SOLARCITY TECHNOLOGY ASSESSMENT PARTNERSHIP

Horse Palace Photovoltaic Pilot Project Findings Report

June 2009

Exhibition Place

Prepared in collaboration with

City of Toronto Energy Efficiency Office
Toronto Atmospheric Fund
Toronto and Region Conservation Authority

With funding support from

City of Toronto Better Buildings Partnership
Federation of Canadian Municipalities, and
Toronto Atmospheric Fund

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Special thanks to
Exhibition Place Operations Department
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Executive Summary

In 2005, Exhibition Place initiated a solar photovoltaic (PV) feasibility study and field test as part of the organization's 2010 energy self-sufficiency plan. The roof of the Horse Palace was selected for the installation and when first installed the 100 kilowatt plant was the largest urban PV array in Canada. The project reflects the leadership of Exhibition Place, the City of Toronto Energy Efficiency Office, Toronto Atmospheric Fund and the Federation of Canadian Municipalities in advancing our understanding of PV generation in an urban context.

In addition, the installation of this pilot project coincided with the introduction of the first renewable energy "feed-in tariff" program in North America. The Province of Ontario's Renewable Energy Standard Offer Program (RESOP) provided a premium price of 0.42/kWh for PV generation. As such, the Exhibition Place project provided a key opportunity for learning in an emerging new energy era.

The learning objectives for this initiative were to:

- compare the performance of technology alternatives under otherwise common environmental and operating conditions
- build capacity to operate large roof-mounted PV systems in Toronto and to
- gain experience with the Province of Ontario's then new Renewable Energy Standard Offer Program.

The knowledge gained was intended to inform any decisions to proceed with larger PV installations at Exhibition Place and other similar locations on City of Toronto facilities

The Project, developed in 2005, was installed in summer of 2006 at a cost of $960,000 and monitoring began in November of that year. This first year of monitoring resulted in the identification of several key operational issues and challenges, including complications with inverters and monitoring equipment, shading issues, and data collection and management issues. Securing interconnection with the electricity grid in order to sell the power being produced was also a complicated and protracted matter.

At the end of the first year of the pilot project, an external technical advisor was brought on to correct some technical issues and provide ongoing support to the project. At this time, a problem with the baseline performance modeling used to assess the project was identified and a decision was made to extend the pilot data collection for a second year. A team of project supporters, composed primarily of Exhibition Place staff, took over monitoring and management of the site and began regular meetings to ensure that data flows and technical matters were handled quickly and effectively.

Once baseline performance modeling was adjusted to reflect more realistic assumptions, expected output from the plant was 103,275 kWh/yr. In 2008, the Horse Palace PV Pilot Project produced

96,724 kWh. The slight underperformance (six percent) was caused by energy production losses experienced in part of the array due to a problem caused by night-time power use by inverters. Simple payback for the project is 16.7 years when taking into account grant support for the initiative and the Standard Offer premium of 42 cents per kWh (without the grant support, the system would have a 30.5 year payback at 42 cents per kWh, and closer to 50 years if the system switched to net-metering at 12 cents per kWh after the 20 year Standard Offer contract ended). The plant is now participating in RESOP and receiving monthly payments, although difficulties in establishing the interconnection delayed payments for a full year at a loss of $36,000 in expected income.

Conclusions regarding the relative performance of the arrays, composed of differently angled panels, two types of collectors and two types of inverters, provided some important insights but are confounded by the number of variables at play and difficulties in providing estimates of the differences in costs related to installation of each separate array. The understanding of the necessity for close observation of the monitoring data and clear protocols for action when data irregularities occur is perhaps one of the most important findings of the pilot. Further details on the many lessons learned – and resulting recommendations for those establishing large PV facilities in the Toronto area – are provided in the full report.

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SECTION ONE
Project Development

1. Background and Purpose of the Project

In 2005, Exhibition Place decided to implement an on-site solar photovoltaic (PV) feasibility study and field test as part of the organization's 2010 energy self-sufficiency plan. The intent of the Horse Palace PV Pilot Project at Exhibition Place was to engage one or more solar photovoltaic contractors to design, supply all necessary components, and install photovoltaic systems of cumulative energy production capacity totaling from 50 to 100 kilowatts (kW). The electricity generated was to be fed back into the Horse Palace electrical system and the Exhibition Place property's electrical distribution grid. The systems were to be operated for a period of at least 12 months during which time their performance would be monitored. Following the 12-month period, performance results were to be evaluated and recommendations made to Exhibition Place to inform the development of a 1 - 2 megawatt PV system.

2. Knowledge Outcomes Sought

The Request for Proposals (RFP) issued through the City of Toronto Purchasing Department required that each proponent incorporate into their proposals a limited number of different photovoltaic technologies in order to **compare the performance of technology alternatives** under otherwise common environmental and operating conditions. This may have included, for example, different types of solar panel technologies, different mounting systems, and the type of power inverting systems. This would then allow comparative evaluations of factors such as: initial capital cost, installation complexity, ongoing operating and maintenance costs, robustness under local environmental conditions, effect of different mounting angles and overall electrical performance efficiencies. A copy of the RFP is available at www.toronto.ca/taf/solar.htm.

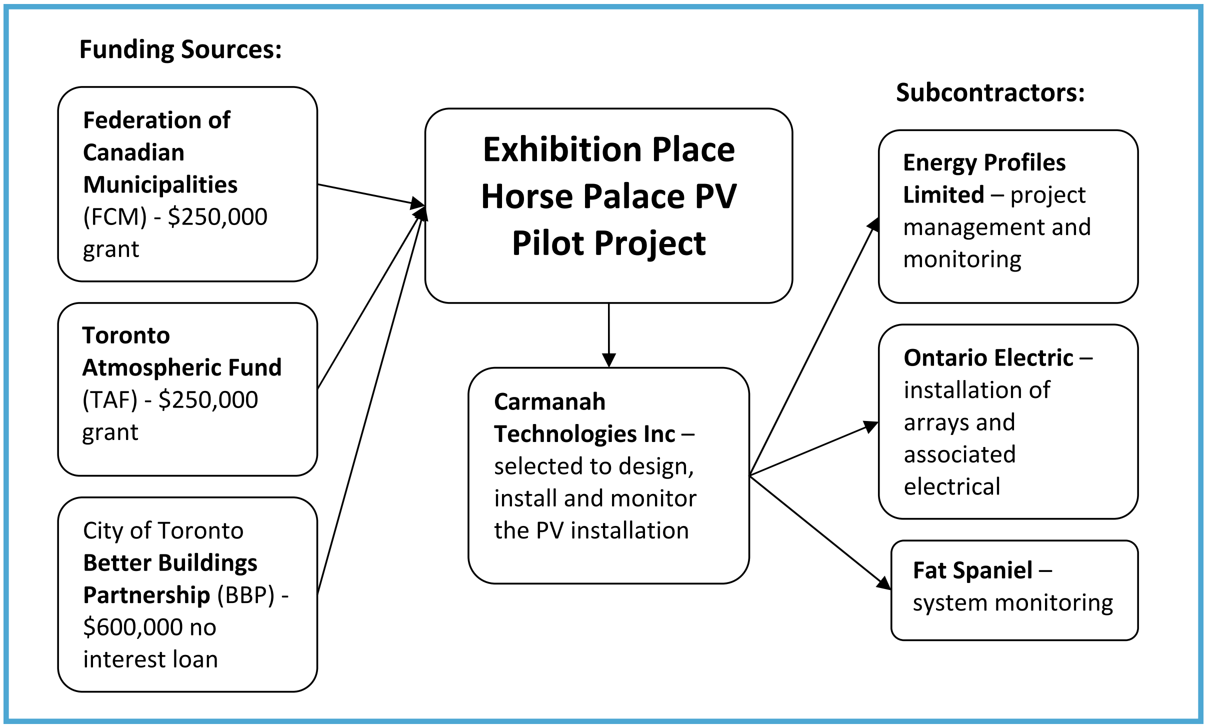
In addition, the project was intended to **build capacity to operate large roof-mounted PV systems** in Toronto and to **build experience with the Province of Ontario's new Renewable Energy Standard Offer Program (RESOP)**.

3. Partners and Roles

Exhibition Place partnered with the Toronto Atmospheric Fund (TAF), the Better Buildings Partnership (BBP) of the City of Toronto's Energy Efficiency Office, Business and Strategic Innovation Section, and the Federation of Canadian Municipalities' (FCM) Green Municipal Fund to fund the Horse Palace PV Pilot Project. FCM and TAF provided grants of $250,000 each and the BBP committed up to $600,000 as a zero-interest loan.

Through the RFP process, Carmanah Technologies Inc. was chosen to design, install and monitor the installation. Carmanah, in turn, engaged Fat Spaniel for the system monitoring and Ontario Electric for the installation of the arrays and associated electrical equipment. As part of its funding agreement with TAF, Exhibition Place engaged Energy Profiles Limited to provide project management and to monitor the Horse Palace Project for a period of one year following full installation.

Figure 1: Exhibition Place PV Pilot Project Partners



4. Description of Installed PV Arrays

Four arrays were installed, using two different types of panels (Sharp and Evergreen models) each with a different inverter (Xantrex and SMA, respectively). The arrays were installed at three different angles (0, 10 and 20 degrees) as indicated in the chart below.

Figure 2: Installed PV Arrays

Array #	#1	#2	#3	#4
Manufacturer	Sharp	Sharp	Evergreen Solar	Evergreen Solar
Panel Model	ND-200U1, 200 watt panels	ND-200U1, 200 watt panels	EV-115, 115 watt panels	EV-115, 115 watt panels
PV Module Type	Solar Crystalline Silicon	Solar Crystalline Silicon	Thin Ribbon Silicon	Thin Ribbon Silicon
# of Panels	216	216	40	40
Array Size	45,600 W	45,600 W	4,600 W	4,600 W
Slope	10 degree	20 degree	0 degree	20 degree
Azimuth	20 degrees east	20 degrees east	20 degrees east	20 degrees east
Inverter Name	Xantrex PV-45 Grid Tie	Xantrex PV-45 Grid Tie	SMA 5200 Watt Grid Tie	SMA 5200 Watt Grid Tie
Inverter Model	P45	P45	SB6000U	SB6000U

The solar technologies employed in the project were as follows:

PV Modules:

- Sharp Solar Crystalline Silicon, ND – 200U1, 200 watt panel, advertised as the most common large format module used on roof-top solar installations with 15% cell efficiency and a 25 year warranty.
- Evergreen Solar Thin Ribbon Silicon, EV-115 watt panel, with a 13.7% cell efficiency and a 25 year warranty. The panel's data sheet indicated the use of 40% less silicon than conventional wafer technologies which then has the future potential to be a 30% lower cost than poly or single crystal systems.

Five hundred and twelve solar modules were installed in total, covering an area of 15,368 sq. ft. The panels were tested at three different angles; 0 degrees (flat), 10 degrees and 20 degrees from horizontal.

Inverters:

- Two different types of inverters installed: Xantrex PV-45 Grid Tie (used with the Sharp modules) and the SMA 5200 Watt Grid Tie Inverter (used with the Evergreen modules).
- The modules are assembled in series and their DC output is converted to approximately 208 volt 3 phase AC by both the Xantrex and SMA inverters.

Mounting:

- All of the solar modules and brackets were installed on ballast plates that allowed them to be weighted and placed directly on the top of the roof membrane without perforating the membrane.

5. Pre-Feasibility Study and Business Case

Industry input was sought on the estimated cost per kilowatt installed and there appeared to be some economies of scale between a 50 kW system costing $750,000 ($15,000 per kW installed) and a 100 kW system valued at $1,100,000 ($11,000 per kW installed). PV electricity output was estimated at 1,100 kWh/yr per kW installed based on Toronto's solar resource. A public Request for Proposal (available in Appendix VI to this report) was then issued through the City of Toronto in order to elicit competitive pricing. Carmanah's winning proposal was in line with the early estimates, with a projected installed price of just over $946,000 for a 100 kW system.

