# Toronto Police Traffic Services
# 52 kW PV Installation

## Final Report – January 2012


Technology

Monitoring

Best Practices

SolarCity
Partnership

## PROJECT SNAPSHOT

| | |
|---|---|
| Address: | 9 Hanna Avenue, Toronto |
| Building Type and Use: | Central traffic and police garage facility |
| Owner: | City of Toronto |
| Owner Contact: | Dejan Skoric |
| Phone #: | (416) 338-5097 |
| Email: | dskoric@toronto.ca |
| System type: | Roof-mounted grid-tied photovoltaic system |
| Array Angle: | 30 degrees from horizontal |
| Azimuth: | 15 degrees east of south |
| String Configuration: | 39 strings of 7 modules (four of the five inverter inputs have eight strings, one of the inputs has seven strings) |
| Module Manufacturer: | Sanyo |
| Module Model: | HIP-190BA3 190 watt |
| Number of Modules: | 273 |
| Inverter Manufacturer: | Satcon |
| Inverter Model: | Powergate Plus 50 kW |
| Number of Inverters: | 1, 50 kW |
| System Size (kW): | 51.87 |
| System Size (sq. meters): | 322 |
| Installation Date: | November 2009 |

### PERFORMANCE

| | |
|---|---|
| 2010 Actual Performance*: | 1,206 kWh/kW |
| RETScreen using on-site irradiance: | 1,138 kWh/kW |
| RETScreen using 20 year historical average: | 1,131 kWh/kW |

*Seven months of energy production data were analyzed. The remaining five months of the year were projected based on production from a nearby similar array in order to obtain a measure of annual yield.

### FINANCIAL

| | |
|---|---|
| Installed Cost (taxes included): | $643,950 |
| Final Cost*: | $657,705 |
| External Funding: | $20,000 from Toronto Atmospheric Fund |
| Annual Income: | $44,319 |
| Simple Payback (excluding external funding): | 14.8 years |
| Cost per kW (excluding external funding): | $12,680 |

*additional costs were incurred to meet FIT connection requirements

*Photos provided by Carmanah*

## MONITORING

| | |
|---|---|
| Monitoring equipment installed: | Yes |
| Overview of the monitoring plan: | Monitoring includes production data from inverter (AC in kWh), solar radiation (on-site pyranometer), and ambient and cell temperature. The monitoring system is linked into the building automation system with alarms set as appropriate. |
| Cost of M&V : | 6.2% of total project cost |
| Who is analyzing the data? | Unknown |
| Is there a dedicated staff person responsible for system operation management? | No |

## SUMMARY

The City of Toronto's 52 kW photovoltaic system at 9 Hanna Street generated approximately 1,206 kWh/kW in 2010/2011, which was 6% higher than simulated yield derived from local irradiance. Designed to take advantage of Ontario's Feed-in Tariff (FIT) program which pays owners for the electricity produced by their system, the system was installed in 2009 for $643,950. Based on historical weather, the project will achieve a simple payback in 14.8 years before external grants and 14.4 years after. Had the site not required the reinforcement of the parapet structure, the financial case would have been more attractive.

The project experienced extra costs ($13,755) and significant delays in securing a Feed-in Tariff contract due to changes in the contract's grid connection rules. Once finalized in early 2012, the twenty-year FIT contract should pay for the cost of the system and provide a reliable revenue stream for the City of Toronto for years after.

## BACKGROUND

In 2007, the City of Toronto hired a consultant to determine the feasibility of a large photovoltaic system installation at 9 Hanna Avenue. The intention was to sell the power generated back to the local utility through the Renewable Energy Standard Offer Program (RESOP was replaced by the FIT program in 2009).

The location was selected in part because there was an existing "parapet", or array support structure, on the roof angled at 30 degrees and facing due south with excellent solar exposure. The building was also in a highly visible area with over 150,000 vehicles passing by per weekday and, as such, would help demonstrate the City's commitment to renewable energy and greenhouse gas reduction targets.

The consultant recommended a 100 kW system. After a lengthy consultation process and further analysis, it was determined that existing billboard structures caused too much shading to warrant a 100 kW system. Further, the existing parapet structure needed structural reinforcement which would be financially prohibitive for a 100 kW system. A 52 kW photovoltaic system was selected to maximize sun exposure and to minimize structural reinforcement costs.

