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Performance and Efficiency of the Solar Thermal System at Riverside Laundromat and Carwash

Final Report

August 2015

Report Number 15-23

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Performance and Efficiency of the Solar Thermal System at Riverside Laundromat and Carwash

Final Report

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West Sand Lake, NY

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NYSERDA Report 15-23 NYSERDA Contract 10211 August 2015

Notice

Abstract

E2G is a renewable energy sales, design, and education company in West Sand Lake, NY. With support from the New York State Energy Research and Development Authority (NYSERDA), E2G designed, installed, and monitored a solar thermal system for the Riverside Laundromat and Carwash in Hoosick Falls, NY. We monitored and analyzed the amount of heat generated by the solar thermal array as well as the amount of propane offset for our client. This report summarizes the facility, design, and equipment associated with this project along with results to date.

Keywords

Solar thermal; flat plate; renewable energy; monitoring

Acknowledgments

E2G wants to express gratitude for the time NYSERDA staff has taken to review the thermal performance information associated with the Riverside Laundromat and Carwash and SunDog Solar projects supported by PON 1085 related grants from NYSERDA.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

AET	Alternate Energy Technologies
Btu	British thermal unit
GPM	gallons per minute
HTF	heat transfer fluid
IRR	internal rate of return
SHW	solar hot water
SRCC	Solar Rating and Certification Corporation

Executive Summary

E2G Solar designed a solar thermal system to cost-effectively provide hot water to a successful laundromat in Hoosick Falls, NY, and to monitor and analyze the performance of this commercial solar thermal system under real-world conditions in Upstate New York. Solar thermal collectors function by harvesting energy from the sun and using it to heat water for domestic, industrial, or commercial use. Solar thermal systems can present a long lasting cost-efficient renewable alternative to using fossil fuels to heat water.

The 10 flat-panel drainback solar thermal system at the Riverside Laundromat and Carwash has operated effectively without any lengthy interruption since its original commissioning in 2008.

The SolarWave monitoring system collected and displayed performance information fairly reliably, although difficulties with sensors and the Ethernet box have recurred. The pyranometer (used to measure incoming solar radiation) failed in 2008 and was replaced February 16, 2009. A software error from October 18, 2008, to February 23, 2009, precluded collection of inflow and outflow solar loop temperature data (and thereby British thermal units [Btu] calculation).

Temperature sensors and the pyranometer have had reliability issues. The pyranometer was temporarily offline from November 22, 2011 – January 8, 2012; January 29 – March 11, 2012; March 25 – July 1, 2012; and July 28 – October 2, 2012. There are also gaps in Btu production data from July 28 – October 2, 2011 and November 21, 2011 – August 2, 2012.

Temperature sensors were added February 16, 2009 to assess Btu distribution within the three solar storage tanks. Data from these sensors suggest that distribution is excellent. Interestingly, the end tank lags in both heating and cooling. However, the thermal differences are relatively small and equilibrate over time via the parallel piping.

During 2009 and 2010, the solar system offset about 1,460 gallons of propane each year. This number is based on a variety of hard data displayed on the following pages and is our best scientific estimate. However, it is nonetheless an estimate, and will be treated as such.

This report analyzes the system performance in several ways. First, it describes the solar system in detail, using schematics to give context. Second, it describes the system's success in offsetting propane usage at the site. Next, it describes the monitoring software developed by SolarWave, and how to access and use it. Graphs of sample days show how the system works and the monitoring software.

This report also includes an introduction to the newest generation of SolarWave monitoring software, which was specially made to fit this project. Sample days are included to illustrate the related improvements in our monitoring capabilities. Finally, a sample of monthly graphs is included, which display total solar production from January 1, 2009, to June 30, 2009. These graphs display incoming solar radiation, total Btu harvested by the system, the outside air temperature, and the temperature of the system's hot water.

1 Background

Peter Skinner P.E. of E2G Solar teamed up with NYSERDA and the Riverside Laundromat-Carwash to design, install, and monitor a commercial solar thermal system. With NYSERDA's support, E2G purchased and installed 10 flat-plate solar thermal collectors at the Riverside Laundromat-Carwash in Hoosick Falls, NY. The array consists of ten 4×10-foot glazed flat-plate collectors from Alternate Energy Technologies (AET). The collectors are plumbed in parallel in two sets of five, and angled to help the heat transfer fluid (HFT) drain back from the collectors when the system is not operational. HTF is fed from the array to three 109-gallon solar storage tanks, which are plumbed in series.

The team chose Web-based solar monitoring and telemetry software developed by SolarWave Energy Inc. to collect, analyze, and display data for the array. The monitoring program provided Internet access to current and previous information about the temperature and Btu production of the array, flow rates of the heat transfer fluid, and weather conditions at the test site. This report provides samples of performance data from the arrays, graphical performance data for sample days, and observations and tentative conclusions of various trends and phenomena related to the solar thermal system.

1.1 Project Objective

The objective of this project was to monitor and analyze the performance of a commercial solar thermal array under real-world test conditions. The goal was to gather 12 months of data in a realistic, northeast environment that has great changes in temperature and large variations in the amount of solar radiation received from one season to the next. Taking this goal one step further, the project was designed to determine the amount of propane that the solar thermal system saved the Laundromat. More than four years of data were collected. Difficulties with monitoring hardware, Internet connections, and monitoring service quality and communications introduced challenges into the completeness of the information record. Business realities arose with SolarWave, and the operators discontinued their monitoring service.

2 Approach

2.1 Facility

The Riverside Laundromat-Carwash is located in Hoosick Falls, NY (Figure 1). The solar array is located on the southern roof of the building, and faces directly south (180°). The collectors are mounted flat on the sloped roof, at a tilt angle of 40°.

Figure 1. Riverside Laundromat-Carwash

2.2 Propane Use at the Facility

This facility has used propane for many years for winter space heating, carwash fluid heating, domestic hot water production and clothes drying. The solar thermal system featured a separate loop (see Appendix C), which could help heat fluids used by the carwash. The facility owner has not reported using this system feature however.

The solar thermal system installation and monitoring budget precluded installation of a separate water meter for hot water consumption. As a result, it was impossible to illustrate the propane offset that the solar thermal system provided for heating hot water alone.

