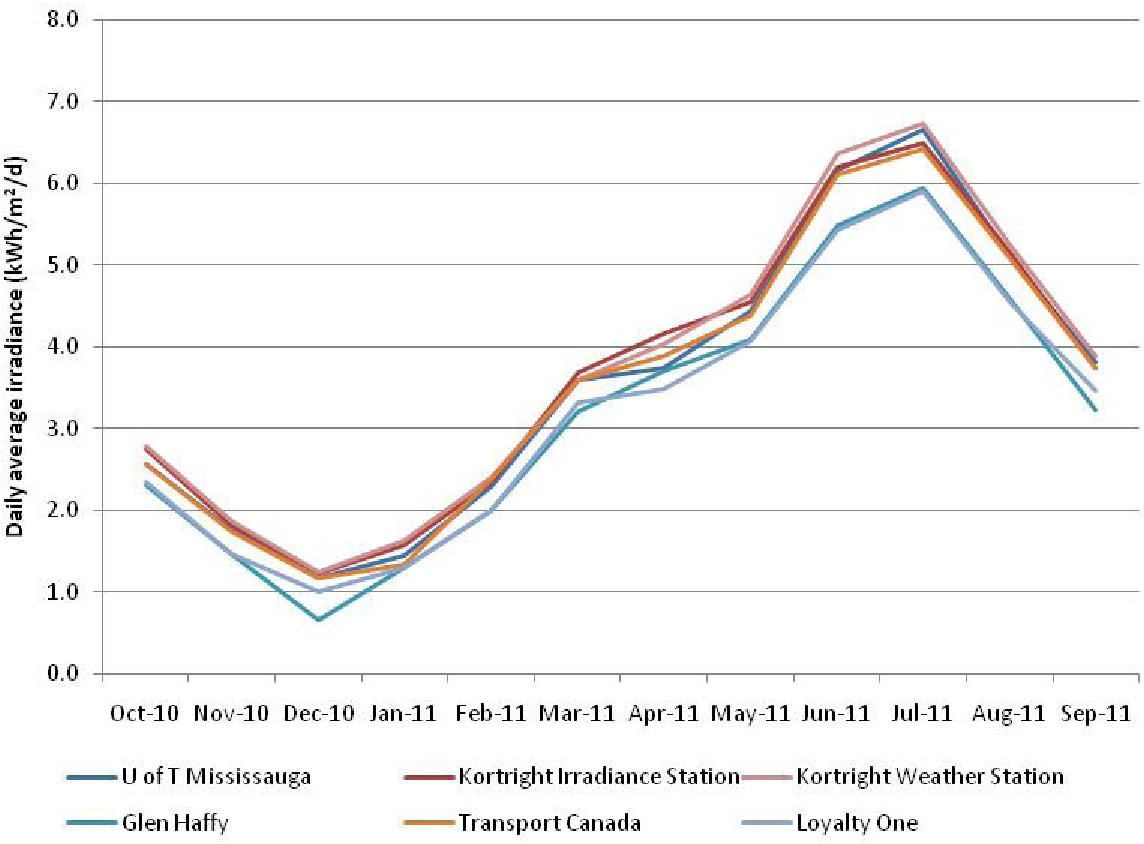
2 Canadian Climate Normals, 1971-2000. Environment Canada National Climate Data and Information Archive. Online. Available at: www.climate.weatheroffice.gc.ca.

Table 2: Solar irradiance in the GTA*

Site	Average daily irradiance (Oct-10 through Sep-11) (kWh/m²/d)	Percent difference from U of T Mississauga
U of T Mississauga	3.56	—
Kortright Irradiance Station	3.64	2.1%
Kortright Weather Station	3.71	4.0%
Glen Haffy	3.16	-11.2%
Transport Canada	3.54	-0.8%
Loyalty One	3.20	-10.3%

*Refer to Appendix 2 for a list of data gaps and estimated time periods.

Figure 1: Solar Irradiance in the GTA



*Refer to Appendix 2 for a list of data gaps and estimated time periods. Pyranometers installed at individual PV sites are not included