In November 2009, a 52 kW grid-tied photovoltaic system was installed on the Police Services garage facility at a cost of $643,950. The project was financed through a combination of capital budget, a zero-interest loan from the City's Sustainable Energy Fund, and a Toronto Atmospheric Fund grant.

### Special Site Considerations

The site was initially selected due to an existing "parapet" structure that would be an ideal location for the PV array as it faced south and was inclined on a favorable angle. However, it was only designed to hide the parked vehicles from view of passing vehicles. The parapet structure required reinforcement to support the PV modules, which added significant costs to the project.

Police representatives voiced concern over the security of the buildings' electrical supply due to the PV system tying into the buildings' electrical distribution system. Clarification of how the PV system worked alleviated their concerns and is a good example of the importance of communication when undergoing a project involving multiple parties.

Two large billboards at the extreme east and west ends of the building are causing some shading of the array. Strings are configured in a North-South orientation to minimize the impact of this shading.

## PERFORMANCE ANALYSIS

### RETScreen Model Parameters

RETScreen was used to predict expected yield. Table 1 shows the key parameters in the two RETScreen scenarios. The first uses a 16% loss factor derived from the California Energy Commission guidelines[1] and historic irradiance and temperature data from a Toronto weather station (RET20yr). The second also incorporates a 16% loss factor, but uses on-site irradiance and temperature data over the same one year period that actual production data were available (RETOnSite). Both scenarios assume 1% miscellaneous losses and inverter efficiency of 95.5% (as rated by the California Energy Commission).

**Table 1. Key parameters in the different RETScreen scenarios.**

| RETScreen Input | RET20yr | RET1yrOnSite |
|---|---|---|
| Annual solar radiation (kWh/m$^2$ on a horizontal surface) | 1,310 | 1,300 |
| Annual average daily irradiance (kWh/m$^2$/d) | 3.59 | 3.56 |
| Annual average ambient temperature (C) | 7.2 | 8.1 |
| CEC weighted inverter efficiency | 95.5% | 95.5% |
| PV array losses | 16% | 16% |
| Miscellaneous power conditioning losses | 1% | 1% |

### Actual Performance vs. RETScreen Simulations

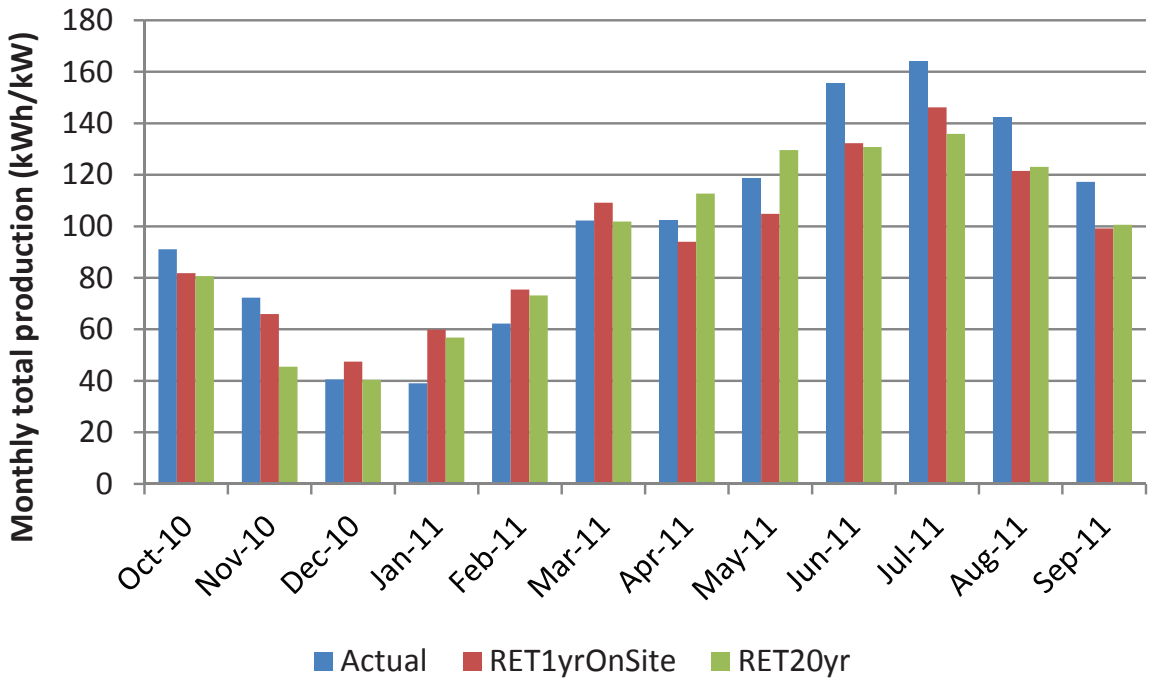
Seven complete months of energy production data (Oct 2010 – Mar 2011 and Sep 2011) were analyzed. The remaining 5 months of the year were projected based on production from a nearby similar array in order to obtain a measure of annual yield (refer to Appendix 2 for a description of the estimation method). During the 7 month period from October 1, 2010 to March 31, 2011 and September 1 to 30, 2011, energy yield of the Toronto Police Traffic Services PV system was 27,355 kWh (527 kWh/kW). Projected annual yield was 62,578 kWh (1,206 kWh/kW).

