Solar Neighbourhoods Pilot Project Technical Findings

Update Report
January 2013

BACKGROUND

Solar Neighbourhoods is a pilot project of the Toronto Atmospheric Fund to install 100 solar thermal systems in one southeastern Toronto neighbourhood. Of these, 16 systems representing different solar thermal technologies were selected for detailed performance monitoring. The project was initiated in 2008, and a Technical Findings Report was published in 2010. This report is an update to these findings, providing monitoring results for a complete year of systems operation.

PERFORMANCE ANALYSIS

Actual performance vs. RETScreen simulations

The delivered energy and hot water draw of each of the 16 solar thermal systems were monitored over a one year period beginning October 1, 2010 and ending September 30, 2011. When actual energy production was compared to RETScreen predictions, the total energy delivered by all systems was 75% of expected output, with individual systems ranging from 44% to 97% of RETScreen predictions (Table 1). These results are consistent with the initial analysis in 2011, in which all systems delivered less energy than the RETScreen simulations.

System sizing appears to be a predominant cause of the low system performance relative to expectations observed at many sites. In this study, many of the systems were grossly oversized, and 10 of 16 systems had predicted solar fractions above 65% (Table 1). The solar fraction is the percentage of the total load supplied by the solar thermal systems over time, which in this case is one year. In general, the higher the predicted solar fraction, the worse was the relationship between measured and predicted energy delivered. That is, systems with a relatively low solar fraction had output much closer to expectations than did systems with a high solar fraction (Figure 1).

The reasons why systems with high solar fractions tend to experience high performance deficits are not completely clear. One possible cause is the predictive method used by the RETScreen program. RETScreen calculates the solar fraction of the hot water load using the F-chart method. This method has limitations, and systems with very high solar fractions would likely operate partially outside of these limitations.

Secondly, systems with high solar fractions have higher operating temperatures and therefore are more likely to overheat. In the Toronto climate, systems with an annual solar fraction greater than 60% have a reasonable chance of overheating in periods of high solar radiation. Different systems have different mechanisms and temperature set-points to avoid overheating. When temperatures exceed the system set-point, most controllers shut down fluid circulation through the collectors, but this is dependent on the temperature set-point and the position of the controller on the solar storage tank.

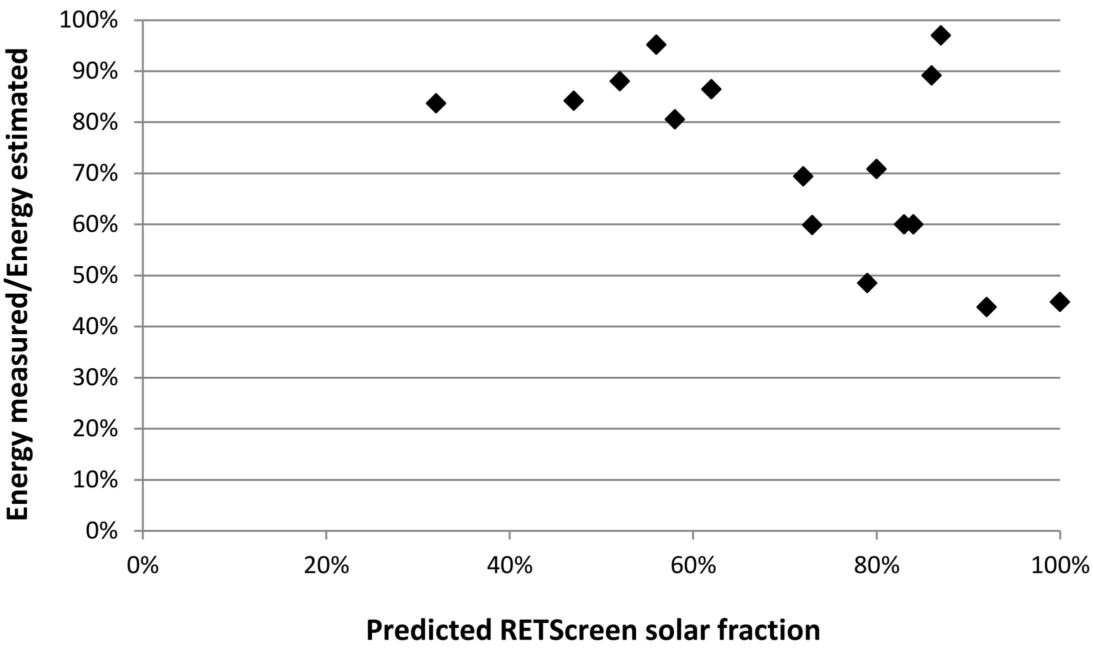

Figure 1: Ratio of measured to predicted energy delivered vs. predicted solar fraction

Energy metering test

There was a concern that the installed energy meters may not accurately measure fast, low duration water draws, and so may be producing unreliable results. To evaluate this possibility, a separate measurement and data acquisition system (DAS) was installed at one site (Participant 2). Flow and temperature were recorded every two seconds over the period between May 17th and 25th, 2011.

During this period, approximately 30% of the volume draw occurred in short intervals of 30 seconds or less. The energy meter recorded 117 Wh of energy delivered, while the DAS measured 118 Wh. This is equivalent to a difference of less than 1%, which is below the measurement uncertainties for the DAS installed. These results suggest that short consumption events were accurately accounted for by the energy meters.