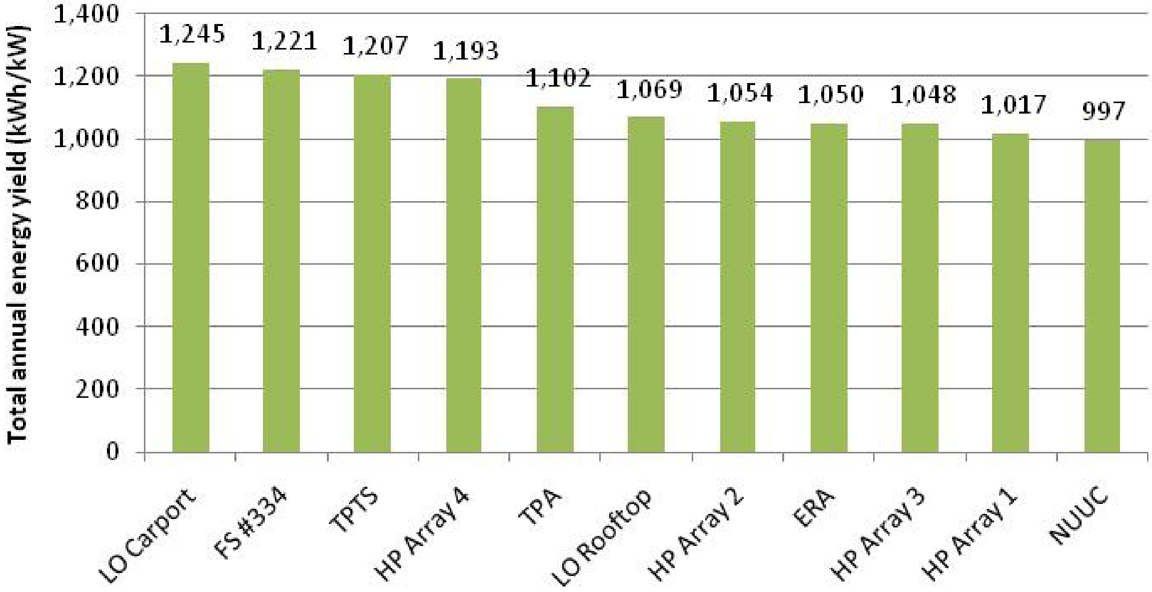
PERFORMANCE ANALYSIS

Actual Performance

Array performance was compared over the one year period beginning October 1, 2010 and ending September 30, 2011 (Figure 2). This was the period in which actual production data were available from the greatest number of sites. If a complete year of data was not available from a site during this interval, monthly energy yield was estimated using the RETScreen program.[3]

All but one installation produced energy within the expected range of 1,000 to 1,250 kWh/kW/yr. It is interesting to note that the only three arrays to exceed 1,200 kWh/kW/yr in energy yield were also the three arrays oriented closest to the optimum panel angle. Only the NUUC system fell slightly below the expected range. Partial shading of the array is suspected at this site, and is currently being investigated.

Figure 2: Annual Energy Yield (Oct-10 through Sep-11) of 11 PV installations in the GTA.*



*The HWTP array is excluded due to an insufficient amount of data. See below for a separate analysis of HWTP performance.

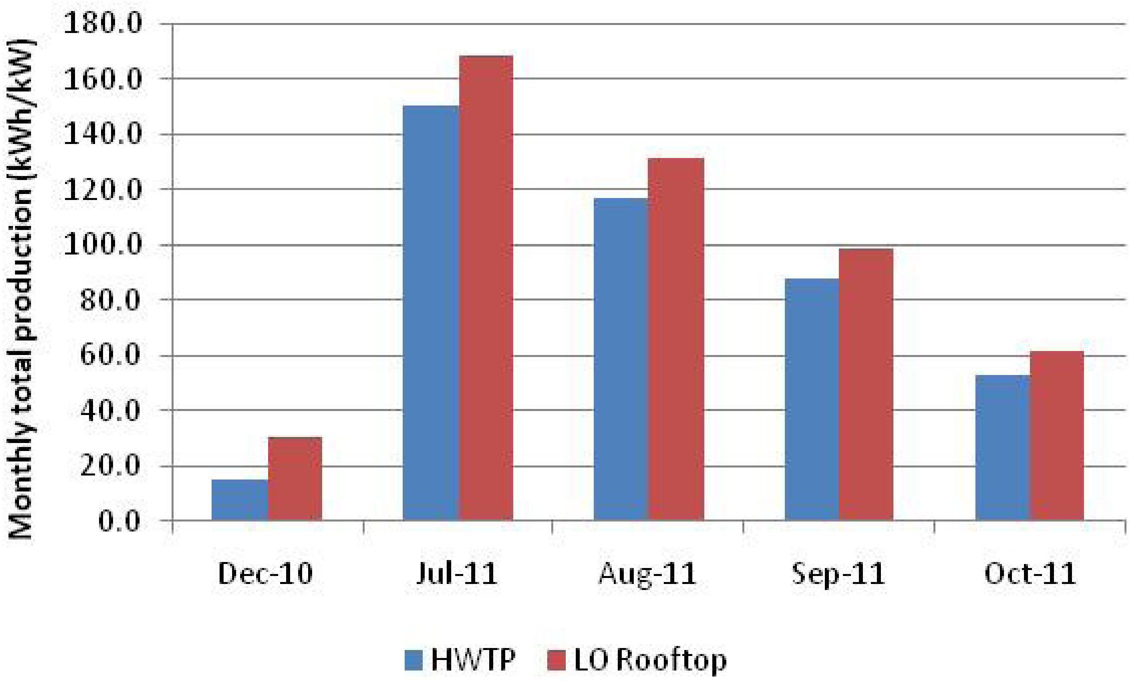
*Refer to Appendix 2, Table 6 for a list of estimated dates for each site.

3 For each month of production to be estimated, the derate factor that best fit monthly total yield in the same month of the previous year was applied to the current RET1yr model. This method is based on the assumption that the derate factor that best fits a given month does not vary significantly from year to year.

Energy Yield of Flat Panel PV Systems in the GTA

Only five complete months of energy yield data were available from the Horgan Water Treatment Plant PV installation (December 2010 and July through October 2011). In order to evaluate the performance of the Horgan system, measured yield was compared to that of another flat panel system located at Loyalty One over the same time interval (Figure 3).

Figure 3: Energy yield of two flat panel PV systems



Over five months, total energy yield of the Horgan PV system was 423.7 kWh/kW, which is 13.9% below the yield of the Loyalty One Rooftop system (492.0 kWh/kW). This difference in production can likely be attributed in part to the difference in efficiency of the two panel types. The module efficiencies of the amorphous silicon panels at Horgan and the hybrid panels at Loyalty One are rated in the RETScreen database as 6.3% and 16.3%, respectively.

