Neighbourhood Unitarian Universalist Congregation

25 kW PV Installation

Final Report – January 2012

Technology

Monitoring

Best Practices

SolarCity

Partnership

PROJECT SNAPSHOT

Address:	79 Hiawatha Road, Toronto
Building Type and Use:	Unitarian Church
Owner:	Neighbourhood Unitarian Universalist Congregation
Owner Contact:	Rick Salay, Greening Committee Chair
Phone #:	416-686-4173
Email:	rsalay@sympatico.ca
System type:	Roof-mounted grid-tied solar photovoltaic system
Array Angle:	52 degrees from horizontal
Azimuth:	15 degrees East of South
String Configuration:	Each micro inverter manages two panels and is independent of the others.
Module Manufacturer:	Canadian Solar Inc.
Module Model:	CS5P 220 watt
Number of Modules:	112
Inverter Manufacturer:	Enphase
Inverter Model:	M190 micro inverter
Number of Inverters:	56
System Size (kW):	24.6
System Size (m^2):	191
Installation Date:	Sept. 30, 2010 (Date that energy production and monitoring began.)

PERFORMANCE

2010-2011 Actual Performance:	997 kWh/kW
RETScreen using local irradiance:	1,101 kWh/kW
RETScreen using 20 year historical average:	1,085 kWh/kW

FINANCIAL

Installed Cost (taxes included):	$220,000
External Funding:	Toronto Green Energy Fund provided an interest-free loan for 49% of the cost. The rest of the funds were raised through donations and the issuing of debentures to friends and supporters of the NUUC.
Annual Income:	$17,334
Simple Payback (excluding external funding):	12.7 years
Cost per kW (excluding external funding):	$8,943

MONITORING

Monitoring equipment installed:	Yes.
Overview of the monitoring plan:	Each micro inverter produces data in real time for each pair of panels. The Enphase monitoring system tracks power output, DC voltage, amperage and temperature of each micro inverter.
Cost of M&V :	Unknown.
Who is analyzing the data?	Toronto and Region Conservation Authority's Sustainable Technologies Evaluation Program
Is there a dedicated staff person responsible for system operation management?	Unknown.

SUMMARY

The Neighbourhood Unitarian Universalist Congregation (NUUC) 25 kW photovoltaic system located at 79 Hiawatha Road, Toronto, ON, was installed for a cost of $220,000 in the summer of 2010. Over the one year monitoring period, the system produced an energy yield of 997 kWh per kW installed. This is slightly below the typical range of productivity observed at other PV systems in the Greater Toronto Area (1,000 to 1,250 kWh/kW). Analysis of yields from each of the 112 micro-inverters indicates that shading from nearby trees was the likely cause of low system yield. Based on historical weather, the system is projected to generate an annual revenue of $17,334 for the NUUC. Under this scenario, the simple payback period is 12.7 years.

BACKGROUND

The Neighbourhood Unitarian Universalist Congregation (NUUC) wanted to take an active role in reducing their ecological footprint, so they chose to install a 25 kW photovoltaic system on the roof of their church. In doing so, their objectives were to:

- increase the sustainability of the local economy;
- involve the community in an inclusive manner;
- be financially viable and self-sustaining so as not to burden the congregation;
- act as a model for groups and individuals looking to install PV systems;
- provide an opportunity to educate others about environmental issues; and
- take advantage of incentives and financing options made available by the City of Toronto (Green Energy Fund) and the province of Ontario (Feed-in Tariff program).

The system was installed at a cost of $220,000, and was funded by a combination of government grants and community support. Half of the cost was obtained through an interest-free loan from the City of Toronto's Green Energy Fund, while the other half was raised through donations and the issuing of debentures to friends and supporters of the NUUC.

The NUUC successfully raised $110,000 from the community by issuing 110 debentures for $1000 each at 5% interest paid annually. The debentures can be held for up to 20 years, but the NUUC has reserved the right to redeem them at any time prior to maturity by paying the principal back to the holder, together with any interest owing. Investors have the option to donate the $1000 principal to the NUUC at some time prior to maturity in return for a receipt which qualifies the investor for an income tax credit. Feed-in Tariff payments for the energy generated will be used to pay back the loans and debentures. The NUUC has gained widespread recognition from the success of this PV project, and qualified as a finalist in the 2010 Green Toronto Awards.