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

Energy production over the 12 month period beginning in October 2010 and ending in September 2011 is shown in Figure 1. Based on the projected annual total, the RET1yrOnSite model predicted output was 5.7% less than actual yield. The RET20yr scenario predicted output was slightly lower at 6.3% less than actual yield.

On a monthly basis, using the RET1yrOnsite model as a benchmark, energy yield fell below expectations during the winter (December through March) by an average of 19.4%. This trend has been observed at other sites in the GTA, and is likely due in part to the RETScreen program's failure to account for snow cover. For the remainder of the year (April through November), energy yield was an average of 14.1% above expectations.

**Figure 1. Actual and simulated energy production of the Toronto Police Traffic Services PV system.***




*Actual production totals from April through August 2011 are projected values.

## BUSINESS CASE

The Feed-in Tariff contract pays a fixed price for energy produced by the Toronto Parking Authority's PV system for the next 20 years. To evaluate the business case, a RETScreen analysis using historical irradiance and ambient temperature data was used to simulate energy production and associated income for the next 20 years. The RET20yr model used in the business case was modified to include a derate factor of 11%, which was the derate factor that best fit the actual production data (which included projections for April through August 2011).

Table 2 presents the business case for the 9 Hanna Avenue PV Project. This analysis predicts an array output of 62,158 kWh per year, which would provide $44,319 of income per year at the current Feed-In-Tariff rate of 71.3 cents/kWh. The simple payback for this scenario would be 14.8 years before grants, and 14.4 years after. Assuming that the system continues to function over a minimum 14 year period, Toronto Police Traffic Services stands to gain significant revenues from the project.

The project was financed through a combination of capital budget ($347,705), a zero-interest loan from the City's Sustainable Energy Fund ($290,000), and a Toronto Atmospheric Fund grant ($20,000).

**Table 2.** Toronto Police Traffic Services PV Project: Business Case

| | Total cost installed | Grants | Array output (kWh/yr) | Annual Income from electricity sales | Simple payback (years) | Simple payback after grants (years) |
|---|---|---|---|---|---|---|
| **Adjusted feasibility study** (using RET20yr model) | $657,705 | $20,000 | 62,158 | $44,319 | 14.8 | 14.4 |

## Installed System Costs

The breakdown of installed system costs are shown in Table 3. The total cost of the system was $657,705, or $12,680 per kW installed. Materials and labour for construction accounted for approximately 55% and 17% of total costs, respectively. This building required structural upgrades amounting to 12.1% of total costs but benefitted from lower material and installation costs because the array support structure was already on the roof. A grant of $20,000 was provided for the project by the Toronto Atmospheric Fund, bringing the final project cost down to $637,705, or $12,294 per kW installed.