A RETScreen pre-feasibility study was completed based on Carmanah's proposal and the technical assumptions outlined in Appendix II. This established a baseline regarding expected monthly energy output, revenues, costs, and system payback periods. With the announcement in late 2006 of the Ontario Power Authority's RESOP Program, which provided a payment of 42 cents per kilowatt-hour (kWh) of solar-based electricity produced, it was estimated that the simple payback period would improve to 24 years for the 100 kW system, or 13 years after factoring in the grants detailed Section 3.

Figure 3: Initial Business Case for Horse Palace PV Pilot Project

	Total Cost Installed	Grants[1]	Loan[2]	Array Output (kWh/yr)	Income from Electricity Sales ($/yr)	Simple Payback (years)	Payback after grants (years)
Initial Estimate	$1,100,000[3]	$500,000	$600,000	110,000	$46,200[4]	23.8	13.0
Pre-Feasibility Study (based on selected proposal)	$946,144	$500,000	$446,144	124,210	$52,168	18.1	8.6

6. Installed System Costs

The installed cost (by array) of the Horse Palace PV system is shown in Figure 4, below. The final as-built total system cost was $960,047, only slightly (1.5%) above the price quoted in the initial proposal.

7. Monitoring Protocols

Fat Spaniel of San Jose, California, created a data acquisition system to provide monitoring and information accessibility via an internet enabled device for each of the arrays in the system, 24 hours a day, seven days a week. The monitoring system includes voltage and current meters on both the AC and DC sides of the inverters; a pyranometer to measure solar irradiance; ambient air temperature and module temperature sensors; data loggers and communication equipment. This data acquisition and monitoring is to be carried out under contract for five years by Carmanah. It also provides web-based system performance data in an easy to understand, highly visual format so that visitors to the Exhibition Place website (www.explace.on.ca) can understand the "real-time" performance of the PV Project. A monitor on public display at the DEC Heritage Court at Exhibition Place also highlights the PV installation and shows visitors current system performance.

All performance data from the Fat Spaniel system was collected from November 1, 2006 to October 31, 2007 by Energy Profiles Limited in order to produce a preliminary project monitoring report to inform future installations. Since November 2007, Exhibition Place has developed and instituted internal reporting protocols with on-site Exhibition Place facilities staff.

Figure 4: Exhibition Place - Horse Palace PV Arrays: As-Built Cost Breakdown

Carmannah's Installation Costs	#1 Sharp (10 degree)	#2 Sharp (20 degree)	#3 Evergreen (0 degree)	#4 Evergreen (20 degree)	Total System Costs	Percent of Total Cost
1. Electrical Materials	$236,778	$236,778	$28,588	$28,588	$530,732	48.1%
2. Mounting	$58,226	$60,873	$6,947	$6,947	$132,994	12.1%
3. Installation	$86,320	$90,244	$10,300	$10,300	$197,164	17.9%
4. Project Management	$4,939	$4,939	$549	$549	$10,976	1.0%
5. Engineering	$6,088	$6,088	$676	$676	$13,529	1.2%
6. Cameras	$3,737	$3,737	$415	$415	$8,305	0.8%
7. Monitoring	$7,828	$7,828	$870	$870	$17,397	1.6%
8. Fencing	$1,992	$1,992	$221	$221	$4,427	0.4%
9. Temporary Array Tethering	$280	$280	$31	$31	$623	0.1%
10. Accelerated Installation	$19,756	$19,756	$2,195	$2,195	$43,902	4.0%
Installation Total Pre-Tax	**$425,946**	**$432,516**	**$50,793**	**$50,793**	**$960,047**	**87.0%**
11. PST					$66,311	6.0%
Installation Total Post-Tax					**$1,026,358**	**93.0%**
Other Costs						
12. Engineering Fees					$29,616	2.7%
13. Standard Offer Program Metering Equipment					$27,749	2.5%
14. Legal Fees					$3,042	0.3%
15. In-house charges					$16,508	1.5%
Subtotal					**$76,915**	**7.0%**
FINAL TOTAL					**$1,103,273**	**100%**
Grants and Loans						
FCM/TAF Grants					**$500,000**	
BBP Loan					**$600,000**	

Notes: Lines 1-2 have a heavy component (roughly 95%) of materials purchased in USD. The costs shown reflect an exchange rate where $1 USD = $1.17 CAD.
Lines 4-10 are simply pro-rated for their percentage of total array size.
Costs for the two Evergreen/SMA arrays (#3/4) were not recorded separately, and as such costs were evenly split between the two.
Cost for electrical materials include both PV modules and inverters; no record of separate costs.
Costs are FOB EX Place.

Figure 5: Screenshot from Fat Spaniel monitoring website for Exhibition Place PV system (for live data, see http://view2.fatspaniel.net/FST/Portal/TorontoHorsePalace/)

SECTION TWO
Purchase, Installation, Monitoring

As a pilot of the largest photovoltaic system in Canada, the Horse Palace PV Pilot Project provided not only an assessment of the technical and production aspects of such a system within an urban setting, but it also provided an opportunity to assess and learn from the operational issues that arose within the first year. Below is a synopsis of many of these "lessons learned" related to system installation, operations and finance.

1. System Design, Purchase and Installation

The Horse Palace PV Pilot Project Request for Proposals did not specify a type or layout of the system to be installed, but rather allowed bidders to propose a design for a 100kW system that they would then install. This design-build approach allowed Exhibition Place to award a contract based on the expertise of the designer and installer within a competitive process, and award the contract based on the experience and capacity of the bidders. See Appendix VI for a copy of the RFP.

Late-stage adjustment to research design added costs and caused delays. While the winning design called for the arrays to be set at only two different angles – 10 and 20 degrees – during the install process it was decided to include a flat array in order to compare output versus the angled arrays. Though not a concern at the Horse Palace, the loads created by the heavy ballasting (concrete blocks) for the angled arrays could be excessive for some sites. In order to gather performance data to inform future installations, the 10 degree Evergreen array was changed to a flat zero-degree installation (in reality closer to 1 degree in order to prevent water from pooling on the panels). This last minute redesign added to costs and created delays in installation as the mounting brackets needed to be sent back to the manufacturer to be modified and set at zero angles. In addition, since the flat layout was not part of the original design, there was no accommodation made to increase natural air circulation around the panels. As a result, heat build-up at the back of the zero degree panels appears to have reduced their efficiency somewhat, although the performance was still much higher than anticipated (see section 4(3) below).

Factors missing from initial performance modeling created an inaccurate baseline. The pre-feasibility study, carried out using RETScreen, provided an idea of system capacity and expected performance, but did not fully take into account some variables that would ultimately affect system performance. Shading and obstructions, such as flag poles and exhaust fans, need to be determined prior to system design – these were overlooked in the early stages of Horse Palace PV Pilot Project planning and therefore were not accounted for in RETScreen pre-feasibility modeling.

Feasibility studies also rely on accurate local irradiance data. By default, RETScreen uses historic weather data from a local Environment Canada weather station. In some situations, this may not account for local microclimatic conditions or for changes in local climate over the past 20 years and may not provide an accurate estimate of future system performance. To address these issues, a pyranometer was installed at the Horse Palace along with the PV arrays. This allows for evaluation of system production against actual irradiance on site and is a tool for assessing system efficiency or production disturbances (e.g. low production on a sunny day could signal a problem with the wiring).

Array siting varied 20 degrees east of solar south. The Horse Palace array varied slightly from the optimal southern orientation, likely due to a desire to keep the installation aligned with existing roof structure or because the array was sited using magnetic south compass readings, rather than true south. However, in this case, the variation produced only a minor reduction in plant effectiveness (less than 1%).

Monitoring and metering needs were not fully integrated into project design. Verification and monitoring programs should be specified in the initial design of the PV system, as this informs the structure of the wiring sequence required for monitoring and grid connection metering.

This was not possible at Exhibition Place due to uncertainties in the RESOP program (as outlined below) but would have helped avoid changes to the system design during and after installation.

In all, the installation process took roughly four months, including a two-week break while the Canadian National Exhibition was underway on the Exhibition Place grounds.

Recommendations on System Design, Purchase and Installation:

- **Establish desired knowledge outcomes** at the outset of the program, since these inform system design and monitoring/data collection parameters.
- **Limit the number of variables** you study in a pilot project in order to get clear results from project analyses that will be applicable to future installations.
- **Employ a "design-build" approach**, with clearly laid out requirements in terms of knowledge and performance outcomes.
- As part of the design-build competitive process, it is important to **verify that the bidders (or supplier subcontractors) have the capacity to deliver** components on time when required.
- The tender document needs to **clearly identify system performance expectations**. For example, do you want to know output per nameplate rating or actual generated capacity?
- An initial site pre-feasibility study done by the site owners and provided to contractors during the RFP process would help **identify shading and roof loading issues** that are needed to elicit more accurate bid responses.
- Need to **identify wind loading potential and roof structural limits** prior to finalizing the PV system design, and, in turn, determine the installation angles and design the mounting system (brackets and ballasting) well in advance of the installation in order to avoid delays and additional costs or even structural damage to the building.
- **RETScreen analyses must use realistic array loss factors** (such as those recommended by the California Energy Commission), insolation and weather data.
- **On-site insolation measurements** should be carried out as part of an initial feasibility study, particularly if reliable local data is not available, and to verify system performance against

actual irradiance after installation. Ideally two pyranometers should be installed – one measuring horizontal irradiance (the standard method for reporting irradiance and therefore useful for comparison against other data sets), and one at the angle of the array in order to calculate system efficiency compared to actual solar energy available. If local insolation data is not yet available, use historic local insolation data as a baseline for feasibility studies.

- **Shading from obstructions such as flag poles, exhaust fans, billboards and other buildings, needs to be accurately identified** in order to develop realistic performance models. While RETScreen does not explicitly account for array shading, shading losses (as measured using a device such as a Solar Pathfinder) can and should be included as an array efficiency loss in the modeling software.
- **Design for air circulation with flat systems.** Because zero-degree arrays have little air flowing under and around the panels, they should be located in such a way as to maximize cooling through air circulation, while minimizing potential for lift. If this isn't possible (for example with Building-Integrated PV), losses incurred due to higher operating temperatures need to be accounted for in the feasibility study.
- **Ensure that, when practicable, the array is sited with a zero-degree azimuth in relation to true south** (rather than magnetic south). This is achieved using a magnetic compass and then adjusting based on the magnetic declination table for your region.
- **Ensure a thorough commissioning, verification and monitoring program is in place in advance of construction** as this is needed to inform the structure of the wiring sequence required for monitoring and grid connection (and could ultimately affect RESOP payments).
- **Maintain detailed invoices for equipment and services** in order to do financial analyses, particularly if comparing arrays or systems with differing configurations and costs.

2. Monitoring and Maintenance

Problems with array function, if unnoticed and uncorrected, may cause significant energy and data losses. A well-designed monitoring system maximizes the production from the PV system and ensures prompt troubleshooting. Data should be reviewed regularly to ensure that problems are identified and addressed in a timely manner. For example, in the case of Exhibition Place a power outage caused several days of data loss that would have been immediately detected through regular review of data output. The time lag in identifying this problem caused such significant data loss that an extension of the pilot project was ultimately required to ensure a full set of data was available for analysis. If reviewed on a daily basis, corrections can be made to ensure maximum production. If possible, direct access to data by the owner of the system is ideal along with an obligation for the monitoring company to inform the owner of data collection issues immediately so they can be investigated and problems corrected promptly.

Some problems can best be identified through visual inspection. It is important to do visual inspections of the entire system on a regular basis and not just rely on the data collection and monitoring system. There was one incident of an array cable from one set of arrays becoming unattached, which did not cause the system to go down completely but resulted in a reduced production rate. This was not noticed for some time because it happened in the winter very early on in the project, so staff were not alerted by low production levels. However the incident would likely have been noticed during a physical inspection.