The facility installed two propane-fired Munchkin hot water boilers just prior to installation of the solar thermal system. One Munchkin is dedicated to domestic hot water production and the other for wintertime space heating. The Munchkin boiler can operate at conversion efficiencies in the 90% range when boiler water output temperatures settings are low (130 degree Fahrenheit range). At boiler water temperatures of 180 degrees Fahrenheit used for heating hot water at satisfactory recovery rates, however, fuel conversion efficiencies fall to the mid-85% range. When pipe and heat exchanger losses are added in, Btu delivery efficiency of 81% for heating the facility's hot water is justifiable. Consequently, the solar thermal Btu collection was updated by 123% (1/81%) to calculate propane equivalency because the solar Btus were used exclusively to heat hot water (not for winter space heating or drying clothes) (see Table 1 in Section 3).

2.3 Collector Configuration

The solar array consists of 10 collectors connected in parallel. All of the flat plate collectors are mounted "portrait style," so that their shortest sides are oriented toward the top and bottom of the roof.

The flat plates are Alternate Energy Technology model AE-40 glazed flat plate collectors, and their frames measure 4 feet by 10 feet. They have been rated and certified by the Solar Rating and Certification Corporation (SRCC). The two sets of five flat plates are piped in parallel, and are mounted flush on the sloped roof of the building. More information about the specifications and SRCC's performance data is in Appendices A through E.

2.4 Protocols

The purpose of this project was to gather 12 months of data from a commercial solar thermal array under real-world conditions. As such, no attempts were made to artificially manipulate the natural conditions that affected the collector arrays to simulate "typical" or "rating" days. Only natural sun was used for the tests, and heat lamps were never used to simulate sunlight. Mechanical trackers were not used to rotate the collectors as the sun moved across the sky. The collector arrays only experienced the natural movement of the sun across the sky.

Production data was collected under a full range of weather conditions during the test period. Data includes operation during sunny days, cloudy days, rain, snow, and nighttime conditions. The sensors logged data even when the collectors were obscured by snow and frost. As such, the production data does not reflect collector performance under ideal conditions, but rather over a wide variety of real-world conditions. This data will hopefully be useful for installers and owners of solar thermal systems.

E2G designed and installed the collector arrays based on several industry standards. For instance, most of the piping is done with steel and copper pipes, which were insulated to minimize standing heat loss. The HTF in the arrays is circulated by a Taco 009 pump, which is used in many solar thermal installations. The HTF itself is a 90-10 mix of water and propylene glycol, which is a nontoxic antifreeze commonly used in solar thermal systems. Since the initiation of the test project, the fluid has been pumped 8 and 10 gallons per minute (GPM). This flow rate range is consistent with the panel manufacturer's recommended flow rates.

The project's sensor and monitoring network was occasionally subject to problems and malfunctions. There were periods when the monitoring system did not function, or functioned imperfectly. Whenever a problem was detected with the monitoring network, efforts were immediately made to troubleshoot it, often with the assistance of SolarWave Energy Inc. However, despite these efforts, there are periods of time when the system did not log data or did not log data reliably. These periods sometimes lasted for several days or several weeks. Specifically, the system was not fully functional October 18, 2008 – February 23, 2009; July 28 – October 2, 2011; January 29 – March 11, 2012; and November 21 – August 2, 2012.

3 Data Analysis

The data displays included in this report discuss aggregating Btu consumption and solar production at the Riverside Laundromat and Carwash from January 2006 to December 2010. The 10 flat-panel drainback solar thermal system operated effectively, without interruption, throughout the period in question. During this period, however, there were two periods that SolarWave's monitoring data did not provide Btu information (approximately 11/15/10 to 11/28/10 and 7/20/10 to 8/2/10). This missing Btu data was offset by proportionally increasing the measured output by a factor proportional to the number of days during that month for which the data were missing – (30% more for the first period and 50% for the second one).

Figure 2 and Table 1 display propane use and solar production from July 2008 to December 2010. This time period is chosen because software and sensor issues caused the 2011 data to be incomplete.

The Riverside Laundromat and Carwash uses propane as its primary fuel to heat water, for the clothes dryers, and the facility boilers. In a typical month, the facility receives two shipments of propane with the size of the shipments increasing or decreasing in response to consumption. Improvements at the site over the past four years including new washing and drying machines may have reduced Btu consumption per customer, but increased customer visits may have increased overall consumption.

Figure 2. Propane Deliveries Before and After Solar Thermal System Installation in July 2008

