Solar Neighbourhoods Technical Findings
2012 Update Report

Summary

We measured 16 systems for a one-year period. None of the systems met the modelled energy projections.

Actual system yields ranged from 44-97 percent of predicted yields.

The reasons for this finding are as yet unclear, but could include:

1. Limitations of the RETScreen modelling process used to estimate the energy output.
2. Over-sizing of systems which potentially meant that systems were providing more energy than could possibly be consumed in the household.
3. Mechanical problems causing malfunctioning of the overall system.

Toronto Atmospheric Fund and the TRCA are exploring ways to fund continued research to further examine system performance issues.

Background

Solar Neighbourhoods is a pilot project of the Toronto Atmospheric Fund, through which 100 solar thermal systems were installed 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

The delivered energy and hot water draw of each system 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 a 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).

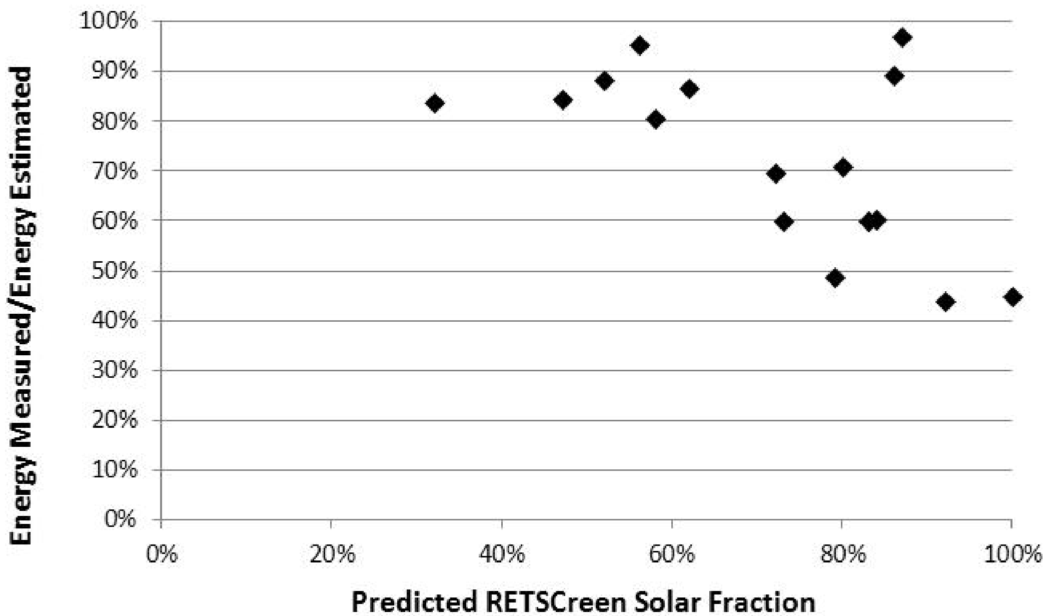

Figure 1. Ratio of Measured to Predicted Energy Delivered vs. Predicted Solar Fraction.

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 solar storage tank.

Energy Metering Test

There was a concern that the installed energy meters may not accurately measure fast, low duration water draws, and thereby produce 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 for 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.

This test also showed that some thermosyphoning of hot water into the cold water inlet piping occurred. 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. This 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 9°C, the energy delivered would increase by 5.7%. This effect may be even greater in systems with a high solar fraction, since these tend to operate at a higher temperature which increases the thermosyphoning flow.

Conclusions

Of the 16 solar domestic hot water systems under study, none exceeded RETScreen predictions over the one year monitoring period. 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. 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 temperatures and a reduction in the amount of energy delivered by the system.

Table 1. 2011-2012 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/Viessman	104.3	3	34.8	24.7	37.6	2.5	4.2	60.0%	83%
2	Boss/Viessman	234.6	4	58.7	22.6	24.2	6.1	6.4	95.2%	56%
3	Boss/Viessman	114.6	2	57.3	24.7	36.1	3.2	4.4	70.9%	80%
4	Boss/Viessman	91.08	4	22.8	37.1	39.7	3.5	3.6	97.0%	87%
5	Boss/Viessman	203.3	4	50.8	21.1	26.5	5.3	6.1	86.5%	62%
6	EnerWorks	45.7	1	45.7	21.2	48.1	1.0	2.2	44.8%	100%
7	EnerWorks	258.1	5	51.6	15.9	22.8	4.9	5.9	84.2%	47%
8	EnerWorks	78.7	2	39.4	17.1	41.8	1.9	3.2	60.0%	84%
9	EnerWorks	93.4	5	18.7	15.4	39.3	1.7	3.6	48.5%	79%
10	EnerWorks	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/Viessman	155.2	4	38.8	20.4	31.1	3.4	5.6	59.9%	73%
15	EnerWorks	244.1	3	81.4	15.6	23.6	5.0	5.7	88.0%	52%
16	EnerWorks	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%**