Eighteen months following full installation, bulging of some panels was noted and it was determined that this was due to condensation in the module frames freezing and splitting the frames. While the panels have drainage holes at the bottom corners to avoid this problem, these drainage holes were inadvertently blocked in some of the arrays because of the way the array was mounted on the brackets. Carmanah was notified of the issue and has decided to remove all of the Sharp modules, drill drain holes in the mounting brackets and replace all damaged (bulging) modules before reinstalling the array.

Equipment incompatibilities can cause disruptions and add expense. The energy meter specified initially in the Project resulted in issues when communicating with the Fat Spaniel data collection program. The existing PML 7330 energy meter had to be replaced with a PML 6200 that was compatible with the Fat Spaniel data collection software in order to work properly.

Inaccurate monitoring equipment can skew project results. During the evaluation of the system performance, it came to light that the insolation data from the pyranometer installed on-site was significantly different from data from other meters in the greater Toronto area (GTA). While at first there was speculation that Exhibition Place's unique waterfront location resulted in different solar insolation (e.g. due to extra fog or clouds), in the end it was determined that the installed pyranometer was in fact faulty. Portable pyranometers brought to the site showed that irradiance was actually very similar to readings across the GTA, and that the installed pyranometer was consistently off by roughly 20%. Carmanah has since installed a new pyranometer.

Inverters can cause phantom load. The Xantrex inverters (arrays 1 & 2) draw power from the grid at night when the modules are not producing power as the inverter's isolation transformers run continually. This causes the bidirectional meters to record net electricity consumption from the arrays at night when there is no solar output, which affects production data and payments under the RESOP program. This can be avoided by installing inverters that do not require isolation transformers or that include a nighttime isolation switch.

Power outages can disrupt data collection. Data was lost when there was a power outage at Exhibition Place unrelated to the PV system. When power was restored to the site, the Fat Spaniel monitoring system did not reset. This was an unexpected result and there was a resulting two-day lapse in data collection. This problem was solved with the installation of an uninterruptible power supply (UPS) to prevent similar data loss in the future.

Dirt and snow accumulations may affect production in flat panels. The zero-degree panel accumulated dust and grime in periods of no rain, which could negatively affect output. Further study would be needed to determine the productivity loss from dust, grime and particulates and whether or not regular cleaning is called for.

Snow also accumulates on the zero degree panels and takes longer to melt off than on the angled panels. During a major snow fall in December 2007 it took two days longer for snow to melt off the flat panels compare to angled panels. Despite this, the impact on production is low, as there is generally less insolation on winter days and once the sun does come out fairly

strongly the snow melts off. As such, is does not appear necessary to manually remove snow from the panels.

Recommendations on Monitoring and Maintenance:

- **The task of regular monitoring of data and a protocol for alerting appropriate parties to data anomalies** needs to be clear to all parties involved, so that problems are identified and addressed in a timely manner. To assist with this process, the owner of the data communication system should be given direct access to the system to investigate data inconsistencies as soon as they are identified. It may also be helpful to include in the monitoring contract an obligation for the monitoring company to inform the owner of data collection issues immediately.
- It is helpful to **do visual inspections of the entire system on a regular basis** and not just rely on the data collection and monitoring system. Visual inspections may identify obvious physical deficiencies before data anomalies are detected.
- **Ensure that energy and monitoring equipment selected does not pose any incompatibilities and that monitoring equipment is properly commissioned to ensure accurate readings.**
- **Back-up power supply (e.g. a UPS) should be installed with the monitoring equipment** to prevent data losses in the case of power outages, particularly if there is not a dedicated staff person monitoring the system on a daily basis.
- Ideally, in sites that require isolation transformers for the inverter, **a nighttime isolation switch should be installed to avoid phantom power** losses when the system is not producing electricity.
- **Consider allowing for manual washing of flat panels** during spring and summer to remove dirt accumulations.

SECTION THREE
Interconnection and Payment

An early participant in the Province of Ontario's RESOP, Exhibition Place experienced many challenges and delays in achieving interconnection and payment for the Horse Palace PV Pilot Project.

Lack of clarity regarding demand-side tie-ins. Initial challenges stemmed from the fact that the Horse Palace PV installation ties into the grid power lines on the demand side of the main switch board, not the supply side. This posed a problem with the local utility, Toronto Hydro Electric Services Limited (THESL), whose interpretation of the program eligibility requirements excluded demand-side tie-ins. Given the substantial increase in cost to tie into the supply side, Exhibition Place and THESL resolved this issue and found an acceptable solution to tie into the demand side, but this process slowed down the approvals and the date for commencement of the RESOP. It would have been advantageous to have reached an understanding with THESL about the grid connection in advance of construction, but as this was one of the first systems installed under the RESOP and these details had yet to be hammered out.

Lack of clarity regarding metering requirements. In October 2006 when the Horse Palace PV Pilot Project came on stream, the RESOP metering requirements were also as yet undefined by THESL, which resulted in a requirement to change the standard revenue-grade metering system to an assembly that required a separate metering cabinet and phone line for a Toronto Hydro supplied meter at additional costs. The newly specified metering system also required a neutral line connection, but since the inverter did not require one, it was not designed into the system. A neutral had to be installed to accommodate the metering equipment, also at additional cost.

Delays cause income losses. The delay in finalizing the RESOP agreement and installing the THESL approved meter resulted in 100 MWh of solar generation (from November 2006 to December 2007) being accounted for as simply offsetting Exhibition Place's overall electricity consumption (at an estimated $0.06/kWh rate) rather than receiving the RESOP payment of $0.42/kWh, a loss of $36,000 of potential revenue.

Delay in RESOP payments. While the Ontario Power Authority and THESL accepted the date of commencement under the RESOP as December 19, 2007 (the date when the THESL-approved meter was installed), Exhibition Place did not receive its first payment until late November, 2008, a delay of 11 months. Payments are expected to be issued monthly or bimonthly in the future.

Lack of clarity regarding RESOP payments. Until Exhibition Place received their first RESOP payment, in December 2008, it was unclear how the payments would be calculated or what other administrative or regulatory charges would be deducted. Much of the confusion resulted from Exhibition Place's unique situation as a large-scale electricity consumer with its own property-wide electricity distribution system serving its extensive grounds and buildings.

Rather than having one connection to the external electricity grid for each building (as residential houses and most commercial buildings would), there is one grid connection, with one utility meter, which serves the entire property. In addition, Exhibition Place is billed at the Hourly Ontario Energy Price (HOEP) for electricity use, a varying rate based on the average price of electricity being supplied at any given hour, rather than the flat rate that most small-scale electricity customers would pay to their utility company.

The Horse Palace PV system is embedded in the Exhibition Place electricity system, behind the THESL utility meter. This means that the photovoltaic system connection point is on the customer side of the utility metering equipment (rather than having its own, separate connection to the grid on the utility side of the service entrance). The energy produced by the PV system feeds directly into the Exhibition Place electricity system, rather than going first to the external grid and then feeding back into Exhibition Place through the utility meter. The PV system has its own meter to measure electricity generation from the PV system and consumption by the inverters before this electricity goes out into the Exhibition Place electricity system.

The Exhibition Place utility metering equipment measures all electricity imported from the external Toronto Hydro grid. Total electricity used by Exhibition Place is actually the amount read by the utility meters (showing energy drawn from the grid) plus the electricity generated by the Horse Palace PV system, as measured by the PV system meter.

As such, THESL must calculate the RESOP payment based on all the electricity produced by the PV system, but also charge Exhibition Place for then consuming that electricity on-site. Exhibition Place is charged for the solar-based electricity it consumes at the HOEP rate, just as it would be for electricity provided from the grid.

RESOP payments for PV electricity generated at Exhibition Place are thus calculated as the $0.42/kWh RESOP rate minus the HOEP (Hourly Ontario Energy Price) rate Exhibition Place would otherwise pay for electricity from the grid, which averages around $0.06/kWh. There are also associated flat-rate account costs, both monthly and annual, and possibly other standard charges (such as debt-retirement) that are averaged into the monthly payments (resulting in roughly $100 of deductions per month), but are not clearly specified on the statements. These are expected to be clarified shortly.

Recommendations on Grid Inter-Connection and Payment

- **In advance of construction an understanding must be reached with the local utility provider about the viability of grid connection for the PV system.**
- Uncertainty over new government incentives can result in delays and unexpected costs. If possible, try to **establish metering, connection and procedural requirements before installation** to accommodate these requirements, as well as incorporate them into system costs and financial models.
- **Other connection and generating fees should be established with the local utility and/or distribution company early on in project planning** in order to develop a more accurate financial model for the system. Ideally these should be known prior to project development, as they could significantly affect the return on investment of the project.

SECTION FOUR
Performance and Research Findings

1. System Performance

The Horse Palace PV system has been operational since October of 2006. Initially, the Pilot Project was expected to run one year, with data then being analyzed and used to guide decision making on a larger 1-2 MW installation. The first year of active project monitoring resulted in identification of several key operational issues and challenges, including complications with inverters and monitoring equipment, shading issues, and data collection and management issues.

At the end of the first year of the pilot project, an external technical advisor was brought on to correct some technical issues and provide ongoing support to the project. At this time, a problem with the baseline performance modeling used to assess the project was identified and a decision was made to extend the pilot data collection for a second year, once these initial challenges were overcome. A team of project supporters, composed primarily of Exhibition Place staff, took over monitoring and management of the site and began regular meetings to ensure that data flows and technical matters were handled quickly and effectively.

Extensive data is now available from 2007 and 2008 for each of the installed arrays. Aggregate electricity production and array performance data is summarized in Figure 6. Data by month and array is available in Appendix III.

Figure 6: Horse Palace PV Arrays: 2007 and 2008 electricity generation and array performance

Array #	**#1**	**#2**	**#3**	**#4**	**System Total**
Panel Manufacturer	Sharp	Sharp	Evergreen	Evergreen	-
Slope of Array Installation	10 degree	20 degree	0 degree	20 degree	-
kW installed	45.6	45.6	4.6	4.6	**100.4**
2007 Electricity generated (kWh/yr)	42,409	44,746	4,491	4,835	**96,481**
2007 Array performance (kWh/kW)	930.0	981.3	976.3	1,051.1	**961.0**
Electricity generated 2008* (kWh/yr)	43,272	44,575	4,442	4,436	**96,724**
2008 Array performance (kWh/kW)	948.9	977.5	965.5	964.2	**963**