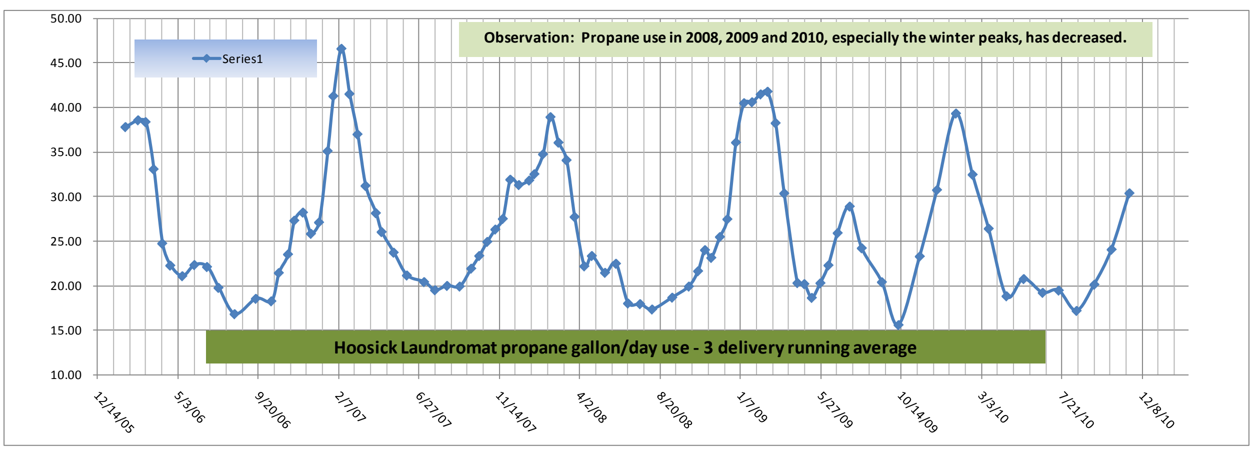


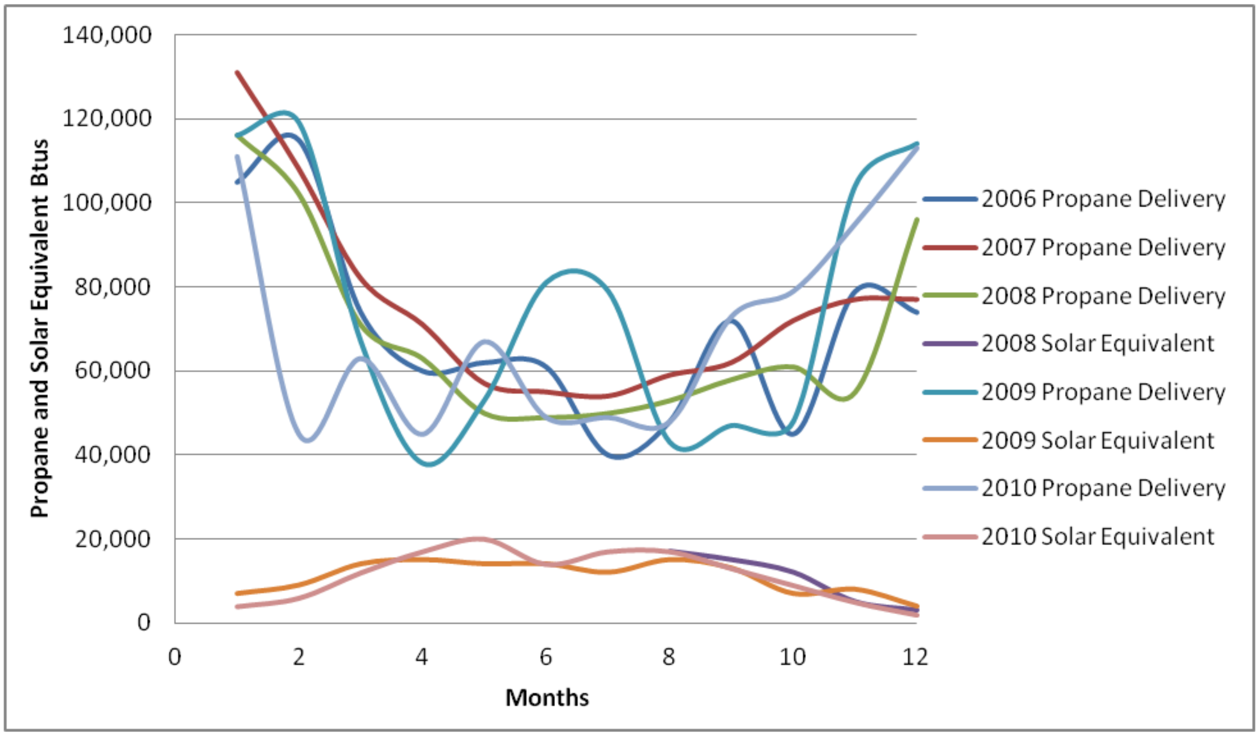
Table 1. Propane Consumption and Solar Contribution

Monthly Laundromat propane use data based upon actual deliveries.
Solar contribution data based upon Solarwave aggregate Btu collection data.

Months	2006 Propane Deliv kBtus 100%	2006 Solar kBtus 123%	2007 Propane Deliv kBtus 100%	2007 Solar kBtus 123%	2008 Propane Deliv kBtus 100%	2008 Solar kBtus 123%	2009 Propane Deliv kBtus 100%	2009 Solar kBtus 123%	2010 Propane Deliv kBtus 100%	2010 Solar kBtus 123%
Jan	104,953	0.0	130,482	-	116,299	0.0	116,299	7,126	110,626	4,154
Feb	115,293	0.0	107,606	-	102,482	0.0	119,136	8,755	45,476	6,351
Mar	73,751	0.0	82,260	-	70,914	0.0	66,659	13,633	63,114	12,289
Apr	59,568	0.0	71,372	-	63,136	0.0	38,431	14,602	44,607	16,555
May	62,404	0.0	56,731	-	50,349	0.0	53,186	13,915	66,659	20,378
Jun	60,666	0.0	54,901	-	49,411	0.0	80,979	14,387	49,137	14,450
Jul	39,712	0.0	53,895	-	49,640	497	78,856	11,599	48,647	16,905
Aug	48,222	0.0	59,284	-	53,186	17251	43,258	14,611	48,222	16,761
Sep	72,470	0.0	62,450	-	57,646	15045	46,666	13,103	73,019	12,561
Oct	44,818	0.0	72,332	-	60,986	11692	48,222	7,451	79,282	9,148
Nov	79,058	0.0	76,862	-	54,901	5102	104,999	7,674	95,391	4,748
Dec	73,751	0.0	76,587	-	96,443	2674	114,881	3,661	113,462	2,254
Month totals	834,663	-	904,763	-	825,394	52,261	911,570	130,519	837,641	136,554
Annual Solar Contribution		**0.0%**		**0.0%**		**6.0%**		**12.5%**		**14.0%**

All measurements in Table 1 are in the Btu values of propane burned. Energy data on solar production is taken from the SolarWave monitoring system. Difference between the amounts of energy produced by the solar thermal system is primarily due to variations in weather from year to year.

Figure 3. Propane Deliveries vs. Solar Contribution 2006 - 2010



The contribution of the solar thermal system is modest compared to the total amount of propane used on the site (Table 2). The Riverside Laundromat – Carwash also uses propane for space heating and for the clothes dryers. The solar thermal system does not regularly contribute to these two loads.

Table 2. Aggregate Propane and Solar Totals

	Total Propane Btus	Solar Equiv. Btus	Solar Contribution %
August-December 2008	323,162	52,261	13.8%
January-December 2009	911,570	130,519	12.5%
January-December 2010	837,641	136,554	14.0%

Note that the solar thermal system offsets about 12- 14% of the total propane used at the site. A large but undetermined amount of that propane is used for space heating and for laundry dryers, so the percent of hot water being offset by the solar system is actually much higher than 14%. The lack of a water flow meter precluded disaggregation of the solar thermal system's contribution to production of hot water alone.