## Feed-in Tariff Issues

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

**Table 3.** As-Built Cost Breakdown

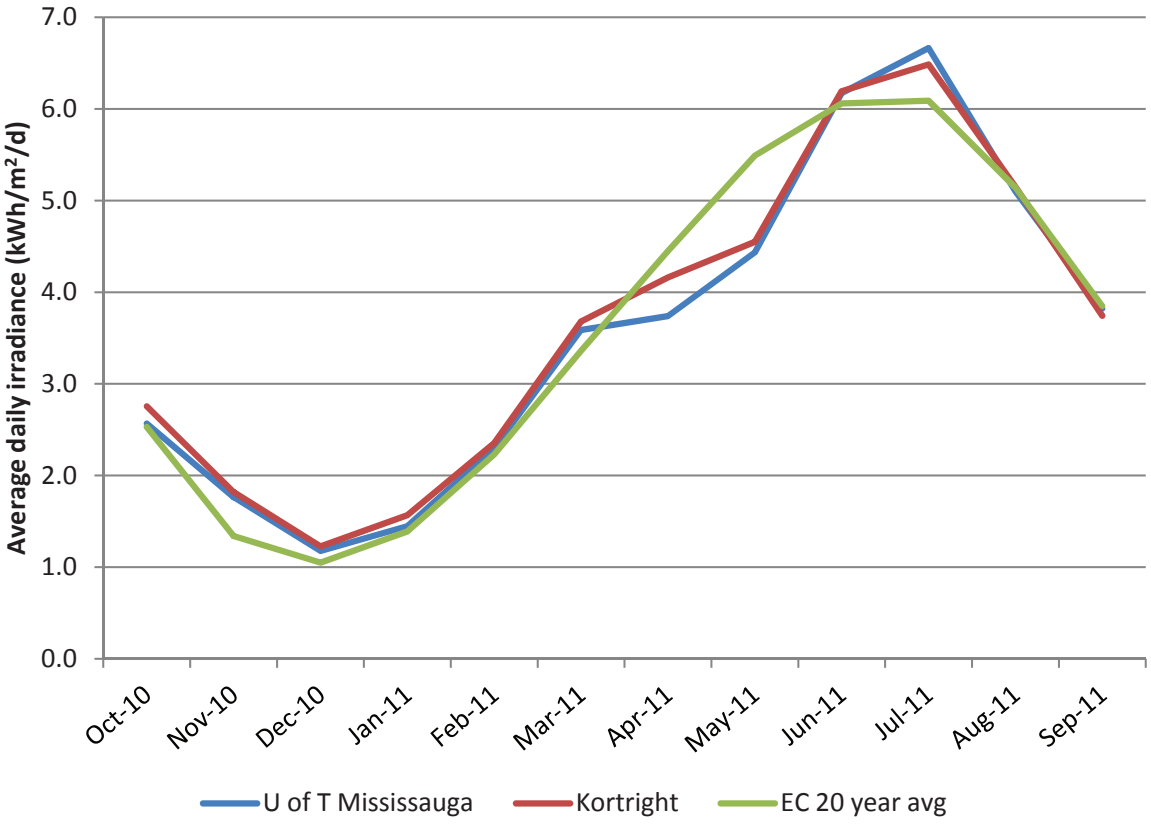
| Cost Items | Component Costs | Percent of Total Cost |
|---|---|---|
| Materials | | |
| Electrical Materials | | |
| PV Modules | $289,575.00 | 44.0% |
| Inverters | $39,033.33 | 5.9% |
| Racking | $27,266.94 | 4.1% |
| Switchgear, spare parts and balance of materials | $6,463.16 | 1.0% |
| | | |
| Labour | | |
| Installation | $74,563.00 | 11.3% |
| Project Management & Commissioning | $17,678.67 | 2.7% |
| Design & Engineering | $18,363.00 | 2.8% |
| | | |
| Miscellaneous | | |
| Cameras | - | - |
| Monitoring | $40,000.00 | 6.1% |
| Freight | $9,397.00 | 1.4% |
| Utility interconnection | | |
| Documentation | | |
| Construction Contingency | $11,594.26 | 1.8% |
| Structural Upgrading | $79,351.00 | 12.1% |
| | | |
| Sub-total | $613,285.36 | |
| PST | $30,664.27 | 4.7% |
| | | |
| **Total Before FIT Contract Changes** | **$643,949.63** | |
| | | |
| FIT Metering Requirements | | |
| In-Series to Parallel Connection Conversion | $9,004.76 | 1.4% |
| Toronto Hydro Meter and Installation | $4,750.52 | 0.7% |
| | | |
| **Total After FIT Contract Changes** | **$657,705** | |
| | | |
| External Funding | $20,000 | |
| | | |
| **FINAL TOTAL** | **$637,705** | |