Model Simulations

RETScreen was used to predict expected yield over the one year comparison period. Table 3 displays the key parameters in the two RETScreen scenarios. The first uses a 16% array loss factor derived from the California Energy Commission guidelines[4] and historic irradiance and temperature data from a Toronto weather station (RET20yr). The second also incorporates a 16% array loss factor, but uses local irradiance and

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

temperature data over the same one year period that actual production data were available (RET1yr). Local irradiance data used in the RET1yr model are from a reliable weather station located at the University of Toronto Mississauga. The use of a common weather station facilitates the comparison of RETScreen simulated yield across multiple sites, but may fail to account for site-specific microclimatic conditions. Both scenarios assume 1% miscellaneous inverter losses and incorporate CEC rated inverter efficiencies.[5]

Table 3: **Key parameters in the two RETScreen scenarios**

RETScreen Input	RET1yr	RET20yr
Annual solar radiation on a horizontal surface (kWh/m^2)	1,300	1,310
Annual average daily irradiance ($kWh/m^2/d$)	3.56	3.59
Annual average ambient temperature (°C)	8.1	7.2
Inverter efficiency	CEC rating (range of 92% – 96%)	CEC rating (range of 92% – 96%)
PV array losses	16%*	16%*
Miscellaneous inverter losses	1%	1%
Source and duration of irradiance data	U of T Mississauga Apr 2010 to Mar 2011	City of Toronto 20 year average

*The Horse Palace models incorporate a 17% array loss factor. The extra 1% accounts for known shading, as determined from a Solar Pathfinder analysis.

Using the RET1yr model as a performance benchmark, the majority of the arrays exceeded expectations during the comparison period (Figures 4 and 5). The low yield of Horse Palace Arrays 1 and 2 was due to night-time power use by the inverter's isolation transformer. Shading is the most likely explanation of the low yield of the ERA and NUUC PV systems given their proximity to tall trees.

Energy yield at the sites with no known shading or performance issues exceeded predicted values based on the 16% array derate factor, suggesting that this factor provides a very conservative estimate of energy production. In order to determine a more accurate derate factor for use in RETScreen modeling, the individual array models were re-run to find the derate that best fit the actual yield data over the study period. The four arrays with known shading or tare loss issues were excluded to provide a better estimate of typical array losses. Based on this approach the average best fit array loss factor was 11.1%, with a range between 6.5% and 16.4%. For the purposes of yield prediction, the 16% factor still provides a good conservative estimate, but it should be recognized that the performance of a well functioning array may well produce more energy than predicted using this factor.

5 With the exception of the Horse Palace models, in which the inverter efficiencies are consistent with the values used in the 2009 Project Findings Report.

Figure 4: Actual annual energy yield vs. RETScreen simulated yield

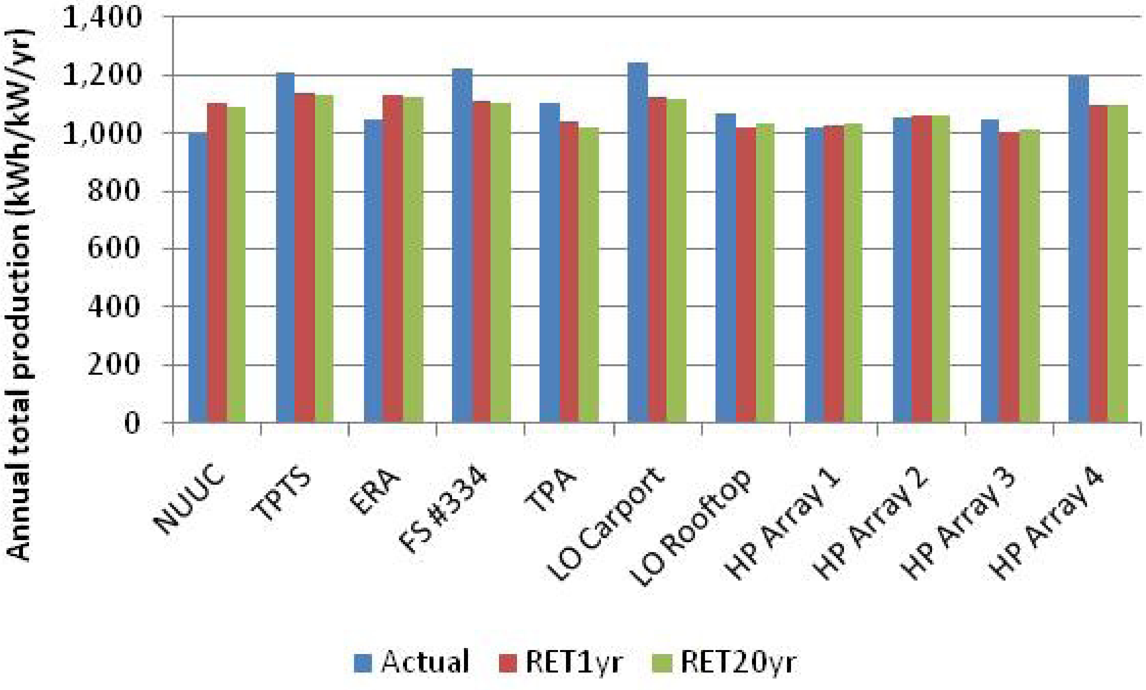
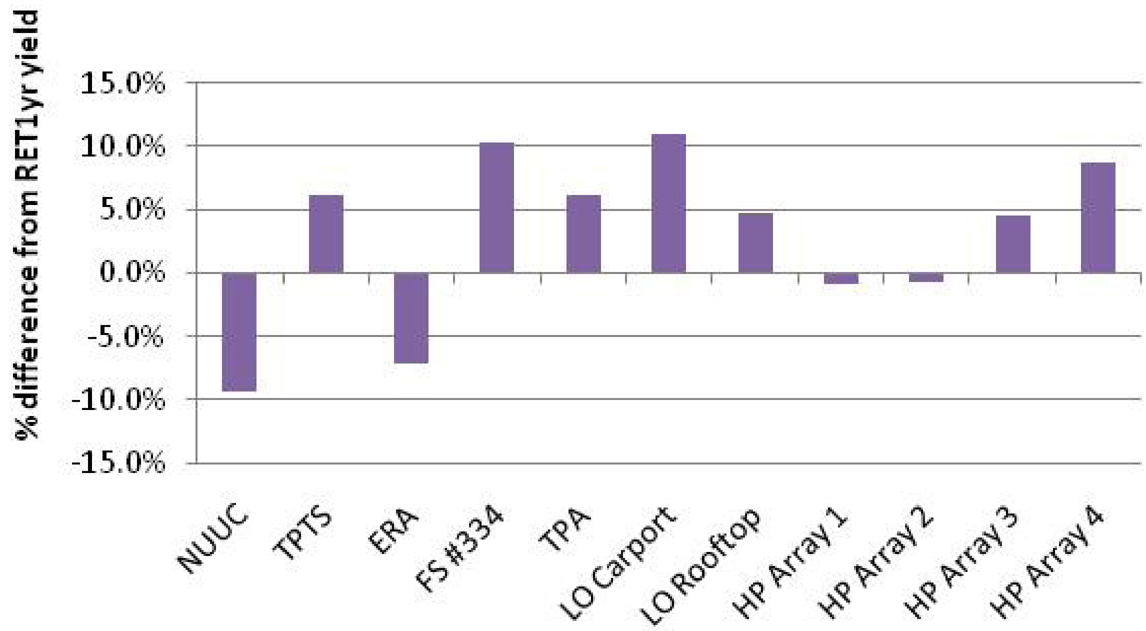