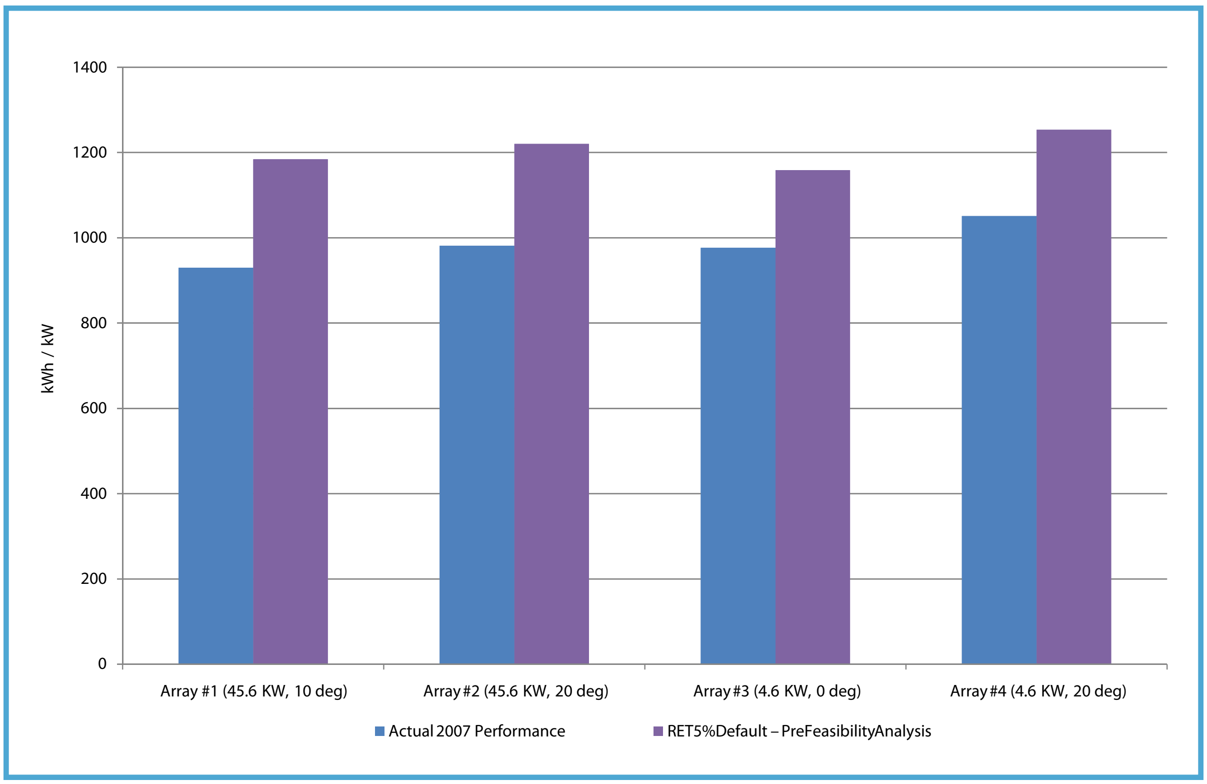
* The data for November-December 2008 is from Toronto Hydro, because the Fat Spaniel monitoring system was down for most of those two months. Values have been prorated for each array based on the array size/total system size.

2. Performance Compared to Feasibility Study

Early findings for the Horse Palace PV Pilot Project showed that the system was not meeting energy output expectations from the pre-feasibility study. However, subsequent examination of the factors used to establish the performance model in the pre-feasibility study revealed that flawed assumptions caused inaccuracies in the baseline. In addition, monitoring equipment used to assess the solar resource at the site malfunctioned. More details on these issues and how they were resolved are provided later in this report. Once these problems were corrected, the Horse Palace PV Pilot Project performed up to expectations with some energy production losses experienced due to night-time power use by inverters' isolation transformers.

A review of 2007 system output found that, overall, the system as a whole is performing below the initial expectations stated in the RETScreen pre-feasibility study outlined in Section 1(5) and Appendix II.

Figure 7: Energy Production per KW Installed - Actual 2007 Data vs. RETScreen Pre-Feasibility Model



In an attempt to explain this underperformance compared to the pre-feasibility study, actual performance (measured in kWh produced per kW installed) was compared against three performance models as follows

Figure 8: Key Variables in RETScreen PV Performance Models

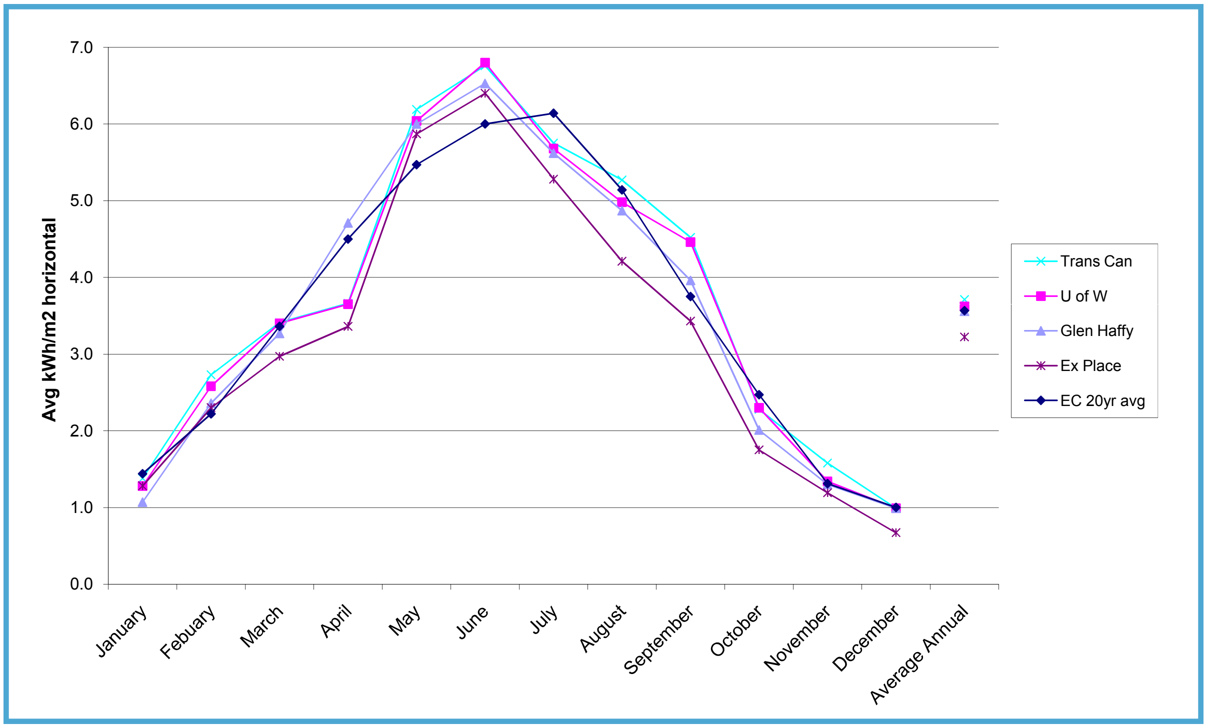
Model Name	De-rating Factors for Miscellaneous Losses	Shading Losses	Irradiance Data
RET17%Historic	17% Miscellaneous PV array losses; 1% Miscellaneous power conditioning losses.	Actual shading losses from Solar Pathfinder (by month) incorporated into miscellaneous losses	Historic (20 yr) data for Toronto, ON, from Environment Canada.
RET17%OnSite	17% Miscellaneous PV array losses; 1% Miscellaneous power conditioning losses.	Actual shading losses from Solar Pathfinder (by month) incorporated into miscellaneous losses	2007 irradiance data measured by pyranometer at Exhibition Place.
RET5%Default*	5% Miscellaneous PV array losses; 0% Miscellaneous power conditioning losses. (Default factors in RETScreen.)	Not accounted for.	Historic (20 yr) data for Toronto, ON, from Environment Canada.

*The RET5%Default model is very similar to what was used in the pre-feasibility analysis done for the project, but with updated details on the installed system, including inverter efficiency for the Xantrex models and a change in the Evergreen panel model. See Appendix II for a detailed comparison

Miscellaneous efficiency losses and shading not accurately accounted for. Unrealistically high performance expectations resulted from the original RETScreen feasibility study, as the **RET5%Default** model used was not modified to fully take into account site shading and used unrealistically low miscellaneous array efficiency loss values. The Horse Palace roof has shading from various roof protrusions and a large flagpole and flag near the building. These were later measured with Solar Pathfinder equipment and modeling software and subsequently incorporated into the **RET17%Historic** and **RET17%OnSite** models. The RETScreen default value for miscellaneous array efficiency losses is 5%, which is considerably lower than the values recommended by the California Energy Commission (CEC). The CEC values, which take into account efficiency losses due to dirt and dust, mismatch and wiring losses, and tolerance values for standard test conditions, predict 17% efficiency losses.[5] As such, 17% miscellaneous array efficiency losses were included in the **RET17%Historic** and **RET17%OnSite** models, in addition to the inverter and temperature related efficiency losses which were already accounted for in the RETScreen models. Miscellaneous power conditioning losses were also increased from the default 0% to 1% in the **RET17%Historic** and **RET17%OnSite** models.

Incongruous on-site irradiance data. As part of the Horse Palace PV Pilot Project a pyranometer was mounted at the site which recorded weather data, including irradiance levels (in a horizontal plane). The **RET17%OnSite** model used this on-site insolation data to predict system performance. The graph below shows that irradiance levels recorded by the Horse Palace meter for the year 2007 were less than the levels used in the RETScreen Feasibility Study (which were based on 20 years of historical data from Environment Canada) or those recorded by other meters within the Greater Toronto Area, including at the University of Waterloo, Glen Haffy Conservation Area, and the TransCanada pipeline site.

Figure 9: Irradiance Levels in the GTA - 2007 Solar Insolation Data from various testing sites, compared to Environment Canada's 20-year average for Toronto

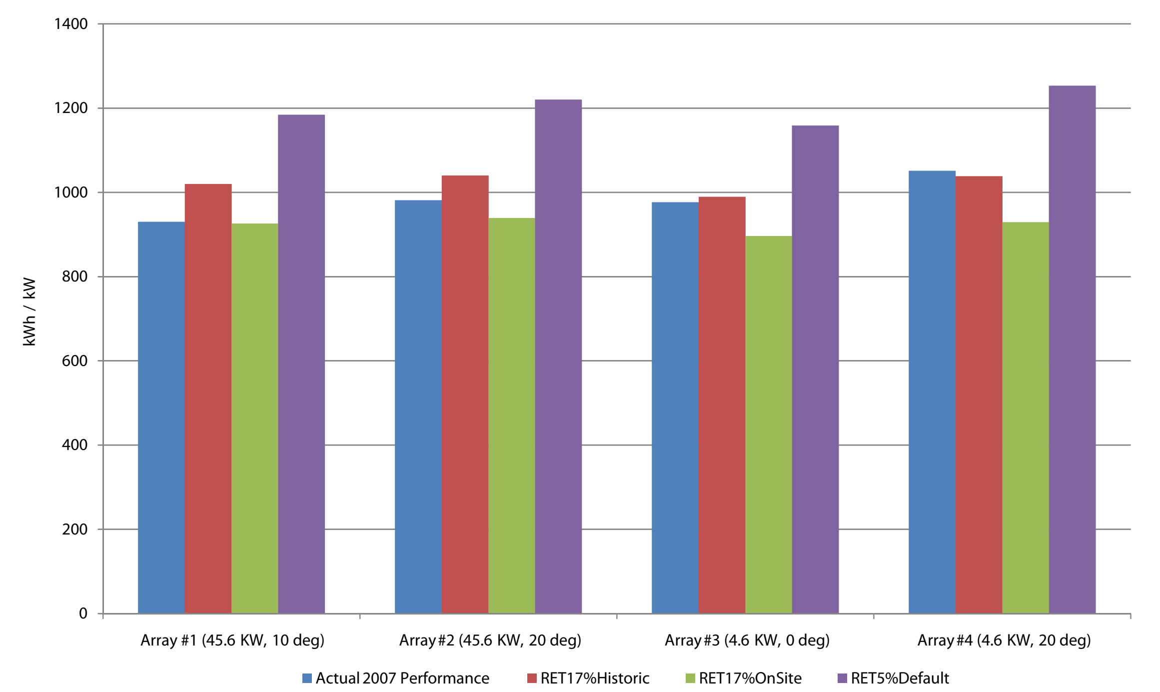


In order to determine whether the pyranometer at Exhibition Place was truly picking up on a distinct microclimate affect, which produced lower solar insolation than surrounding areas, or if there was something wrong with the meter, two additional pyranometers were brought to the site. Measurements from the portable pyranometers were both roughly 25% higher than those from the original meter (727 and 728 W/sq meter, as opposed to 579 W/sq m from the installed pyranometer). As such, it was concluded that the on-site insolation data is inaccurate and should not be used in models to benchmark system performance.