Special Site Considerations

The NUUC PV system is situated on the roof of the church, within close proximity to tall trees. The steep inclination of the array causes it to receive a greater proportion of solar energy in the fall and winter when the sun is lowest in the sky. However, this is also the period when the system is the most susceptible to shading from the nearby trees.

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 local irradiance and temperature data over the same one year period that actual production data were available (RET1yr). Both scenarios assume 1% miscellaneous losses and inverter efficiency of 95% (as rated by the California Energy Commission).

Table 1. Key parameters in the different RETScreen scenarios.

RETScreen Input	RET20yr	RET1yr
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%	95%
PV array losses	16%	16%
Miscellaneous power conditioning losses	1%	1%

Actual Performance vs. RETScreen Simulations

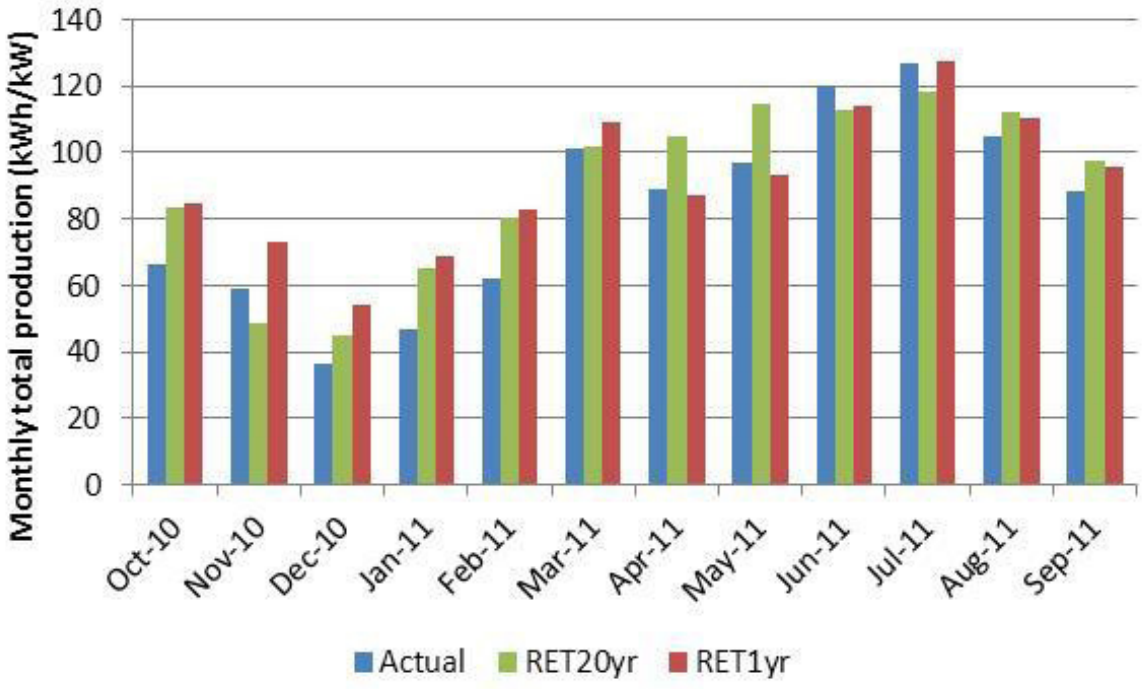
Actual array output is compared to RETScreen estimated production in Figure 1. Over the one year monitoring period, actual yield was 24,526 kWh, or 997 kWh per kW installed. On an annual basis, the RET20yr model was the most accurate scenario. Actual yield was 8.1% below simulated yield based on historic irradiance and 9.5% below simulated yield based on local irradiance.

Since the RET1yr model is based on local irradiance and temperature data, it will be used as a benchmark to assess production of the NUUC PV system. On a monthly basis, measured energy yield was greater than expectations during the spring (April through June) by an average of 3.7%. During the remaining months of the year, energy yield fell below expectations by an average of 16.9%.

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 NUUC site.

Similar seasonal variations in energy yield relative to expectations have been observed at other PV systems in the GTA. However, at most other sites, measured energy yield typically fell below expectations only in the winter months (December through February). This is likely due to the fact that RETScreen does not account for snow cover. At the NUUC, actual yield was below expectations for 9 months of the year. As discussed in the next section, shading is the likely cause of the lower than expected yield.