Figure 5: Percent difference of actual from RET1yr simulated yield

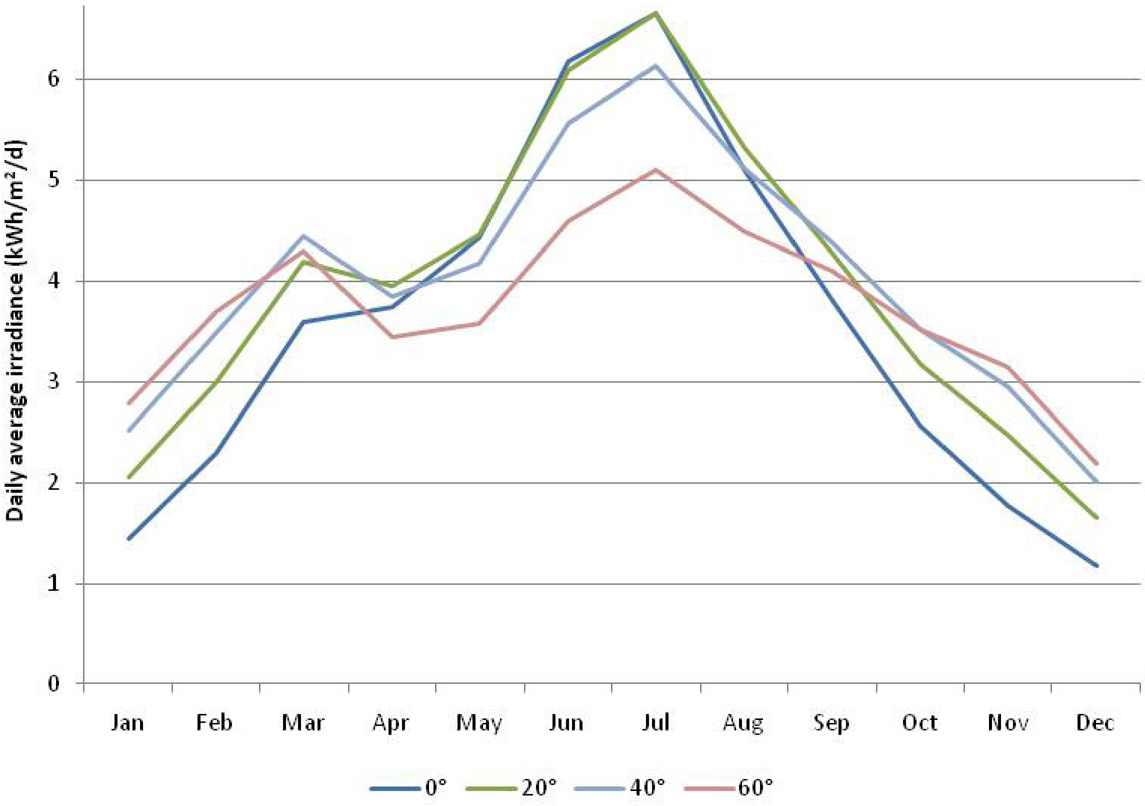


The Effect of Panel Angle

The effect of angle on available solar irradiance (keeping the azimuth constant at 0° from due south) was calculated using RETScreen over the one year study period based on irradiance data from the U of T Mississauga meteorological station. As expected, more solar radiation is available to panels with lower slopes during the spring and summer, while panels with steeper slopes registered higher irradiance during the fall and winter (Figure 6). Consequently, the unusually cloudy months of April and May are shown to have had a more prominent adverse effect on the steeper angled systems.