New performance baseline established using modified RETScreen model. The third RETScreen model used, RET17%Historic included a 17% efficiency de-rating factor (thereby accounting for actual shading and more accurate miscellaneous losses as recommended by the California Energy Commission), while using average historic irradiance data from Environment Canada's Toronto weather station. This proved to be the most accurate model when totaled over the year (monthly values differ between the model and actual 2007 production data, as each year there are somewhat different weather patterns, but roughly the same amount of irradiance over the course of the year, as shown by Environment Canada's historic weather data).

Under the **RET17%Historic** model, the Evergreen/SMA systems (arrays 3 and 4) are performing almost exactly at expected levels, while the Sharp/Xantrex systems (arrays 1 and 2) are still performing below expectations. This underperformance of the Sharp/Xantrex arrays is explained in large part by night-time power use by the inverter's isolation transformer, as discussed in more detail in section 2(2) below. The following graph shows the actual overall performances of the different arrays compared to the various RETScreen models. More detailed analysis by array and by month can be found in Appendix IV.

Figure 10: Energy Production per KW Installed - 2007 data vs. RETScreen models



In summary, the RETScreen pre-feasibility study over-estimated expected performance, because it did not take shading into account, and it underestimated miscellaneous array losses. Models using on-site insolation data from the installed pyranometer underestimated expected performance because the installed meter was inaccurate. The model which combined historic Toronto insolation data with the higher (17%) efficiency de-rating came the closest to modeling actual performance of the system, and should be used for future modeling exercises.[6] The RETScreen inputs used for this model can be found in Appendix II.

3. Performance of the Inverters

As noted above, the Horse Palace PV Pilot Project tested two different types of inverters, one manufactured by Xantrex Technology Inc. and one by SMA Solar Technology AG. Six months into the Project, it was noted that the two Xantrex inverters used on the two 45 kW Sharp solar arrays were performing below the expected efficiency level of approximately 90% based on the nameplate data for the inverters. On further analysis, it was determined that these lower levels were solely due to the isolation transformer since the inverter itself consumes an insignificant amount of power when it enters the "sleep" mode. This night-time tare loss is sufficient to account for the underperformance of the Sharp/Xantrex arrays as compared to the "RET17%Historic" model outlined above.

Xantrex has now designed an inverter that does not require an isolation transformer, but Xantrex was not manufacturing this design for a 45 kW unit at the time of construction of the Horse Palace PV Pilot Project. Solutions to this "tare" loss would be to convert to a newer Xantrex model or install an automatic isolation switch after the isolation transformer that is opened whenever the inverter enters the "sleep" mode. This is discussed further in section 3(4) below.

4. Performance of the Different Angled Arrays and Cost Effectiveness

The arrays at the Horse Palace were installed at various angles (0, 10 and 20 degrees) in order to compare performance of the system at different slopes. Because there are several confounding factors involved in determining performance (including panel model, inverter type, and shading), performance cannot be wholly attributed to the angle of installation, but it is clear that the arrays set at 20 degree tilts performed better than their lower-inclination counterparts, as shown in Figure 11 below. Between the two Sharp arrays, the 20 degree array performed six percent better over they year than the array at 10 degrees. The 20 degree Evergreen array performed eight percent better than the horizontal Evergreen array. The lower performance of the zero and 10 degree arrays is most distinct in the winter months (when the sun is lower), as shown in Figure 12.

Figure 11: Total Energy Production in 2007 per KW of PV Installed

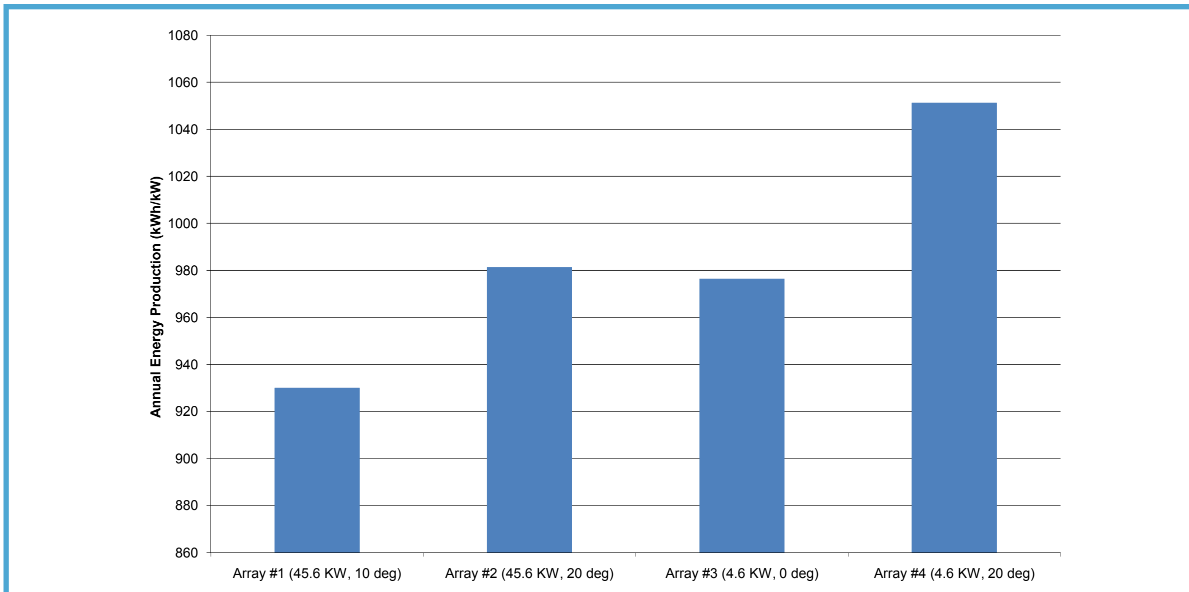
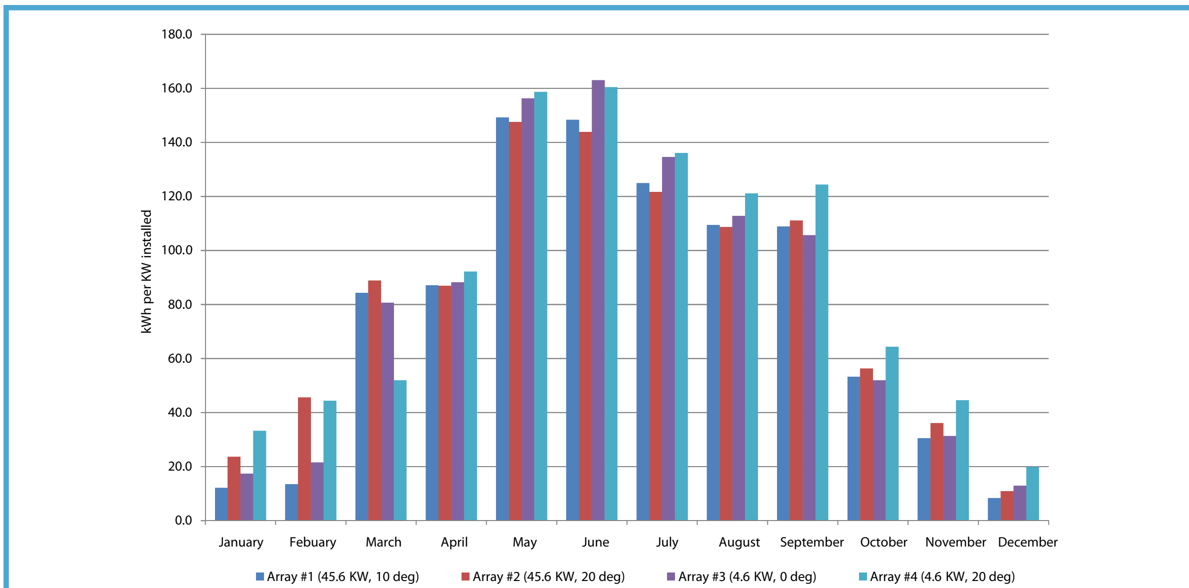


Figure 12: 2007 Energy Production by Array per KW installed



As shown in Figure 13, over the course of the year the arrays at 20 degree slopes produced more electricity per kW installed than their less-inclined counterparts. The higher output is to be expected based on higher direct radiation on the 20 degree arrays. Mathematically, the best angle to maximize energy yield per watt of PV installed in Toronto is 45 degrees, but this assumes clear skies year-round. When you take into account local weather (increased cloudiness in the winter, clearer skies in the summer), the ideal angle of installation is closer to 32 degrees. However, the relatively strong performance of the flat panels should encourage greater consideration of flat array configurations as it is possible that they could be installed at a lower cost than angled panels on racks.

Figure 13: ExPlace - Horse Palace PV Arrays: 2007 Performance per kW and per square meter of roof space

Array #	#1	#2	#3 (actual spacing)	#3 (contiguous)	#4
Panel Manufacturer	**Sharp**	**Sharp**	**Evergreen**	**Evergreen**	**Evergreen**
Slope of Array Installation	**10 degree**	**20 degree**	**0 degree**	**0 degree**	**20 degree**
kW installed	45.6	45.6	4.6	4.6	4.6
kWh produced in 2007 (kWh/yr)	42,409	44,746	4,491	4,491	4,835
Array performance (kWh/kW)	930	981	976	976	1051
Array performance (kWh/m^2 roof)	83	72	70	107	67

There are a number of factors to consider when determining optimal array installation angles for a given project site. It is important to balance roof loading and shading issues, as well as size and cost issues. At Exhibition Place, snow did not have a major impact on overall performance for the flat or angled panels. Although the flat panels would tend to stay covered with snow for 2-3 days longer than the angled arrays, irradiance is so much lower in the winter (and particularly during periods of precipitation) that the impact of snow coverage on annual production is very low. In addition, if there is particularly sunny -winter day, any snow will melt away quickly allowing even the flat panels to produce electricity soon after the sun comes out.[7]

While they still produce slightly less electricity per kW installed, flat arrays do have other advantages. Flat arrays reduce roof loads, and can make better use of available roof space since they reduce the distance required between arrays because they create no shading. Panels installed at higher angles need to be spaced farther apart to avoid shading one another. As an added bonus, flat panels can act as additional insulation for the building, reducing heating and cooling loads. Flat panels would make sense in future installations where the roof cannot handle large loads associated with racking systems or wind loading, and/or the owner wants to maximize system size at a given site (rather than maximize cost effectiveness). Covering the entire roof with flat arrays would allow for greater electricity production over the entire roof as there is no shading or need to space the arrays apart from one another, although the production would be less per panel as compared to an array mounted closer to 32 degrees (in Toronto). Note that in Figure 13 a hypothetical array has been added, "#3 (contiguous)", which is the same as "#3 (actual spacing)" only without any spaces left between the panels. In this case, the amount of electricity produced per square meter of roof space is much higher than any of the installed arrays. Flat panels may also cost less since they do not require racking.

On the other hand, installing a sloped system would make sense if you are only installing a small number of panels compared to available roof space, and high roof loads are not an issue. This would allow for maximum output per panel (i.e. kWh per watt installed), and so would also maximize cost effectiveness, assuming the cost of the mounting system is reasonable. Depending on the cost of mounting, a flat array may actually produce electricity at a lower cost per kW installed than a racked array, but determining this would require detailed quotes for a racked array versus an otherwise identical flat array. This is an area for future research.

5. Optimum Electrical Equipment & Cost Effectiveness

The Xantrex inverters used more energy overnight than accounted for in the performance models due to the requirement to install an isolation transformer. This reduced overall energy production as measured by the two-way meter (after the isolation transformer). These losses are avoided in larger Xantrex inverter models, as a nighttime isolation switch is incorporated into the inverter equipment. Any new installations should use nighttime isolation switches to prevent these losses, or use inverters that do not require an isolation transformer.