Thermosyphoning flow

Thermosyphoning is a type of passive heat exchange in which liquid is circulated by natural convection. The energy metering test of Participant 2’s system also provided evidence that some thermosyphoning of hot water into the cold water inlet piping was occurring. The cold water average temperature was 17.8°C during the metering period, which is significantly higher than expected for the time of year and geographic location. It is suspected that hot water was traveling up the inlet piping and heating up the sensor. However, in the case of Participant 2, this likely did not occur often because Participant 2 had a fairly high usage and in this system the sensor is located a few metres upstream from the tank.

An increase in cold water inlet temperature would have caused a reduction in the amount of energy metered. During the measurement period, if the metered energy is adjusted based on a cold water temperature of 9ºC, the energy delivered would increase by 5.7%. Participant 2 had one of the best performing systems, at 95% of predicted output. Therefore, system performance may have exceeded expectations if the thermosyphoning effect had not interfered with the energy metering.

This thermosyphoning effect may be another explanation as to why systems with high solar fractions tended to have poor performance. Since systems with high solar fractions generally operate at higher temperatures, more heat would be available to flow up the cold water inlet, causing a greater reduction in the output measured by the sensor. Further investigation of this problem is warranted, as it has also been observed in the solar water heating systems at Toronto Fire Stations 212 and 231.

CONCLUSIONS

This study assessed the performance of 16 solar domestic hot water systems installed in one southeastern Toronto neighbourhood. Over the one year monitoring period, none of these systems exceeded RETScreen predictions. Actual system yields ranged from 44% to 97% of expectations. This may have been due to the limitations of RETScreen's F-chart method in predicting the performance of high solar fraction systems. Systems with high solar fractions may also be overheating under conditions of high solar radiation, causing them to temporarily shut down. Sizing systems appropriately can help to avoid this problem. In the climate of southern Ontario, most solar water heating systems perform optimally when sized to supply approximately 50% of the hot water load. A third possible cause of the lower than expected performance may be related to thermosyphoning of hot water into the cold water inlet piping. This was observed at one site, and resulted in elevated cold water inlet temperatures and a reduction in the amount of delivered energy recorded by the sensor.

FUTURE RESEARCH

It is recommended that all Solar Neighbourhoods systems be checked for thermosyphoning flow. The system layout and position of the meter in each metered system should be assessed. In systems with the lowest performance, a week of detailed temperature measurements (and possibly flow measurements) should be taken in the spring or summer when the thermosyphoning effect would be most pronounced.

Table 1: Solar Neighbourhoods performance findings

Participant	Technology	L/day	Users	L/day. person	Actual Wh/L	Predicted Wh/L	Actual kWh/day	RETScreen predicted kWh/day	Actual/ RETScreen kWh/day	RETScreen solar fraction
1	Boss/Viessmann	104.3	3	34.8	24.7	37.6	2.5	4.2	60.0%	83%
2	Boss/Viessmann	234.6	4	58.7	22.6	24.2	6.1	6.4	95.2%	56%
3	Boss/Viessmann	114.6	2	57.3	24.7	36.1	3.2	4.4	70.9%	80%
4	Boss/Viessmann	91.08	4	22.8	37.1	39.7	3.5	3.6	97.0%	87%
5	Boss/Viessmann	203.3	4	50.8	21.1	26.5	5.3	6.1	86.5%	62%
6	EW	45.7	1	45.7	21.2	48.1	1.0	2.2	44.8%	100%
7	EW	258.1	5	51.6	15.9	22.8	4.9	5.9	84.2%	47%
8	EW	78.7	2	39.4	17.1	41.8	1.9	3.2	60.0%	84%
9	EW	93.4	5	18.7	15.4	39.3	1.7	3.6	48.5%	79%
10	EW	72.6	1	72.6	31.3	42.9	2.7	3.0	89.2%	86%
11	Thermodynamics	176.9	3	59.0	20.8	28.9	4.0	5.7	69.4%	72%
12	Thermodynamics	604.1	4	151.0	8.5	11.8	7.2	8.6	83.7%	32%
13	Solsmart/ Sunnyback	74.4	1	74.4	17.0	42.5	1.4	3.2	43.8%	92%
14	Solsmart/ Viessmann	155.2	4	38.8	20.4	31.1	3.4	5.6	59.9%	73%
15	EW	244.1	3	81.4	15.6	23.6	5.0	5.7	88.0%	52%
16	EW	196.6	2	98.3	17.0	27.1	4.3	5.3	80.5%	58%
Total	-	**2747.7**	**48.0**	**955.1**	**330.4**	**524.1**	**57.9**	**76.6**	**75.6%**	-
Average	-	**171.7**	**3.0**	**59.7**	**20.6**	**32.8**	**3.6**	**4.8**	**72.6%**	**71%**

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 Toronto and Region Conservation (TRCA), with support from the Federation of Canadian Municipalities Green Municipal Fund. Phase 2 of the Partnership, co-ordinated by TRCA, 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.

Toronto Atmospheric Fund | Toronto | Region of Peel Working for you

FCM | Green Municipal Fund Fonds municipal vert | York Region | Toronto and Region Conservation for The Living City

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:

SolarCity Partnership

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