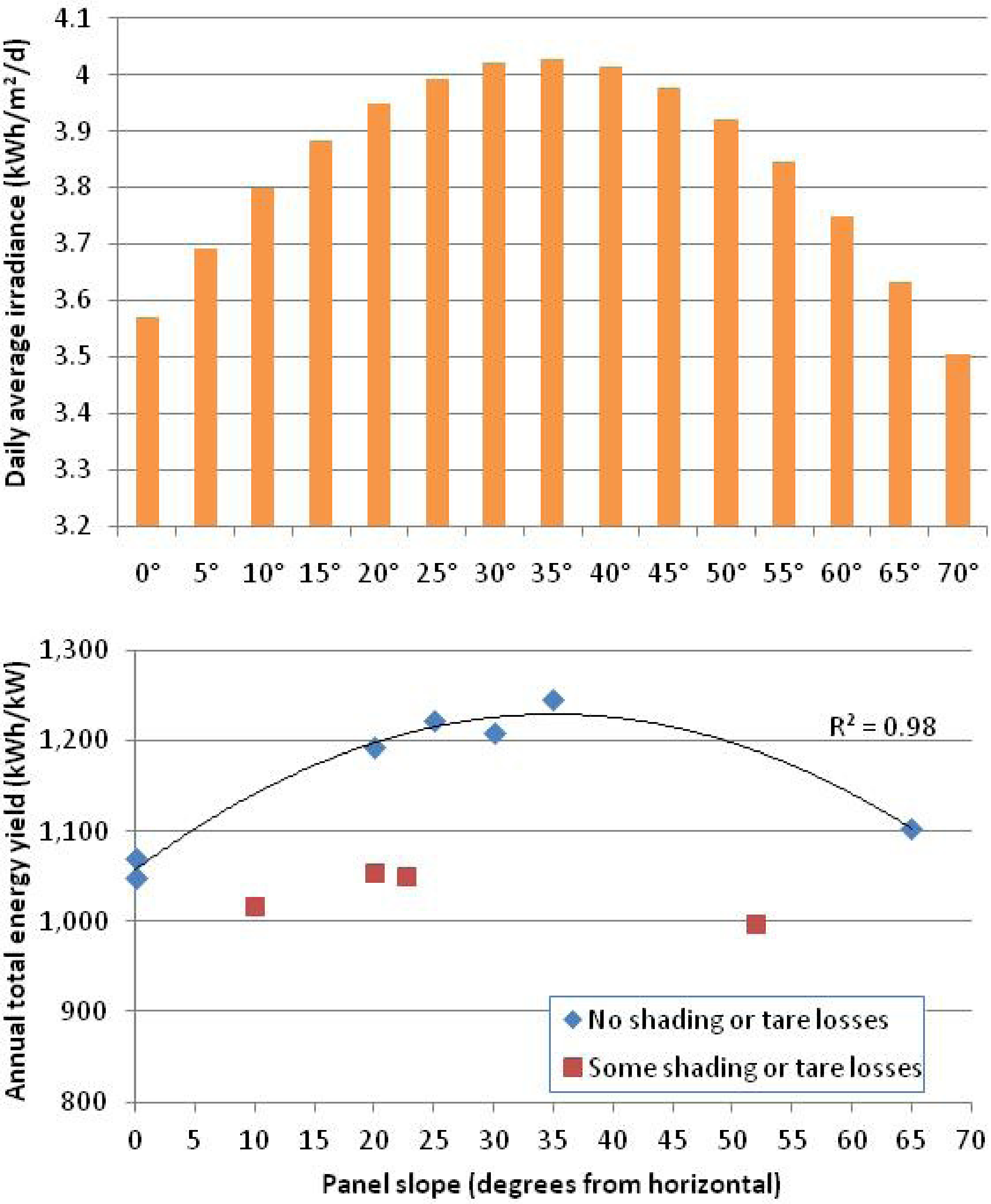
The effect of snow is not accounted for in the model simulations. These effects would be more prominent on low tilt systems because they do not shed snow as readily. However, the effect on yield would be minor because, as shown in Figure 6, production over the winter only accounts for a relatively small portion of total annual yield from these systems.

Figure 6: The effect of panel angle on monthly average solar irradiance



On an annual basis, the 35 degree panel angle captured the greatest amount of solar radiation over the one year comparison period, at an average of 4.03 kWh/m^2/d in the plane of the array.   A plot of actual yield from the 7 arrays, on which there were no major performance issues, such as shading (2 arrays) or phantom draw (2 arrays), show a very similar pattern with the optimal angle occurring at 35 degrees (Figure 7).   The building integrated PV system was not included in this analysis because a full year of data was not available.