3.1 Cost Effectiveness of the Solar Thermal System

The cost effectiveness of the contributions of solar thermal systems can be assessed in numerous ways. The simplest is payback period. Based upon the budget data set forth in Table 3, the solar thermal system (not including $8,328 for monitoring that is not usually included in most solar thermal systems) has a simple payback of 7.5 years, an internal rate of return (IRR) of 5.6% and a net present value of about $40,400 before any incentives and preferential tax treatment. At present, commercial solar systems enjoy a 30% federal tax credit and accelerated asset depreciation schedules applied after any NYSERDA solar hot water (SHW) grants (that in this case in 2014 would garner a $25,000 SHW grant). Applying this grant incentive and the tax incentives would generate a very high internal rate of return and short payback for this investment (66% and 1 year, respectively). For this analysis, an average propane cost per gallon of $3.00 was used. Should the real cost be higher, paybacks and the IRR will be faster and higher respectively.

Table 3. Cost Effectiveness

Cost	
Purchased Parts for System	$ 21,000
Installation	$ 11,500
Travel and Administrative	$ 1,200
Total	**$ 33,700**

Annual Savings	
Propane	1500 gallons
Value	$3 per gallon
Total	**$4,500**

Time Horizon	10 years
Discount Rate	2%

Results	
Payback years	7.5
IRR at 10 years	5.64%
NPV	$40,421.63

3.2 SolarWave Performance Monitoring Displays for the Riverside Laundromat and Carwash

A software package from SolarWave Energy was used to monitor the solar thermal system. In the past, users visited beta.solarwave.net to log on. After inserting the username and the password, the user entered a very well designed dashboard for performance visualization. Unfortunately, SolarWave discontinued its monitoring program in 2012.

Once logged in, the user could choose one of three sites displayed in a box on the upper right corner: Littleton (a home in Massachusetts), Hoosick, or Solaqua. When Hoosick is chosen, the user could add and remove variables from the graph, and change the date and time of the data being graphed.

Figures 4 thorough 10 show production data from the site, arranged by month. January –June 2009 was chosen because the production data was unhampered by sensor issues during that time period.

Figure 4. August 11, 2010 Sample Day Performance

Monthly performance data for January 2009-June 2009.