Figure 1. Actual vs. RETScreen simulated performance (2010-2011).



Preliminary Shading Assessment

A preliminary shading analysis was conducted using yield data from each of the 112 micro-inverters. Figure 2 shows the location of the micro-inverters within the array and the yield measured by each micro inverter cumulatively from Sept 30, 2010 to Nov 4, 2011, and over the month of September.

The analysis shows a clear pattern of low yield at the bottom right corner of the array, with yield increasing towards the top and left. This pattern is characteristic of shading effects. If all of the panels performed as well as the average cumulative yield (264 kWh) recorded by the upper left 24 inverters (8 across by 3 down), the total system yield would have been just over 10% better than actual yield. A more comprehensive shading analysis using a Solar Pathfinder or similar instrument is recommended in order to determine the exact sources of the shading and better quantify shading losses.

Figure 2. Layout and yields (kWh) of micro inverters in the NUUC PV array over a 13 month period (top) and over the month of September (bottom).*

279	275	282	278	275	271	271	265	263	261	257	254	256	195	253	247	247	247	236
282	276	277	274	267	265	259	256	254	252	237	243	240	237	238	232	239	232	226
273	271	270	269	263	257	259	249	247	244	235	234	230	146	227	230	231	223	215
262	250	265	259	261	254	251	240	234	232	206	221	218	219	216	214	220	200	207
245	257	261	255	257	248	240	235	231	223	217	212	204	200	206	202	200	196	-
232	248	254	251	247	241	234	227	219	217	206	204	198	198	198	195	189	179	-

23.8	23.6	23.9	23.4	23.1	23.0	23.1	23.0	23.3	23.4	23.3	22.9	22.7	1.7	21.8	20.9	20.7	20.4	19.5
23.8	23.4	23.1	22.7	22.1	21.7	21.1	20.9	20.9	21.2	20.4	21.7	21.7	21.4	21.0	20.1	20.6	19.6	19.0
23.1	22.6	22.6	22.2	21.5	20.6	20.7	19.7	19.3	18.9	18.3	18.9	19.7	15.6	20.4	20.6	20.3	19.4	18.6
21.8	20.3	21.9	21.1	21.1	20.3	19.9	18.8	18.0	17.6	14.9	16.3	16.4	17.4	18.3	18.6	19.8	17.4	18.3
18.3	20.5	21.2	20.6	20.5	19.6	18.8	18.2	17.8	16.8	16.0	15.3	14.8	14.8	16.1	16.6	17.5	17.3	-
16.3	18.7	19.9	19.9	19.5	18.9	18.1	17.4	16.7	16.3	15.3	14.9	14.2	14.3	14.7	15.1	15.2	14.0	-

LEGEND	
	0-25% (Poorest performance)
	26-50%
	50-75%
	76-100% (Best performance)

*Note: the 14th inverter on the top row malfunctioned and has since been replaced.

BUSINESS CASE

The Feed-in Tariff contract pays a fixed price for energy produced by the NUUC 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 23.5%, which was the derate that best fit the actual production data over the one year monitoring period.

Table 2 presents the business case for the NUUC PV Project. This analysis predicts an array output of 24,312 kWh/yr (988 kWh/kW/yr), which would provide $17,334 of income per year at the current Feed-in Tariff rate of 71.3 cents/kWh. The simple payback for this scenario would be 12.7 years. Assuming that the system continues to function over a minimum 13 year period, the NUUC stands to gain significant revenues from the project.

Feed-in Tariff Issues

The project is connected to the grid and has been generating FIT revenue since September 30, 2010. However, payments have not yet been received due to delays at the Ontario Power Authority.