Figure 7: **The effect of panel angle on annual average solar irradiance: simulated (top), actual (bottom). The best fit trend line is plotted for sites with no shading or inverter tare losses.**



TECHNICAL CHALLENGES

The photovoltaic projects evaluated encountered some technical challenges, but once the projects were up and running, most required relatively little maintenance to keep the systems operating. The key challenges occurred in establishing the initial FIT contract for the system, overcoming site specific challenges relating to roof loads and other considerations, and ensuring the system was operating at optimal capacity once the system became fully operational.

Grid connection delays and uncertainties resulted in significant loss of revenue. Wait times for the approval and initiation of FIT contracts often exceeded a year, and in some cases facilities were still not receiving FIT revenues three years after the systems were installed. Energy metering problems were a common issue because the type of metering that would be acceptable under the FIT program was not adequately specified at the outset. When the metering requirements were specified, several sites had already installed a different metering system and were subsequently subject to delays and/or significant additional costs to modify the way meters were originally set up. For example, delays at the Horse Palace in finalizing the initial RESOP agreement and establishing appropriate metering resulted in a loss of $36,000 of potential revenue at the project outset.

Overcoming installation challenges resulted in unanticipated costs and delays at some sites. For instance, the Toronto Parking Authority site at Church Street was originally planned as a roof mount system, but concerns about vandalism resulted in a late change in the design to a steep angle wall mount system. Both at Horse Palace and the TPA sites, a separate metering cabinet needed to be built to house the electrical equipment, which again added to the installation costs. At the Loyalty One site, a structural assessment of the building indicated that the roof would not support the large flat panel system planned for the building. Two overcome this challenge, the panel racking was anchored to the building's structural columns. The micro-inverters were housed within the lunch and games room with an interactive education display to make better use of available space and show employees and guests how much the system is producing in real time. At the Hanna site, significant structural reinforcement was required to prepare the apron surrounding the garage to support the weight of the photovoltaic array.

Shading was often not accounted for in pre-feasibility assessments of systems. Even a small amount of shading on part of an array can significantly affect system performance. The Earth Rangers and NUUC arrays both experienced shading during part of the year from surrounding trees. The effect was more pronounced at the NUUC site because the panels were installed at a relatively steep angle (52 degrees), and therefore derives a higher proportion of their annual yields from periods when the sun is low in the sky. The Horse Palace site also had some shading from a nearby flag pole, but the effect was relatively minor. In all cases, the effect of shading was not sufficiently identified and/or quantified in pre-feasibility assessments of the systems.

Data irregularities frequently went undetected even when monitoring systems were present. Most sites had data acquisition systems that provided monitoring data and information via an accessible website. The websites provided simple performance metrics such as PV yield. Detailed data could also be downloaded for further analysis if desired. In several cases, however, the data were not regularly inspected, and data gaps linked to short term failures of the system (e.g. ground faults) or data logging equipment went unnoticed. Problems resulting in lower yield (e.g. shading, phantom draw by inverters) were the most difficult to detect because the system looked liked it was functioning normally. These problems could be avoided if data acquisition systems also included a design benchmark against which performance of the PV system could be compared to determine whether it is operating within a 'normal' range based on local irradiance measurements.

FINANCIAL ANALYSIS

A financial analysis was performed for each of the eight study sites. Although there are a total of 12 PV arrays under study, the Loyalty One and Horse Palace sites contain two and four arrays, respectively. The business cases are based on the total energy produced at each site. Long term energy yield was estimated based on a RETScreen simulation using historic irradiance data and derate factors that best fit actual production data over the monitoring period.

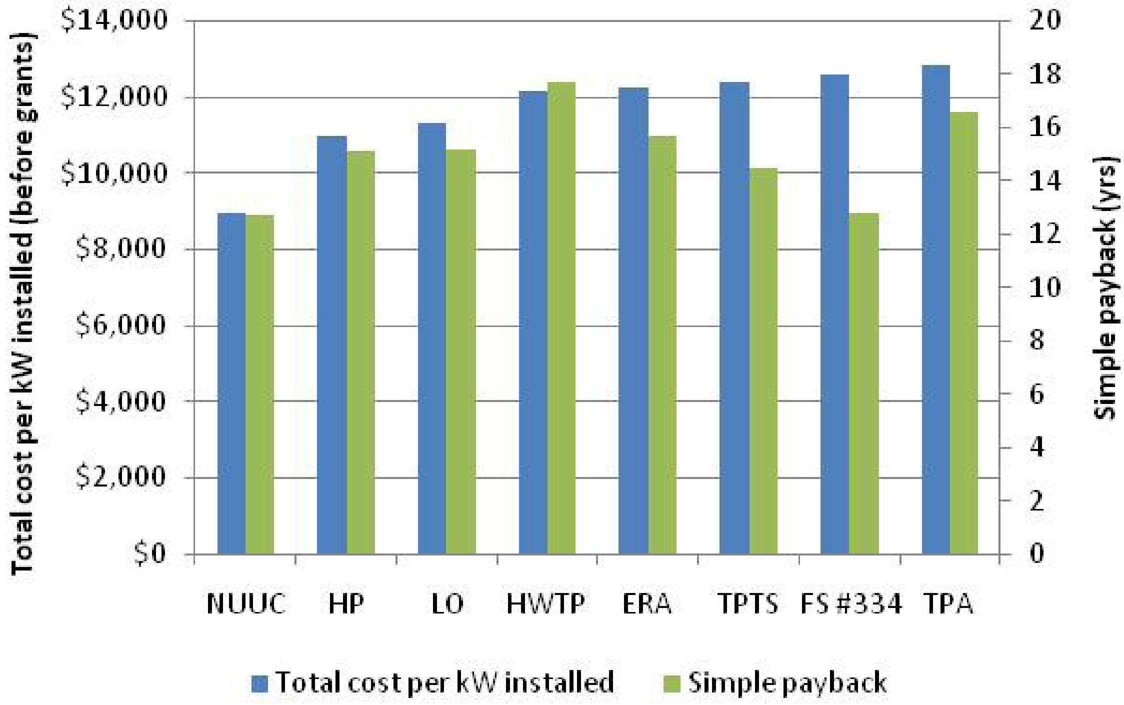
Total cost of the installations ranged from roughly $8,943 to $12,845 per kilowatt installed. Simple payack periods varied between 12.7 and 17.7 years (Figure 8). The simple payback for each PV system does not account for annual discount rates and future life cycle costs associated with inverter replacement, system maintenance, repair and other factors.