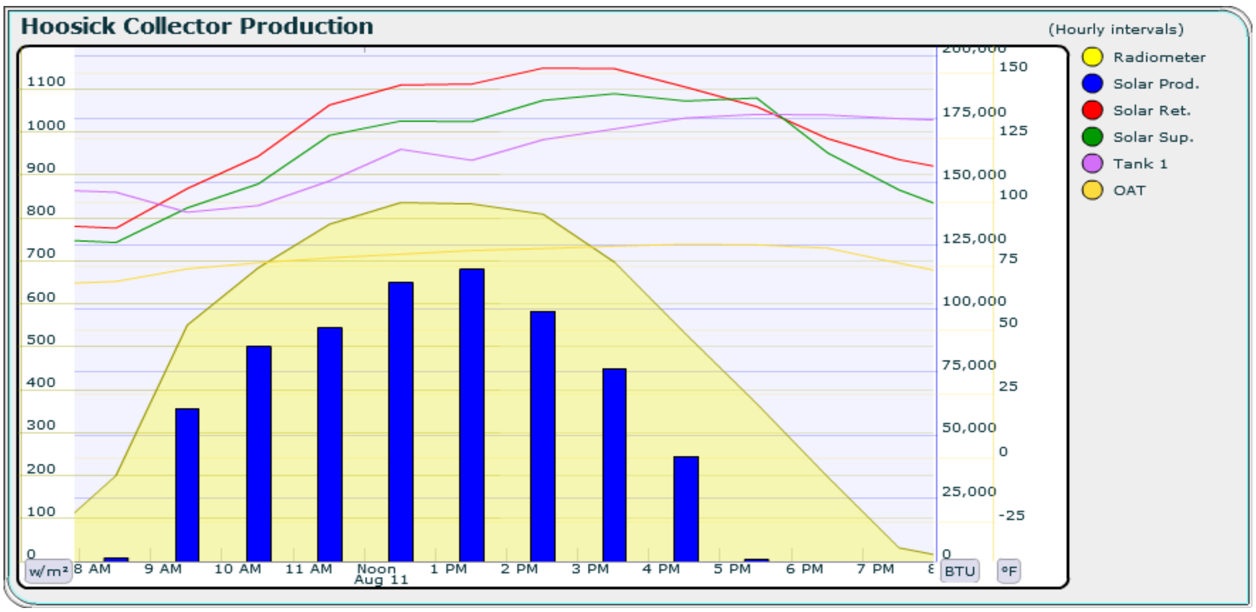


Figure 5. January 2009 Performance Data

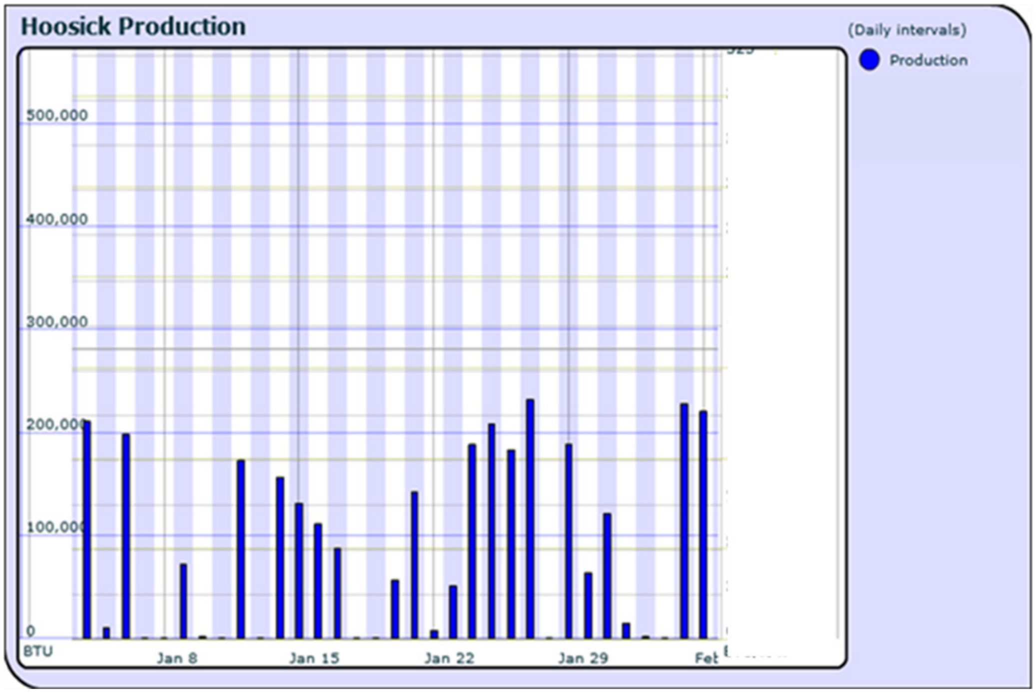
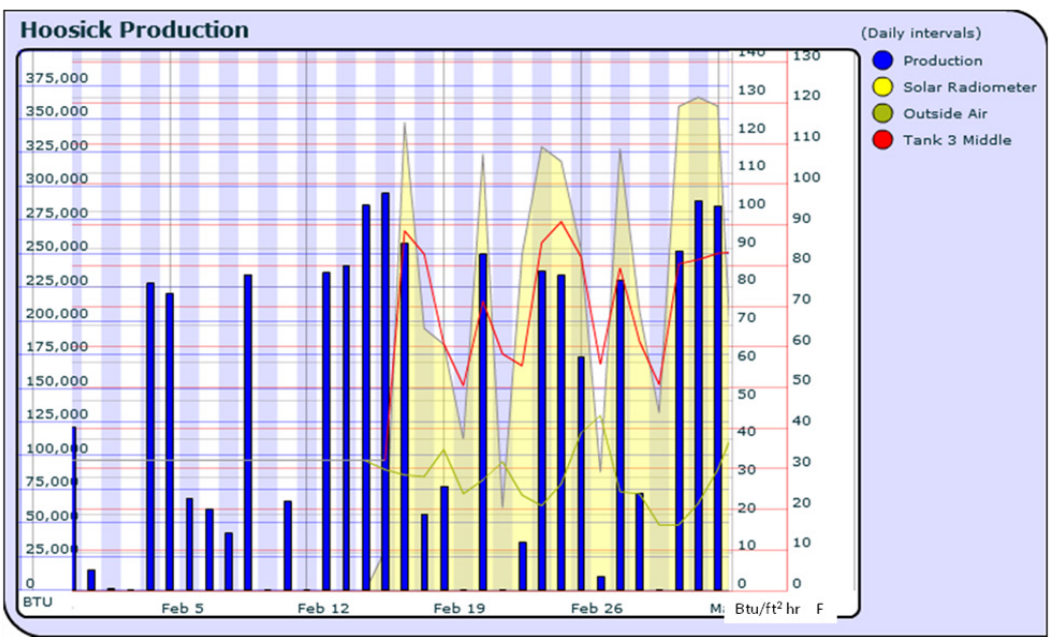


Figure 6. February 2009 Performance Data



During the February 1- March 1 2009, there were periods of time when the Solarwave server could not access data for solar insolation, outdoor air, and tank temperatures. This issue explains why some data is missing in Figure 6. Note the right most scale of Figure 6, and the following figures is for the outside air and tank 3 middle temperatures.