While one of the Pilot Project goals was to analyze the relative cost-effectiveness of the different inverter technologies tested in this project, various factors obscured our ability to accurately compare the two. Because both Sharp arrays were installed with Xantrex inverters, and both Evergreen arrays with SMA inverters, and we do not have an electrical equipment price breakdown of the inverter and array costs, it is impossible to know from these results whether the superior cost effectiveness of arrays 1 and 2 was due primarily to the panel price and efficiency (particularly as there may have been economies of scale with the Sharp panels) or the inverter price and efficiency. This remains an area for future study.

6. Updated Business Case

There appeared to be some potential economies of scale given industry estimates that a 50 kW system would cost $750,000 ($15,000 per kW installed) and a 100 kW system was estimated at $1,100,000 ($11,000 per kW installed). PV electricity output was estimated at 1,100 kWh/yr per kW installed based on Toronto's solar resource. These figures provided a first estimate of the site's potential. A public Request for Proposal (RFP) (available in Appendix VI to this report) was then issued through the City of Toronto to solicit competitive bids. Carmanah's winning proposal was in line with the early estimates, with a projected installed price of just over $946,000 for a 100 kW system.

A RETScreen pre-feasibility study was completed based on Carmanah's proposal and the technical assumptions outlined in Appendix II. This established a baseline regarding expected monthly energy output, revenues, costs, and system payback periods. With the announcement in late 2006 of the Ontario Power Authority's RESOP Program, which provided a payment of

42 cents per kilowatt-hour (kWh) of solar-based electricity produced, it was estimated that the simple payback period would improve to 18 years for the 100 kW system, or nine years after factoring in the grants detailed above.

As previously discussed, the most accurate model for predicting system performance is the "RET17%Historic" model, which combined historic Toronto insolation data with the higher (17%) efficiency de-rating. Figure 14 shows the Business Case from section 1(5) updated with this adjusted feasibility study. The last row in the chart shows the actual installed costs, array output, and income from the RESOP for 2008. As mentioned in section 1(6), the final installed cost was slightly higher than originally quoted. Net array output was lower than the feasibility study predicted due to the nighttime electricity use by the inverters, as discussed in section 4(3). Income from the RESOP was also smaller than originally anticipated, due to the accounting methods and additional charges used by THESL, which brought the actual payment rate to about $0.36/kWh. The deductions from the RESOP payments for electricity used on-site ($6,754 worth of electricity in 2008, calculated using the HOEP), though, should offset an equivalent amount of electricity that Exhibition Place did not have to pay for on their main utility bill.

Based on the actual data from 2008, the payback (after grants) is expected to be just under 13 years. Because RESOP payments did not begin until December 2007, a full year of expected income was lost. As such, the simple payback period now extends to mid- 2018, barring any other significant performance or payment disruptions.

Figure 14: Horse Palace PV Pilot Project Updated Business Case

	Total Cost Installed	Grants[8]	Loan[9]	Array Output (kWh/yr)	Income from Electricity Sales ($/yr)	Simple Payback (years)[10]	Payback after grants[11] (years)
Initial Estimate	$1,100,000[12]	$500,000	$600,000	110,000	$46,200[13]	23.8	13.0
Pre-Feasibility Study (based on selected proposal)	$946,144	$500,000	$446,144	124,210	$52,168	18.1	8.6
Adjusted Feasibility Study (using RET17%Historic model)	$946,144	$500,000	$446,144	103,275	$43,376	21.8	10.3
Actual (using final installed cost & 2008 performance data)	$1,103,273	$500,000	$600,000	96,724[14]	$36,176	30.5	16.7

7. Research Opportunities

There are many opportunities for continued research using the data from the Horse Palace PV Pilot Project. Some of the research questions that remain include:

- How does the increased installation cost of racked systems compare to the increased electricity production from racked systems (due to higher direct radiation levels)?
- How do smog days affect power output from the PV panels?
- How does dirt and grime buildup on the panels affect electricity production, and should panels be washed manually?
- How does solar electricity generation compare to peak electricity loads? How closely do the two mirror one another? What is the price paid on the independent electricity market during these peak times, as compared to the RESOP payment for solar PV? How does the capacity factor for the PV panels, broken down by hour, compare to peak demand?
- Does peak shaving from the PV installation affect the price Exhibition Place pays for electricity (as the price they currently pay for electricity is determined monthly based on the HOEP at the time of their peak electricity demand)?

SECTION FIVE
Conclusion

The Horse Palace PV Pilot Project created significant experience with installing and operating a large-scale PV system in Toronto and confirmed that large, urban PV systems located here can perform to expectations, with a 100 kW system producing 103,275 kWh/yr. In addition, the project was very successful in building capacity to operate large roof-mounted PV systems in Toronto, and identified several key elements necessary to ensure their success, including:

- Careful site selection
- Comprehensive initial design that fully integrates monitoring equipment and protocols
- Attentive monitoring including visual inspections
- Clear reporting protocols when anomalies are noted
- Thorough understanding of the requirements and costs of government incentive programs, and
- A clear plan for acceptable grid interconnection before installation begins.

A detailed list of all the recommendations presented in this report can be found in Appendix I.

In addition to practical project management, this pilot project provided insights into the challenges facing participants in the Province of Ontario's Renewable Energy Standard Offer Program (RESOP), namely a lack of clarity regarding metering and interconnection requirements resulting in significant delays and loss of projected revenues.

The experience gained from this project will be used as the first major research contribution to the SolarCity Technology Assessment Partnership, a joint initiative of the City of Toronto Energy Efficiency Office, Toronto Atmospheric Fund, and the Toronto and Region Conservation Authority, intended to proactively gather and share local experience with major solar installations in the Greater Toronto Area.

A limitation of the Horse Palace PV Pilot Project is the multiple variables incorporated into the study, which confounded clear analyses of the relative performance of different types of equipment and installation angles, which was one of the study objectives. We hope that clearer information on this front will be extracted from future study at the site.

APPENDIX I

Exhibition Place Horse Palace PV Pilot Project – Recommendations

As a pilot of the largest photovoltaic system in Canada, the Horse Palace PV Pilot Project provided not only an assessment of the technical and production aspects of such a system within an urban setting, it also provided an opportunity to assess and learn from the operational issues that arose within the first year.

Recommendations on System Design, Purchase and Installation:

- Establish desired knowledge outcomes at the outset of the program, since these should inform system design and monitoring/data collection parameters.
- Limit the number of variables you study in a pilot project in order to get clear results from project analyses that will be applicable to future installations.
- Employ a "design-build" approach, with clearly laid-out requirements in terms of knowledge and performance outcomes.
- As part of the design-build competitive process, it is important to verify that the bidders (or supplier subcontractors) have the capacity to deliver components on time when required.
- The tender document needs to clearly identify system performance expectations.
- Need to identify the wind-loading potential and roof structural limits prior to finalizing the PV system design, and, in turn, determine the installation angles and design the mounting system (brackets and ballasting) well in advance of the installation in order to avoid delays and additional costs or even structural damage to the building.
- An initial pre-feasibility site study done by the site owners and provided to contractors during the RFP process would help identify shading and roof loading issues that are needed to support more accurate bid responses.
- RETScreen (or similar) feasibility and performance analyses must use realistic array loss factors (such as those recommended by the California Energy Commission), and local insolation and weather data.
- On-site insolation measurements should be carried out as part of an initial feasibility study, particularly if reliable local data is not available. This approach can also be used to verify system performance against actual irradiance after installation. Ideally two pyranometers should be installed – one measuring horizontal irradiance (the standard method for reporting irradiance, and therefore useful for comparison against other data sets), and one at the angle of the array in order to calculate system efficiency compared to actual solar energy available. If local insolation data is not yet available, use historic local insolation data as a baseline for feasibility studies.
- Shading from obstructions such as flag poles, exhaust fans, billboards and other buildings, needs to be accurately identified in order to develop realistic performance models. While RETScreen does not explicitly account for array shading, shading losses (as measured using a device such as a Solar Pathfinder) can and should be included as an array efficiency loss in the modeling software.
- Determine whether racked systems or flat installations are more appropriate given project budget and space limitations.

- Mathematically, the best angle to maximize energy yield per watt of PV installed in Toronto is 45 degrees (based on its latitude), but this assumes clear skies year-round. When you take into account local weather (increased cloudiness in the winter, clearer skies in the summer), the ideal angle of installation to maximize production per panel is closer to 32 degrees.
- Flat panel installation may make more sense if you want to maximize electricity production per square metre of roof space (rather than per panel), or if your roof cannot handle extra loading associated with ballasting or wind with racked panels.

• Design for air circulation with flat systems. Because zero-degree arrays have little air flowing under and around the panels, they should be located in such a way as to maximize cooling through air circulation, while minimizing potential for lift. If this isn't possible (for example with Building-Integrated PV) losses incurred due to higher operating temperatures need to be accounted for in the feasibility study.
• Ensure that, when practicable, the array is sited with a zero-degree azimuth in relation to true south (rather than magnetic south). This is achieved using a magnetic compass and then adjusting based on the magnetic declination table for your region.
• Commissioning, verification and monitoring programs should be included in the initial design of the PV system, as this is needed to inform the structure of the wiring sequence required for monitoring and grid connection metering (and could ultimately affect RESOP payments).
• Maintain detailed invoices for equipment and services in order to do financial analyses, particularly if comparing arrays or systems with differing configurations and costs.

Recommendations on Monitoring and Maintenance:

• The task of regular monitoring of pilot data and a protocol for alerting appropriate parties to data anomalies needs to be clear to all parties involved so that problems are identified and addressed in a timely manner. To assist with this process, the owner of the data communication system should be given direct access to the system to investigate data inconsistencies as soon as they are identified. It may also be helpful to include in the monitoring contract an obligation for the monitoring company to inform the owner of data collection issues immediately.
• It is helpful to do visual inspections of the entire system on a regular basis and not just rely on the data collection and monitoring system. Visual inspections may identify obvious physical deficiencies before data anomalies are detected.
• Ensure that the system and monitoring equipment selected does not pose any incompatibilities and that monitoring equipment is properly commissioned to ensure accurate readings.
• A back-up power supply (e.g. a UPS) should be installed with the monitoring equipment to prevent data losses in the case of power outages, particularly if there is not a staff person monitoring the system on a daily basis.
• Ideally, in sites that require isolation transformers for the inverter, a nighttime isolation switch should be installed to avoid phantom power losses when the system is not producing electricity.
• Consider manual washing of flat panels during spring and summer to remove dirt accumulations.