Higher capital costs did not necessarily translate into longer payback since the payback period is determined by yield. The NUUC system, for example, was considerably less expensive than other systems, but shading reduced annual yields by roughly 20% resulting in a simple payback similar to the more expensive Fire Hall #334 system.

These costs and payback periods are representative of the first generation of rooftop PV projects implemented through Ontario's renewable energy incentive programs. They were installed between 2006 and 2009. Since 2008, costs have come down considerably. A recent US summary of installed cost data for approximately 116,500 residential, commercial and utility sector PV systems across 42 states reported a 17% decline in prices from 2009 to 2010, and a further 11% decline in the first six months of 2011.[6] Both module and non-module costs fell, which is important because non-module costs are most affected by incentive programs and policies aimed at accelerating solar technology adoption. Systems smaller than 2 kW averaged $9.80/W in 2008,

6 Barbose, G., Darohouth, H., Wiser, R., Seel, J. 2011. Tracking the Sun IV: The installed cost of photovoltaic projects in the US from 1998 to 2010. Lawrence Berkley National Laboratory, California.

Figure 8: Total system cost per kW installed (excluding grants) and simple payback*



*Fire Station #334 costs and payback exclude structural work, because structural costs were very high at this site and are not usually necessary in PV projects.

while larger commercial systems (>1000 kW) averaged $5.20/W. Installed costs are even lower in Germany ($4.20/W for small residential systems), where grid connected PV capacity is roughly eight times that of the US. As the industry matures in Ontario, a similar decline in prices is expected.

CONCLUSIONS AND RECOMMENDATIONS

Rapid deployment of grid connected photovoltaic systems in Ontario has resulted in considerable growth of the industry over the past five years. This study provides an overview of the performance of some of the early projects implemented under Ontario's renewable energy incentive programs. Recommendations for improvements that will help optimize systems and provide better return on investment are provided below.

High quality irradiance data is needed for simulation modeling and performance verification of PV systems. In this study, solar irradiance measurements at several sites were found to be inaccurate or missing data. Pyranometers need to be calibrated and inspected periodically to ensure they are generating good quality data. If these tasks cannot be conducted due to cost constraints or the availability of qualified staff, irradiance measurements should instead be gathered from nearby sites where good quality data are available.

Sites should have dedicated staff responsible for observing and monitoring PV systems to ensure problems are identified and resolved in a timely manner. While data acquisition systems that generate user friendly data summaries help make detection of problems easier, these are not sufficient to ensure that the problems are corrected and the system is operating at optimal levels. Dedicated staff responsible for system operation are needed, as well as clear protocols on how problems are to be dealt with when they arise. The task of problem identification would be much easier if displays of system performance were benchmarked against expected performance based on measured irradiance. In this way, a temporary drop in yield could be more easily detected.

Improvements in the capacity to predict long-term energy yields are needed to reduce uncertainties. These uncertainties relate to government incentive schemes, grid connection variables, the solar resource and system performance, among other factors. ***In this study, estimates of energy yield and financial benefits of projects based on pre-feasibility assessments were often much higher than actually occurred because of unexpected costs, the failure to account for shading and the use of unrealistic derate factors in models.*** Even among projects without shading or other performance related issues, the model derate that best fit measured yield varied considerably, suggesting that site specific array loss factors (e.g. snow, dirt), micro-climatic effects and model uncertainties may have a significant impact on the capacity to predict yields. In this review, a 16% array loss factor in RETScreen was found to provide a conservative estimate of actual performance.

Current electricity price incentives for rooftop photovoltaic projects offered under the Feed in Tariff Program are appropriate if installation costs documented in this study were to remain the same. The higher electricity price for solar energy has clearly had the intended effect of spurring market growth. However, the incentives are not so attractive as to inhibit suppliers from finding efficiencies that would further improve the business case. A lower incentive may be justified in the future as the market grows and material and installation costs decline.