Figure 7. March 2009 Performance Data

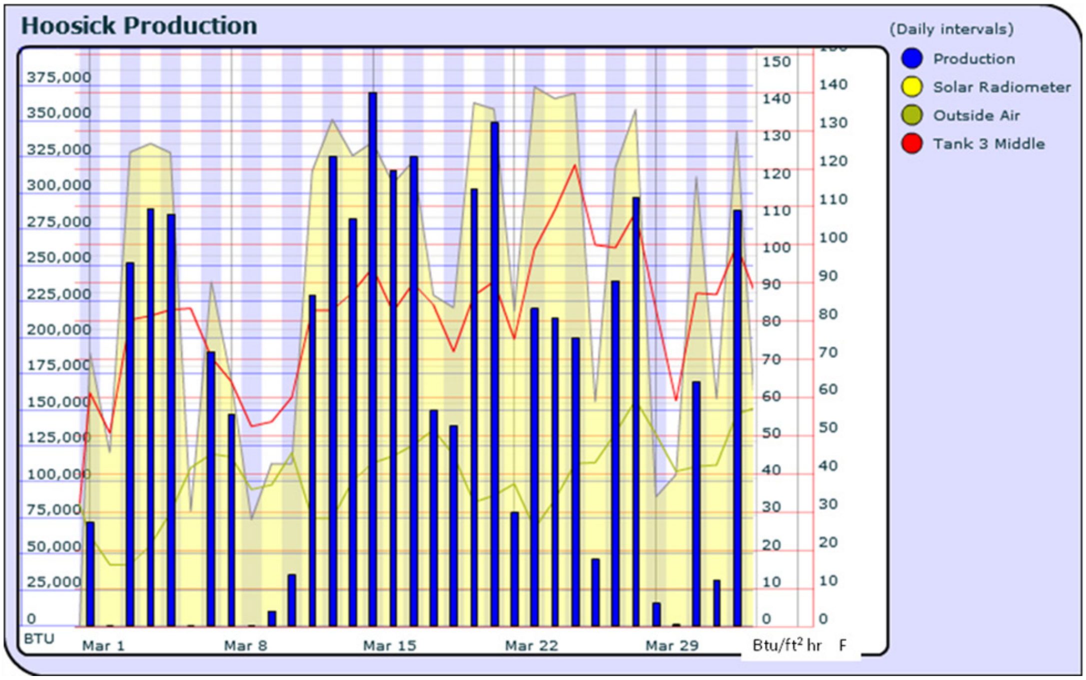


Figure 8. April 2009 Performance Data

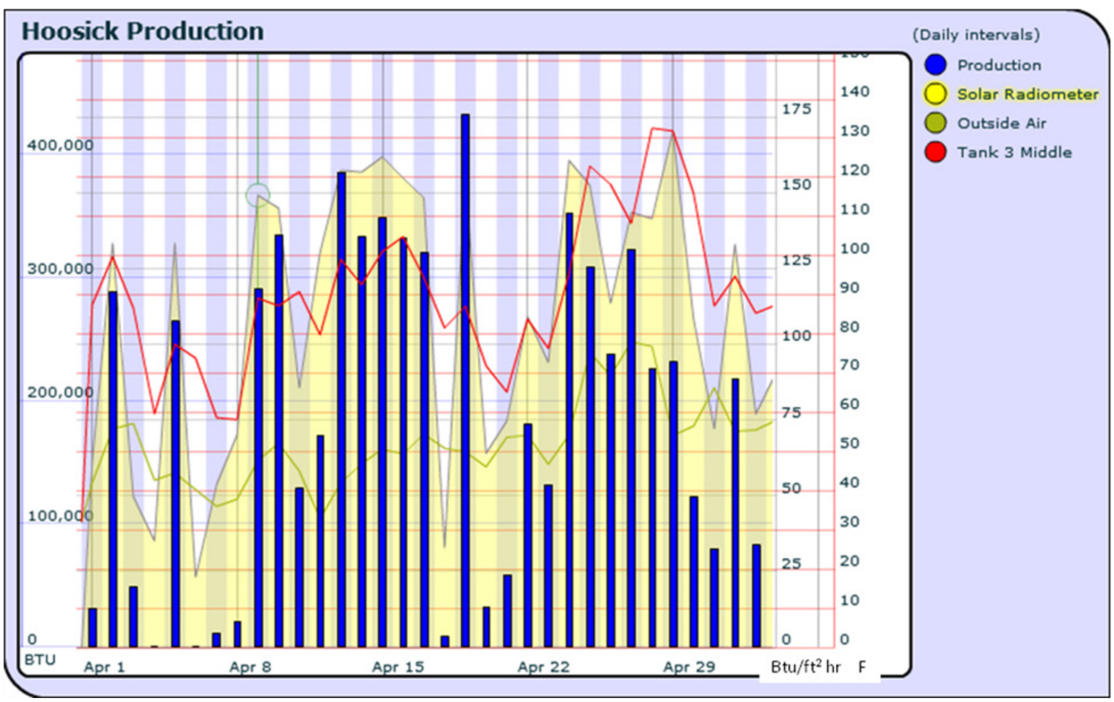


Figure 9. May 2009 Performance Data

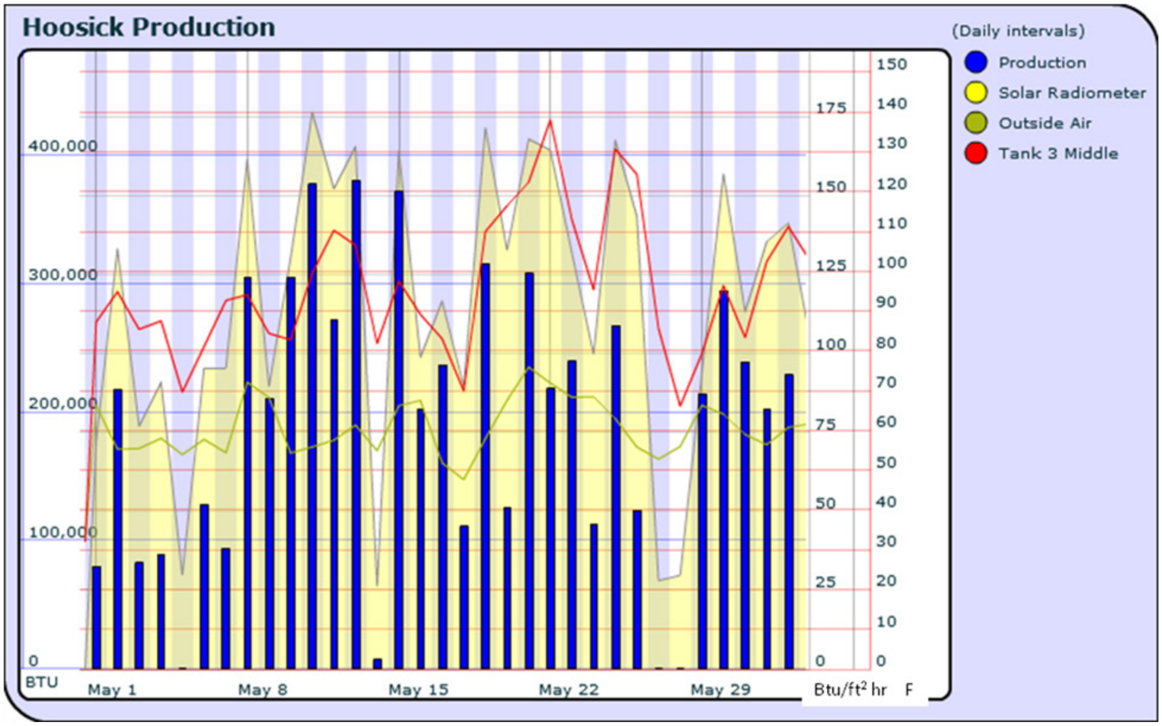
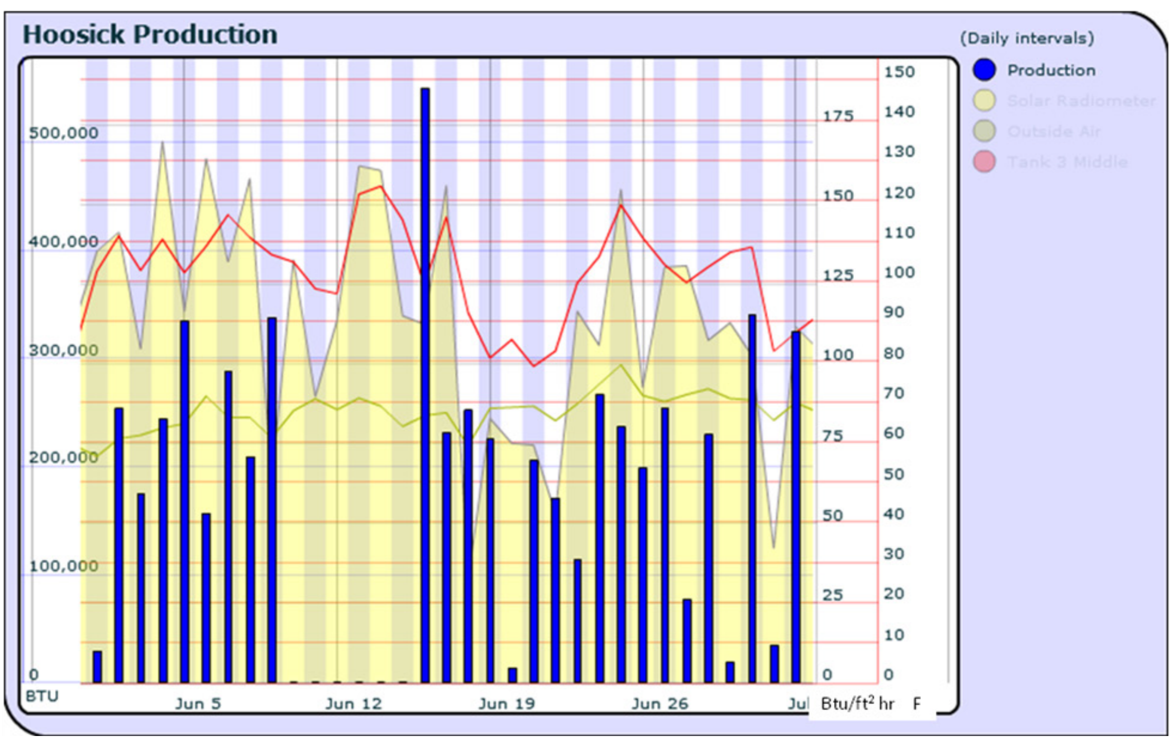