## APPENDIX 1: MONTHLY IRRADIANCE DATA

Although a pyranometer was installed at Toronto Police Traffic Services, data from this instrument were not used in the RET1yrOnSite model due to numerous gaps in the hourly and daily data. Instead, irradiance data measured using a reliable pyranometer at the University of Toronto Mississauga Meteorological Station (UTMMS) were used in the RETScreen simulations. Data from pyranometers located at UTMMS and the Kortright Centre for Conservation are compared with Environment Canada's 20 year average for the City of Toronto in Figure A1. Over the one year period beginning October 1, 2010 and ending September 30, 2011, average monthly irradiance measured at UTMMS was 2.1% below that measured at Kortright and 0.5% below Environment Canada's historical average.

Overall, the irradiance curves from the three weather stations are similarly shaped, with the exception of April and May 2011. The dip in irradiance observed at UTMMS and Kortright in these months is likely the result of an increased amount of cloud cover and precipitation relative to Environment Canada's historical average. Total precipitation in April and May 2011 was 237.4 mm, while the long term average (1971 to 2000) in these months was 140.9 mm.[2]

**Figure A1. Average daily irradiance in the Greater Toronto Area (2010-2011).**




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

## APPENDIX 2: VALIDATION OF PROJECTION METHOD

Since a complete year of energy production data were not available, 5 months of data (April through August 2011) were projected using the following method:

1. Energy production of the Toronto Police Traffic Services and Toronto Fire Station #334 PV systems was compared over a 6 month period when data were available from both systems (October through March 2011).

2. Since both PV systems had similar production (within 1.2%), energy yield of the Police Traffic Services system was estimated based on the energy yield data from Fire Station #334. For each month to be projected, monthly total measured yield of the Fire Station #334 array was decreased by 1.2% in order to obtain an estimation of monthly total yield of the Police Traffic Services array.

3. A full month of production data in August 2011 was not available from Fire Station #334. Therefore, the monthly total yield in August 2011 was based on daily total yield from August 1 – 15, 2011 and August 16 – 31, 2010. Energy output during the last 16 days of August 2010 was a reasonable approximation of yield over the same 16 days in August 2011 because average solar irradiance over this time interval in 2010 was within 3.5% of solar irradiance measured over the same interval in 2011.