APPENDIX 1: DETAILED SYSTEM SPECIFICATIONS

Table 4a: System specifications

System specifications	Neighbourhood Unitarian Universalist Congregation	Toronto Police Traffic Services	Earth Rangers Aviary	Toronto Fire Station #334	Horgan Water Treatment Plant	Toronto Parking Authority
System type	Roof-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system	Building-integrated grid-tied solar photovoltaic system	Wall-mounted grid-tied solar photovoltaic system
Array	112 x Canadian Solar Inc. CS5P 220 W panels (24.6 kW total)	273 x Sanyo HIP-190BA3 panels (51.87 kW total)	144 x Sanyo HIP-195BA3 panels (28.08 kW total)	16 x Sanyo HIP-200BA3 panels (3.2kW total)	120 x Solar Integrated SI-G1 720 panels (86.4 kW total)	120 x Sharp mono-Si NT-175U1 panels (21 kW total)
Module efficiency (from RETScreen)	12.9%	16.1%	16.5%	17.0%	6.3%	13.5%
Inverters	56 x Enphase M190 micro inverters (10.6 kW total)	Satcon Powergate Plus 50 kW (5 inputs)	6 x SMA SunnyBoy 5000US with RS485 board (30 kW total)	1 x Fronius IG 4500-LV (4.5 kW total)	1 x SatCon PVS-100 (480V) (100 kW total)	3 x SMA SB7000US in parallel (21 kW total)
CEC weighted inverter efficiency	95.0%	95.5%	95.5%	93.5%	96.0%	95.5%
Slope (degrees from horizontal)	52	30	22.62	25	0	65
Azimuth (degrees from due south)	15 degrees east	15 east	0	15 degrees west	10 degrees east	15 degrees east
String configuration	Each micro inverter manages two panels and is independent of the others.	39 strings of 7 modules (four of the five inverter inputs have eight strings, one of the inputs has seven strings).	Each inverter is wired to 4 strings, with 6 modules per string. Total of 6 inverters, which gives 24 strings and 144 modules.	4 modules per string, 4 parallel strings.	2 modules in series to form a source circuit. 60 source circuits (120 modules total).	4 strings of 10 panels per inverter (total of 12 strings)

Table 4b: System Specifications

System specifications	Loyalty One Carport*	Loyalty One Rooftop	Horse Palace Array 1	Horse Palace Array 2	Horse Palace Array 3	Horse Palace Array 4
System type	Ground-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system	Roof-mounted grid-tied solar photovoltaic system
Array	48 x Sanyo HIP-205 NKHB1 panels (9.84 kW total)	716 x Sanyo HIP-205 NKHB1 panels (146.78 kW total)	216 x Sharp ND-200U1 panels (45.6 kW total)	216 x Sharp ND-200U1 panels (45.6 kW total)	40 x Evergreen Solar EV-115 panels (4.6 kW total)	40 x Evergreen Solar EV-115 panels (4.6 kW total)
Module efficiency (from RETScreen)	16.3%	16.3%	12.3%	12.3%	11.0%	11.0%
Inverters	2 x SMA Sunny Boy 5000 US inverters (10 kW total)	4 x SMA Sunny Boy 4000, 3 x SMA Sunny Boy 6000, and 15 x SMA Sunny Boy 7000 US inverters (139 kW total)	1 x Xantrex PV-45 Grid Tie (model P45) (45 kW total)	1 x Xantrex PV-45 Grid Tie (model P45) (45 kW total)	1 x SMA 5200 Watt Grid Tie (model SB6000U) (6 kW total)	1 x SMA 5200 Watt Grid Tie (model SB6000U) (6 kW total)
CEC weighted inverter efficiency	95.5%	95.5%	92.0%	92.0%	95.0%	95.0%
Slope (degrees from horizontal)	35	0	10	20	0	20
Azimuth (degrees from due south)	29 degrees east	0	20 degrees east	20 degrees east	20 degrees east	20 degrees east
String configuration	Information not available	Information not available	19 strings of 12 modules per string (228 modules total)	19 strings of 12 modules per string (228 modules total)	2 strings of 20 modules per string (40 modules total)	2 strings of 20 modules per string (40 modules total)

*Portion of the array under FIT contract only.

**Horse Palace inverter efficiencies are those used in the original 2009 Project Findings Report.

APPENDIX 2: ESTIMATED DATES

Table 5: Solar Irradiance Data Gaps and Estimations

Site	Estimated dates
U of T Mississauga	None
Kortright Irradiance Station	23/01/2011 - 11/02/2011 23/04/2011 - 01/05/2011 05/05/2011 - 09/05/2011 31/05/2011
Kortright Weather Station	24/09/2011 - 30/09/2011
Glen Haffy	24/12/2010 - 30/12/2010 01/01/2011 – 28/02/2011 (Loyalty One data used as a proxy)
Transport Canada	15/05/2011 - 19/05/2011
Loyalty One	None
RETScreen historic average	None
PV Syst historic average	None

Table 6: Energy Production Data Gaps and Estimations

PV Installation	Estimated dates
Toronto Parking Authority	Jan – Sep 2011
Toronto Police Traffic Services	Apr – Aug 2011*
Earth Rangers Aviary	None
Toronto Fire Station #334	Mar 25 - 31, 2011** Aug – Sep 2011
Horgan Water Treatment Plant	None (Jul 2011 = Jul 7 – Aug 6, 2011)
Horse Palace Array 1	Jan – Sep 2011
Horse Palace Array 2	Jan – Sep 2011
Horse Palace Array 3	Jan – Sep 2011
Horse Palace Array 4	Jan – Sep 2011
Loyalty One Carport	None
Loyalty One Rooftop	None
Neighbourhood Unitarian Universalist Congregation	None

*Estimated based on FS #334 production, not RETScreen.

**Estimated using on-site irradiance, not RETScreen.

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

416-661-6600 ext. 5337

www.solarcitypartnership.ca

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