Figure 10. June 2009 Performance Data



4 Recommendations

This test project has revealed a wealth of data on the real-world performance of a solar thermal collector under a variety of conditions in the Northeast. Although many interesting trends and patterns were revealed, further testing will help verify or refute the results of the test site.

Specifically, the data suggests that the installed solar thermal array is effectively generating large amounts of thermal energy, and offsetting a significant proportion of the test site’s propane usage (about 1,460 gallons per year according to Table 4).

Table 4. Annual Propane Displaced

Avg. annual 2009-2010 propane displaced	133,537	kBtus
	91.502	kBtus/gal
	1,459.4	gal/yr

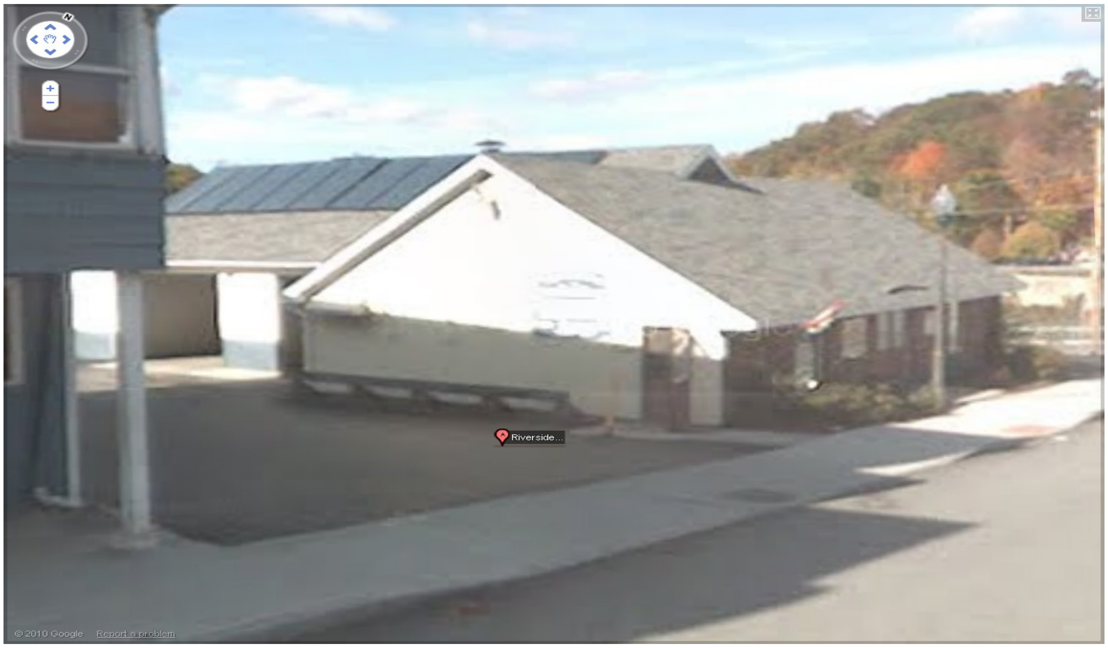
5 Conclusions and Future Work

After over four years of testing, several observations can be made. First, monitoring programs remain problematic. Although the interface and accuracy of the SolarWave system is good, the test site remains plagued with sensor and software issues. Each monitoring issue has resulted in hours of troubleshooting. If monitoring systems are to become more common in solar thermal installations, they must become more reliable.