Recommendations on Grid Inter-Connection and Payment

- In advance of construction an understanding must be reached with the local utility provider about the viability of grid connection for the PV system.
- Uncertainty over new government incentives can result in delays and unexpected costs. If possible, try to establish metering, connection and procedural requirements before installation to accommodate these requirements, as well as to incorporate them into financial models.
- Other connection and generating fees should be established with the local utility and/or distribution company early on in project planning in order to produce a more accurate financial model for the system. Ideally these should be known prior to project development, as they could significantly affect the return on investment

APPENDIX II

Inputs Used in RETScreen Pre-Feasibility Analysis & Performance Modeling

RETScreen Analysis: Variables Used for Horse Palace PV Performance Modelling

Model / RETScreen Input	Array 1				Array 2				Array 3				Array 4			
	Pre-Feasibility	RET5% Default	RET17% OnSite	RET17% Historic	Pre-Feasibility	RET5% Default	RET17% OnSite	RET17% Historic	Pre-Feasibility	RET5% Default	RET17% OnSite	RET17% Historic	Pre-Feasibility	RET5% Default	RET17% OnSite	RET17% Historic
Project Location	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto	Toronto
Latitude of project location (°)	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7	43.7
PV array tracking mode	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed
Annual solar radiation (kWh/m^2 on tilted surface)	1.38	1.37	1.24	1.37	1.43	1.42	1.28	1.42	1.30	1.30	1.18	1.30	1.38	1.37	1.27	1.37
Slope of PV array (°)	10	10	10	10	20	20	20	20	0	0	0	0	10	20	20	20
Azimuth of PV array (°)	0	20	20	20	0	20	20	20	0	20	20	20	0	20	20	20
Application type	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid	On-grid
Grid type	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid	Central-grid
PV energy absorption rate	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
PV module type	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si	poly-Si
PV module manufacturer and model	Sharp ND-200U1	Sharp ND-200U1	Sharp ND-200U1	Sharp ND-200U1	Sharp ND-200U1	Sharp ND-200U1	Sharp ND-200U1	Sharp ND-200U1	Evergreen ES-112	Evergreen EV-115	Evergreen EV-115	Evergreen EV-115	Evergreen ES-112	Evergreen EV-115	Evergreen EV-115	Evergreen EV-115
Nominal PV module efficiency	12.3%	12.3%	12.3%	12.3%	12.3%	12.3%	12.3%	12.3%	6.9%	11.0%	11.0%	11.0%	6.9%	11.0%	11.0%	11.0%
Miscellaneous PV array losses	5%	5%	17%	17%	5%	5%	17%	17%	5%	5%	17%	17%	5%	5%	17%	17%
Nominal PV array power (kWp)	45	45.6	45.6	45.6	45	45.6	45.6	45.6	4.99	4.6	4.6	4.6	4.99	4.6	4.6	4.6
PV array area (m^2)	365.9	370.7	370.7	370.7	365.9	370.7	370.7	370.7	72.3	41.8	41.8	41.8	72.3	41.8	41.8	41.8
Average inverter efficiency	95%	92%	92%	92%	95%	92%	92%	92%	95%	95%	95%	95%	95%	95%	95%	95%
Inverter capacity (kW AC)	50	45	45	45	50	45	45	45	6	6	6	6	6	6	6	6
Miscellaneous power conditioning losses	0%	0%	1%	1%	0%	0%	1%	1%	0%	0%	1%	1%	0%	0%	1%	1%
RETScreen Modeling Results																
Specific yield (kWh/m²)	151	145.7	113.9	125.5	155.9	150.1	115.5	127.9	80.4	127.5	98.6	108.9	84.7	137.9	102.2	114.2
Overall PV system efficiency	11.0%	10.6%	9.2%	9.2%	10.9%	10.6%	9.2%	9.1%	6.2%	9.8%	8.5%	8.4%	6.1%	9.7%	8.4%	8.4%
PV system capacity factor	14.0%	13.5%	10.6%	11.6%	14.5%	13.9%	10.7%	11.9%	13.3%	13.2%	10.2%	11.3%	14.0%	14.3%	10.6%	11.8%
Renewable Energy Collected (MWh)	58.15	58.70	45.90	50.56	60.03	60.47	46.55	51.55	6.12	5.64	4.36	4.82	6.45	6.10	4.52	5.05
Renewable Energy Delivered (MWh)	55.24	54.00	42.23	46.52	57.03	55.64	42.83	47.43	5.81	5.33	4.12	4.55	6.13	5.77	4.27	4.78

APPENDIX III

2007 & 2008 Electricity Generation and Performance by Array and Month

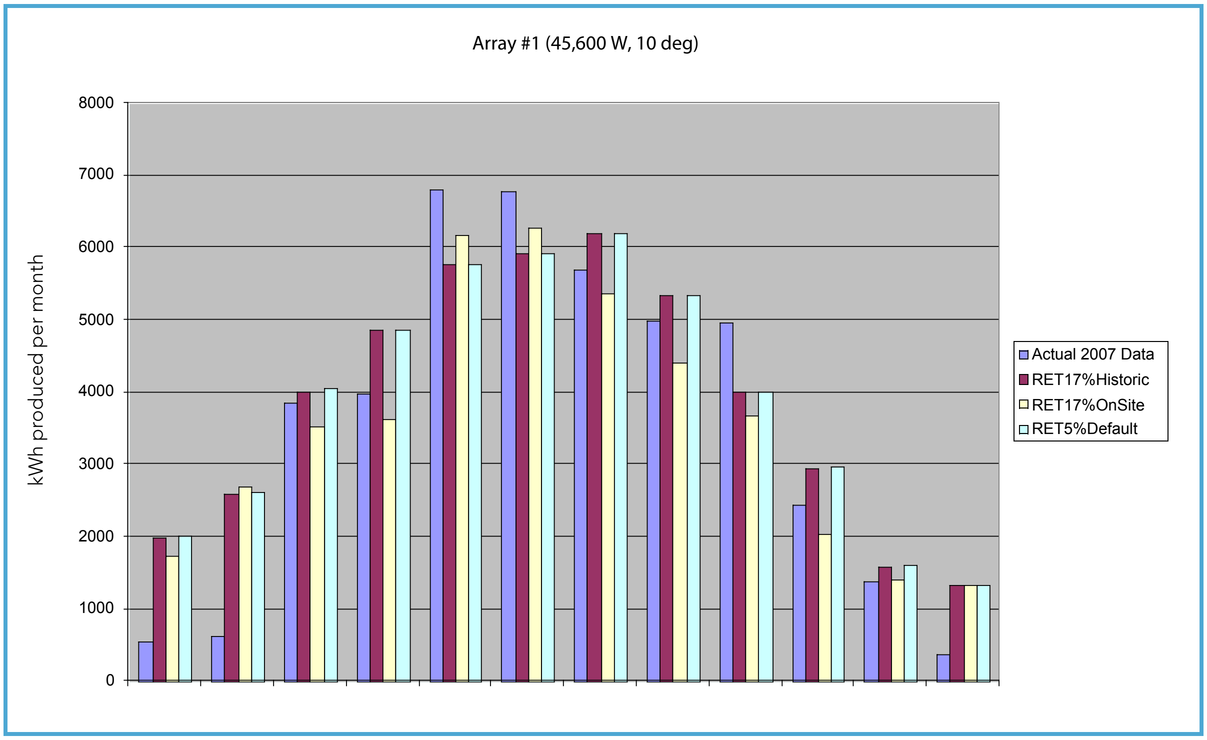
Array	Array #1				Array #2				Array #3				Array #4			
Size (kW)	45.6				45.6				4.6				4.6			
	2007	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**	**2007**	**2008**
	kWh	kWh	kWh/ kW	kWh/ kW	kWh	kWh	kWh/ kW	kWh/ kW	kWh	kWh	kWh/ kW	kWh/ kW	kWh	kWh	kWh/ kW	kWh/ kW
January	552	800	12	18	1077	1144	23.6	25.1	80	101	17	22	153	116	33	25.2
Febuary	615	205	13	4	2079	645	45.6	14.1	99	56	22	12	204	0	44	0.0
March	3844	2703	84	59	4053	3296	88.9	72.3	371	242	81	53	239	0	52	0.0
April	3974	5765	87	126	3964	5844	86.9	128.2	406	572	88	124	424	620	92	4.0
May	6804	5967	149	131	6729	5835	147.6	128.0	719	610	156	133	730	620	159	3.0
June	6767	5485	148	120	6560	5310	143.9	116.4	750	593	163	129	738	588	160	2.5
July	5697	5993	125	131	5549	5858	121.7	128.5	619	656	135	143	626	661	136	1.6
August	4989	5815	109	128	4957	5759	108.7	126.3	519	603	113	131	557	647	121	0.9
September	4965	4377	109	96	5065	4461	111.1	97.8	486	429	106	93	572	505	124	0.7
October	2429	3472	53	76	2569	3733	56.3	81.9	239	314	52	68	296	415	64	0.7
November*	1391	1790	31	39	1648	1790	36.1	39.3	144	175	31	38	205	175	45	0.3
December*	382	900	8	20	496	900	10.9	19.7	60	90	13	20	92	90	20	0.2
Total	42,409	43,272	930.0	948.9	44,746	44,575	981.3	977.5	4,492	4,442	976.4	965.5	4,836	4,436	1,051.2	964.2

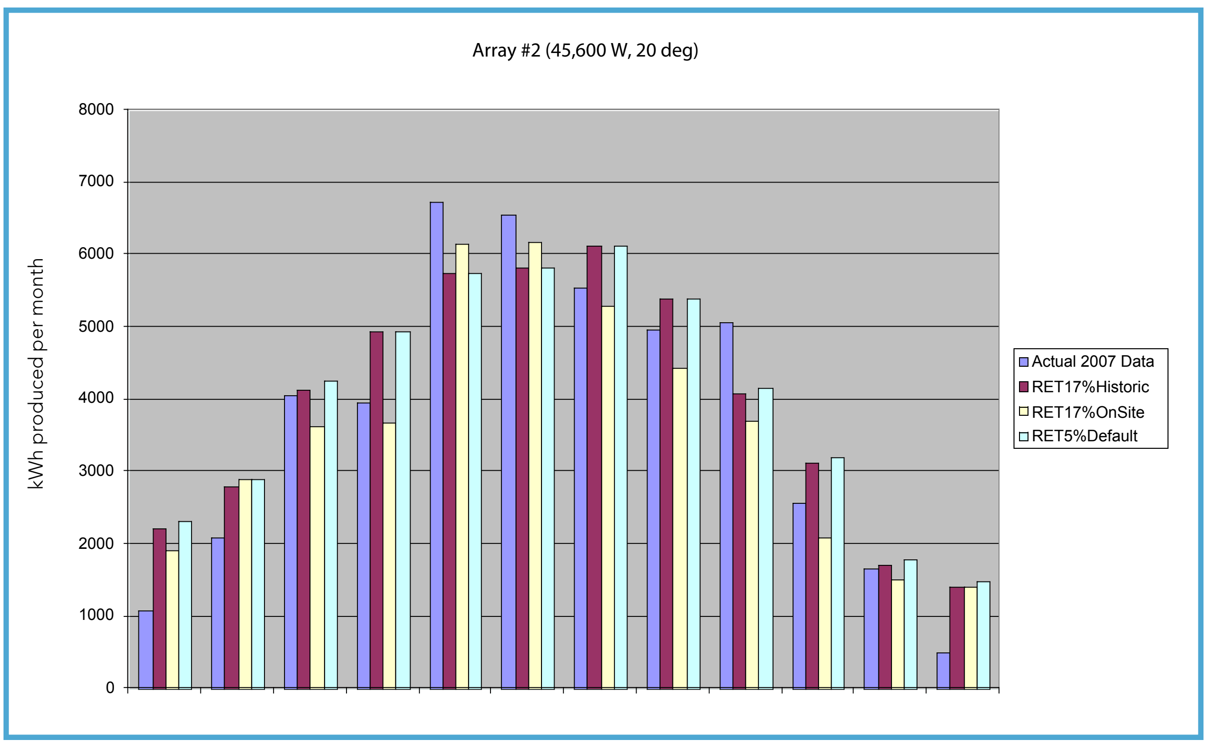
	System Total (100 kW)			
	2007	**2007**	**2007**	**2008**
	Total kWh	Total kWh	kWh/kW	Total kWh
January	1862	1862	19	22
Febuary	2997	2997	30	9
March	8507	8507	85	62
April	8768	8768	87	127
May	14982	14982	149	130
June	14815	14815	148	119
July	12491	12491	124	131
August	11022	11022	110	128
September	11088	11088	110	97
October	5533	5533	7934	7934
November*	3388	3930	34	39
December*	1029	1980	10	20
Total	**96,482**	**96,724**	**961**	**963**