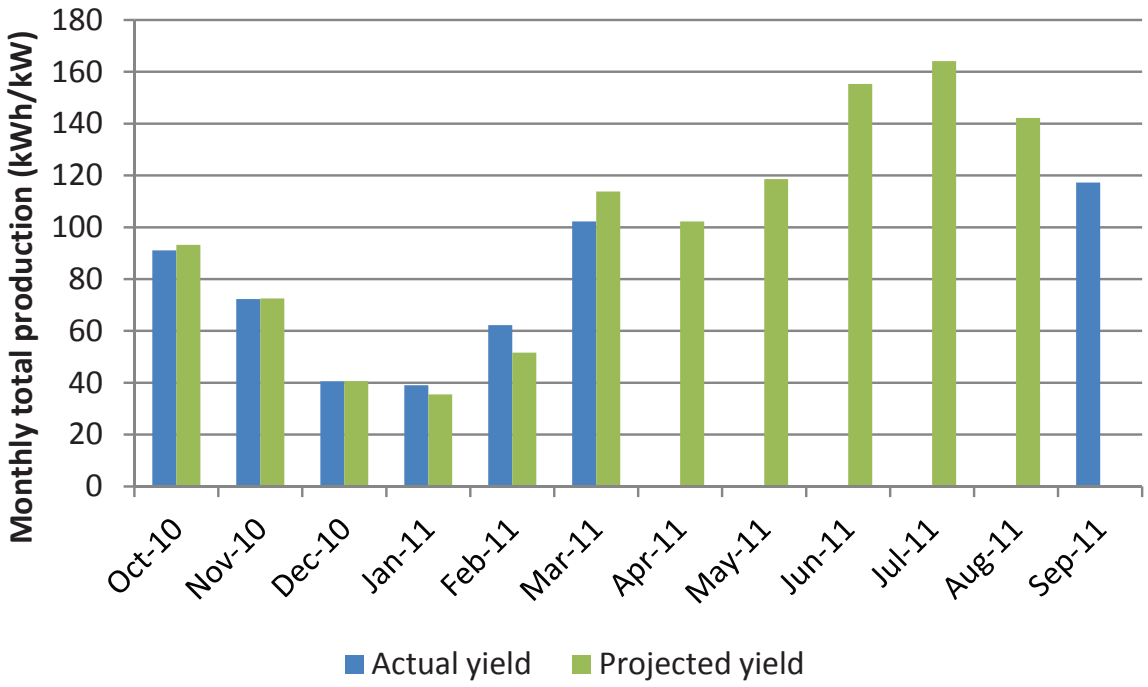
Since the slope of the array located at Police Traffic Services is 5 degrees steeper than the Fire Station #334 array (30° compared to 25°), it was expected that the Police Traffic Services array would out-perform the Fire Station #334 array during the winter months. Instead, yield was observed to be 1.2% below that of Fire Station #334. Applying this 1.2% reduction to the 5 estimated months of yield data from the Police Traffic Services array has therefore resulted in a conservative estimate of energy output.

In order to assess the accuracy of the projection method, the measured yield data were compared with the projected yield data over a 6 month period when actual yield data were available (yield data from Fire Station #334 were not available in September 2011 and therefore a projection was not possible in this month). During the 6 month period, projected total yield was 0.02% less than actual total yield. On a monthly basis, projected yield more closely approximated actual yield during the fall and exceeded actual yield during the winter, with the exception of the month of February (Table A1). Since the winter months represent a relatively small proportion of total annual yield, the projected annual total is considered to be valid.

**Table A1.** Actual and projected yield of the Toronto Police Traffic Services PV system over a known 6 month period.

| Month | Actual energy yield (kWh/kW) | Projected energy yield (kWh/kW) | Percent difference from actual yield |
|---|---|---|---|
| Oct-10 | 92.0 | 92.7 | 0.8% |
| Nov-10 | 73.4 | 72.2 | -1.6% |
| Dec-10 | 42.3 | 40.4 | -4.6% |
| Jan-11 | 33.5 | 35.3 | 5.5% |
| Feb-11 | 66.0 | 51.4 | -22.2% |
| Mar-11 | 98.1 | 113.3 | 15.4% |
| Total | 405.3 | 405.2 | -0.02% |

**Figure A2.** Actual and projected yield of the Toronto Police Traffic Services PV system over a one year period.



## About the SolarCity Partnership

The SolarCity Partnership is a joint initiative of the Toronto Atmospheric Fund, Toronto and Region Conservation Authority and the City of Toronto designed to promote best practices and careful monitoring of large solar installations. SolarCity Partnership is an information-sharing hub for both public and private organizations involved in deploying solar power. Our **SolarCityPartnership.ca** website provides case studies, research, and solar weather data to help with the effective use of zero emissions energy from the sun.

Toronto Atmospheric Fund

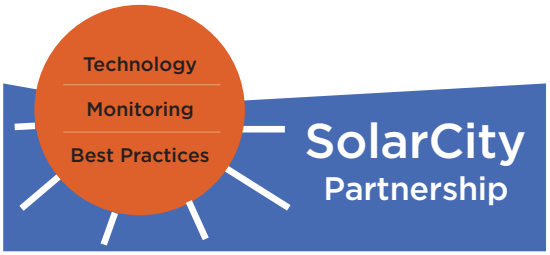
Toronto and Region Conservation for The Living City

Toronto

FCM | Green Municipal Fund / Fonds municipal vert

## We want to hear from you!

If you have further best practices recommendations, insights into system design, deployment or maintenance or a project to profile, please get involved with the SolarCity Partnership! Contact us at:

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This feasibility study was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.