Table 2. NUUC PV Project: Business Case

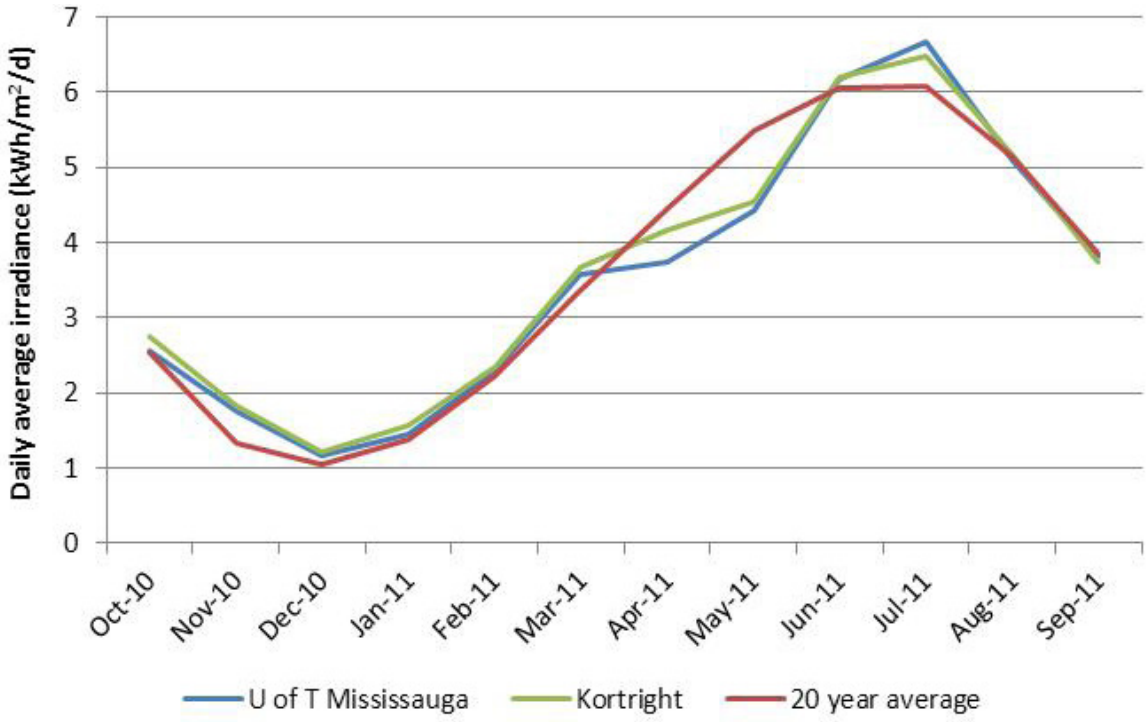
	Total cost installed	Array output (kWh/yr)	Annual income from electricity sales	Simple payback (years)
Adjusted feasibility study (using RET20yr model)	$220,000	24,312	$17,334/yr	12.7

APPENDIX 1: MONTHLY IRRADIANCE DATA

Since a weather station was not installed at the NUUC, irradiance data from the University of Toronto Mississauga Meteorological Station (UTMMS) were used in the RET1yr model. Pyranometer data from this site were compared with data from the Kortright Centre for Conservation and with Environment Canada's 20 year average for the City of Toronto (Figure A1). Over the one year monitoring period, average monthly irradiance measured at the UTMMS was 2.1% below that measured at Kortright and 0.5% below Environment Canada's historic average.

In general, 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 the UTMMS and Kortright stations in these months is likely a 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.

About the SolarCity Partnership

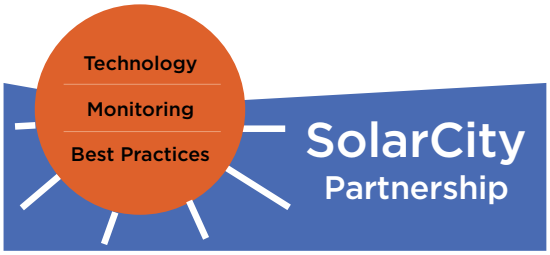
The SolarCity Partnership was developed to provide third party monitoring of large urban solar installations and develop best practice recommendations based on independent project evaluations. The Partnership is an information-sharing hub for both public and private organizations involved in deploying solar power. Our SolarCityPartnership.ca website provides case studies, research, and solar radiation data to help with the effective use of zero emissions energy from the sun.

Supporting Partners

The SolarCity Partnership was founded in 2008 by the Toronto Atmospheric Fund, the City of Toronto Energy and Waste Management Office, and the Toronto and Region Conservation Authority, with support from the Federation of Canadian Municipalities Green Municipal Fund. Phase 2 of the Partnership, co-ordinated by the Toronto and Region Conservation Authority, has expanded to include solar facility assessments across the Greater Toronto Area with funding support from the Region of Peel and York Region, and in-kind contributions from various site partners.

We want to hear from you!

If you have further best practice 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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