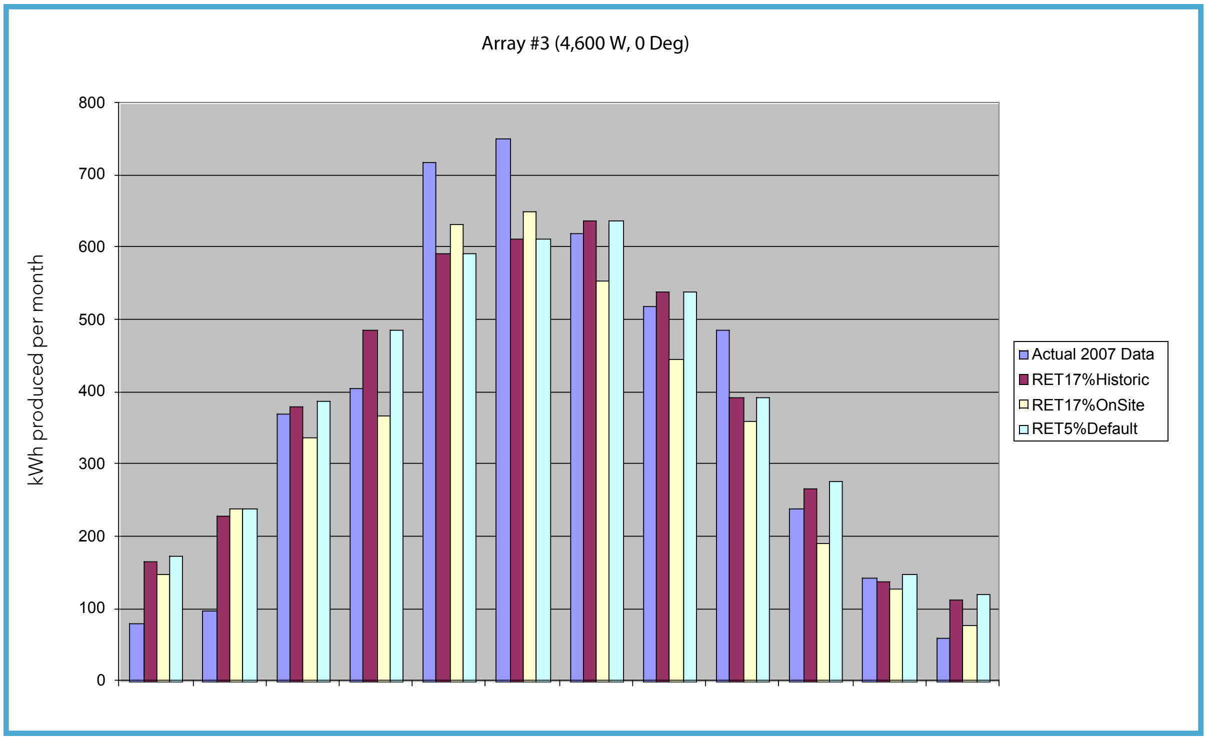
* The data for November-December 2008 is based on Toronto Hydro records, as the Fat Spaniel monitoring system was down for most of those two months. Values have been prorated for each array based on the array size (kW) in proportion to total system size.

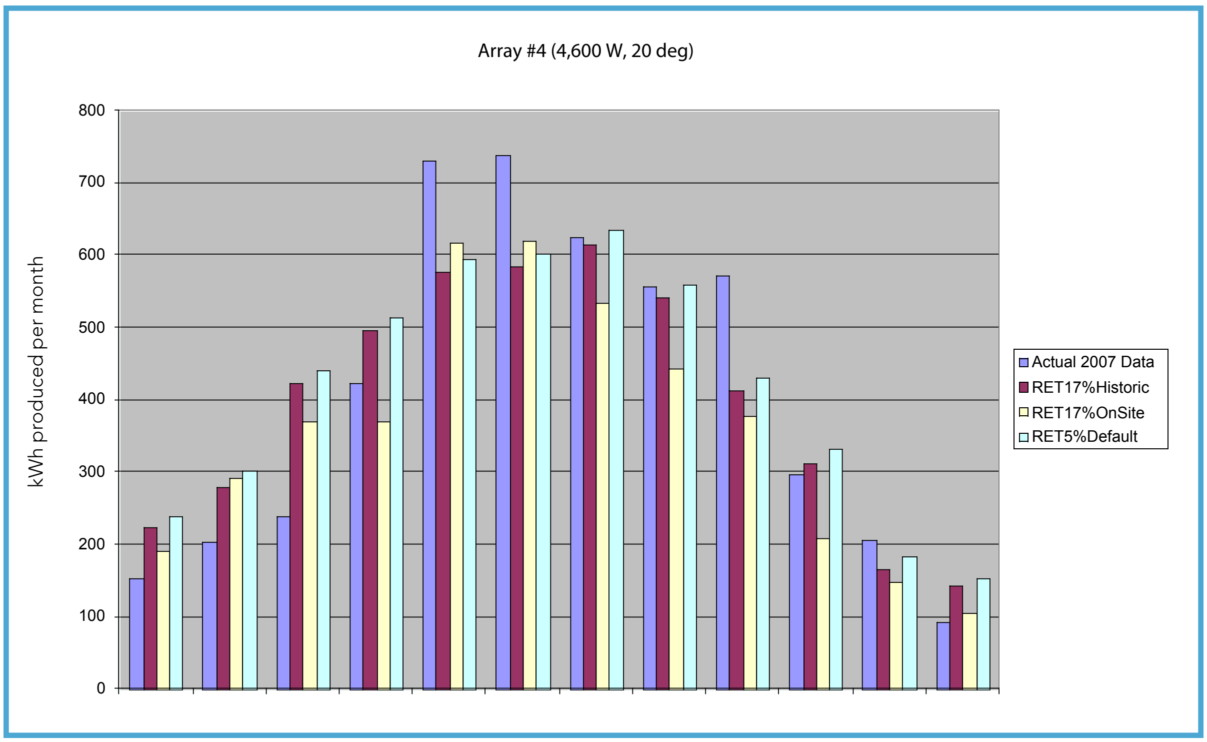
APPENDIX IV

2007 Array Performance by Month Compared to RETScreen Models






Array #3 (4,600 W, 0 Deg)
kWh produced per month
800
700
600
500
400
300
200
100
0
Actual 2007 Data
RET17%Historic
RET17%OnSite
RET5%Default


Array #4 (4,600 W, 20 deg)
kWh produced per month
800
700
600
500
400
300
200
100
0
Actual 2007 Data
RET17%Historic
RET17%OnSite
RET5%Default

APPENDIX V

2008 Horse Palace PV RESOP Payment Breakdown

	A	B	(B/A)	Information Only		C [B*.05]	D	E	(D/E)	(B+C-E)
Period	EXPORTED from generator	RESOP Payment (Credit)	[x - y]	Standard Offer Rate [x]	HOEP [y]	GST Credit	CONSUMED by genera-tor [Note 1]	Electricity Charge (Debit) include GST		Total Receivable
	kwh	$	$/kwh	$/kwh	$/kwh	$	kwh	$	$/kwh	
Dec 31-Jan 31, 2008	2,749.30	1011.23	0.368	0.420	0.052	50.56	517.88	108.79	0.210	$953.00
Jan 31-Feb 29, 2008	1,498.84	521.01	0.348	0.420	0.072	26.05	529.94	107.09	0.202	$439.97
Feb 29-Mar 31, 2008	7,031.06	2533.01	0.360	0.420	0.060	126.65	436.22	122.83	0.282	$2,536.83
Mar 31-Apr 30, 2008	13,105.86	4649.07	0.355	0.420	0.065	232.45	348.48	110.18	0.316	$4,771.34
Apr 30-May 31, 2008	13,286.80	4918.87	0.370	0.420	0.050	245.94	314.34	104.03	0.331	$5,060.78
May 31-Jun 30, 2008	12,216.38	4065.41	0.333	0.420	0.087	203.27	294.72	101.42	0.344	$4,167.26
Jun 30 - Jul 31, 2008	13,403.94	4505.46	0.336	0.420	0.084	225.27	316.66	99.86	0.315	$4,630.87
Jul 31 -Aug 31, 2008	13,091.04	4628.12	0.354	0.420	0.066	231.41	334.46	106.72	0.319	$4,752.81
Aug 31 - Sep 30, 2008	10,111.24	3540.19	0.350	0.420	0.070	177.01	370.40	101.22	0.27	$3,615.98
Sep 30 - Oct 31, 2008	8,350.04	3043.71	0.365	0.420	0.055	152.19	415.20	104.63	0.25	$3,091.27
Oct 31 - Nov 30, 2008	3,930.96	1425.08	0.363	0.420	0.057	71.25	451.14	102.25	0.23	$1,394.08
Nov 30 - Dec 31, 2008	1,988.16	$725.56	0.365	0.420	0.055	$36.28				
Total	**100,763.62**	**$35,566.72**				**$1,778.34**	**4,329.44**	**$1,169.02**		**$36,176.04**
						GL account Photovotaic Debt Repayment:				**$34,453.37**
						GST payable:				**$1,722.67**

Note:
1. OPG Rebate of $8.94 plus 0.45 GST for period May 1, 2008 to Jul 31, 2008 at rebate rate of $0.0028946/kwh applied to Nov invoice.
Information provided by Christine Woon, Toronto Hydro, April 9, 2009.

Endnotes

1. Grants of $250,000 each from FCM and TAF.
2. Better Building Partnership (BBP) of the City of Toronto's Energy Efficiency Office, Business and Strategic Innovation Section, provided a $600,000 no-interest loan.
3. Based on industry consultations.
4. Based on $0.42/kWh RESOP rate.
5. California Energy Commission, *A Guide to Photovoltaic (PV) System Design and Installation*, June 2001, www.energy.ca.gov/reports/2001-09-04_500-01-020.PDF.
6. It should be noted that RETScreen is a *pre-feasability* tool. As such the inputs are not as detailed as in more advanced *design* tools. Using it to model the out put of the array in *feasibility* studies must be done carefully. It also should not be used as a design tool. RETScreen relies heavily on the STC (Standard Test Conditions) rating of the module; different makes of modules with the same STC ratings can give different outputs, even under the same climatic conditions. As such, the STC rating system of modules has its limitations. The electrical design of the array and inverter also can make a difference, not taken into account by RETScreen. How well the power point voltage range of the array matches the inverter's optimal power point tracking voltage ability also affects the performance of the system. Care must be taken in using *pre-feasability* tools to accurately predict the performance of an array. Refer to the RETScreen resource material to understand the expected level of accuracy of this *pre-feasibility* tool.
7. That said, in systems that have transformers, those transformers will continue to draw power while the systems are covered in snow, and as such it would make sense to disconnect the systems during extended periods of snow. This was in fact done in January and February of 2009, as the inverters' parasitic load exceeded the PV system's output. This is another disadvantage of using inverters which require transformers (including isolation, step-up, etc.) for connection.
8. Grants of $250,000 each from FCM and TAF.
9. Better Building Partnership (BBP) of the City of Toronto's Energy Efficiency Office, Business and Strategic Innovation Section, provided a $600,000 no-interest loan.
10. Assumes $0.42/kWh rate extends beyond 20 year Standard Offer Program contract.
11. Does not include financial benefits of zero-percent interest loan provided by City of Toronto's BBP.
12. Based on industry consultations.
13. Based on $0.42/kWh RESOP rate.
14. Actual 2008 data as recorded by Toronto Hydro's embedded PV meter. Electricity "exported from generator" = 100,763.62 kWh for 2008. Electricity "consumed by generator" = 4,329.44 kWh. Net = 96434.18 kWh.

SolarCity, a program of the Toronto Atmospheric Fund, focuses on building local solar generation capacity. The SolarCity Technology Assessment Partnership is one of the first initiatives under this program. The partnership will collect, analyze and distribute information about urban solar installations in the GTA, starting with the Horse Palace PV Pilot Project and other solar installations on City of Toronto facilities. Findings will be used to promote best practices in solar installations, to identify and resolve barriers to the use of solar energy in cities, and to identify research opportunities to help advance solar energy use in the GTA. For more information about this program, how to access future reports or how to participate, please contact Mary Pickering, associate director, Toronto Atmospheric Fund at (416) 392-1217 or mpickering@tafund.org

SolarCity Technology Assessment Partnership is currently supported by:
City of Toronto Energy Efficiency Office
Toronto and Region Conservation Authority
Toronto Atmospheric Fund
Federation of Canadian Municipalities