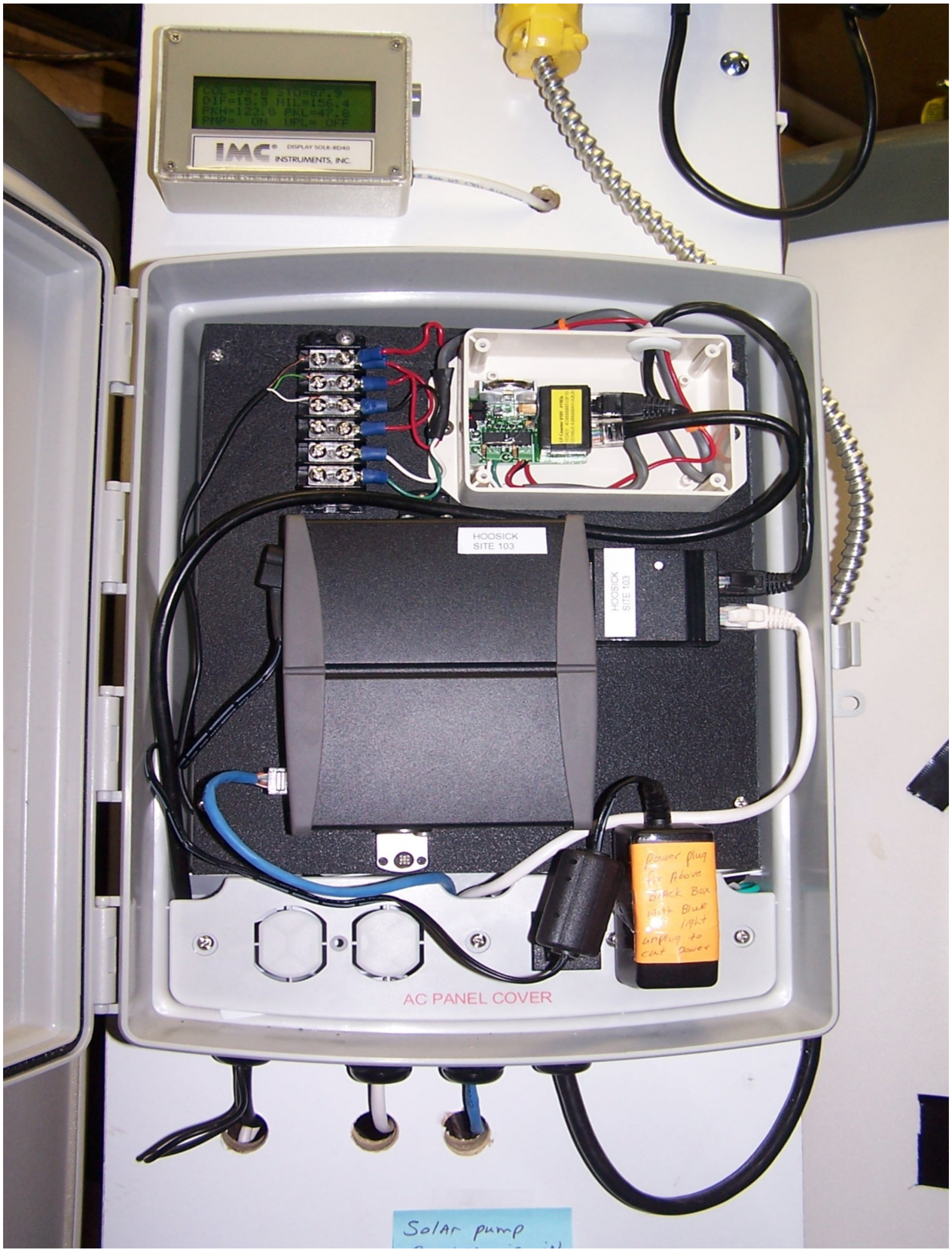
The consistent performance of the solar thermal array has been impressive. The array has produced nearly the same amount of energy over the first three years of its life, despite fluctuations in weather conditions and customer patronage.

Future work may include continued monitoring of the site and continued troubleshooting work on the sensors, pyranometer, and monitoring software.

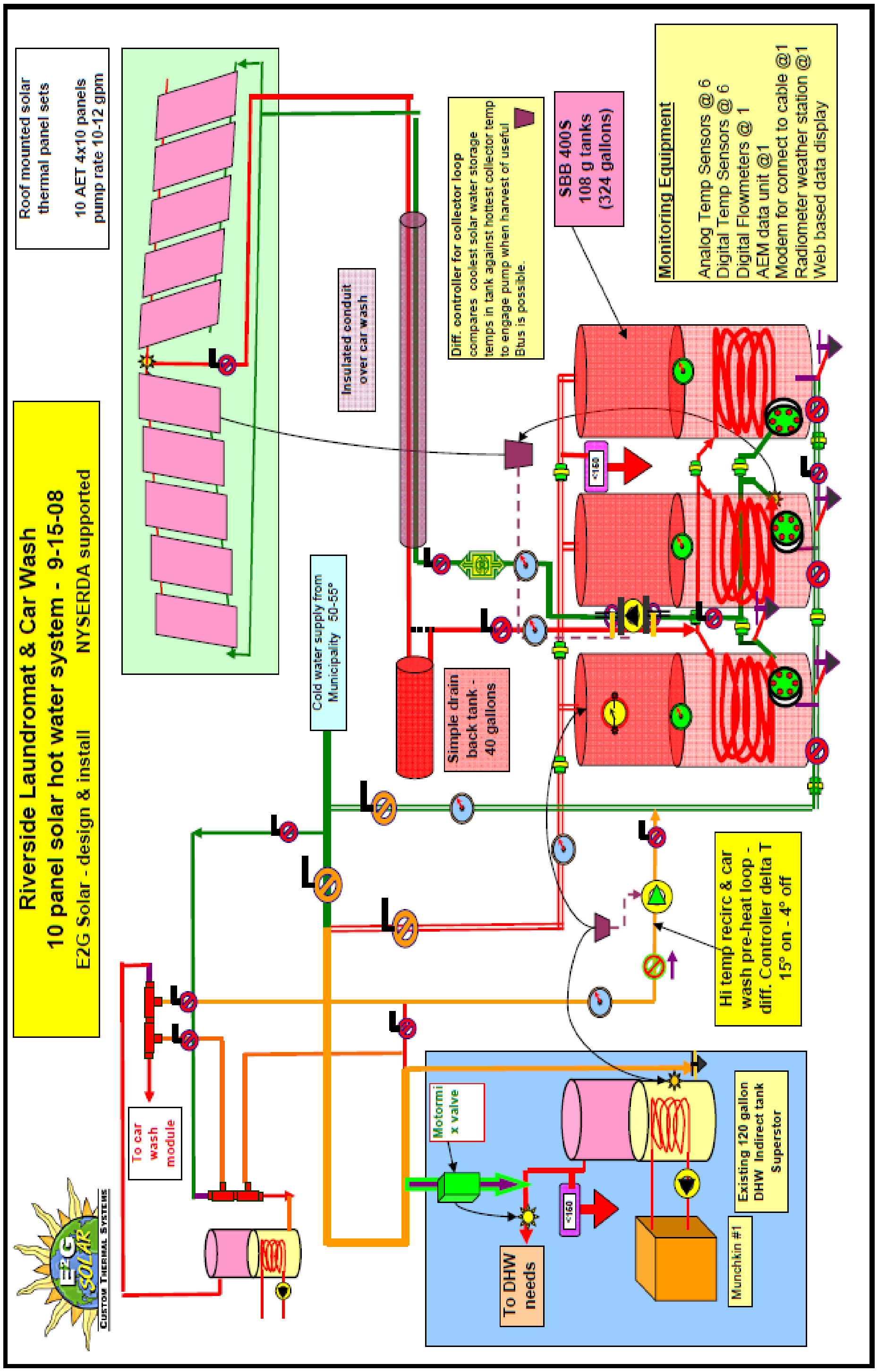
Appendix A: Site Photos



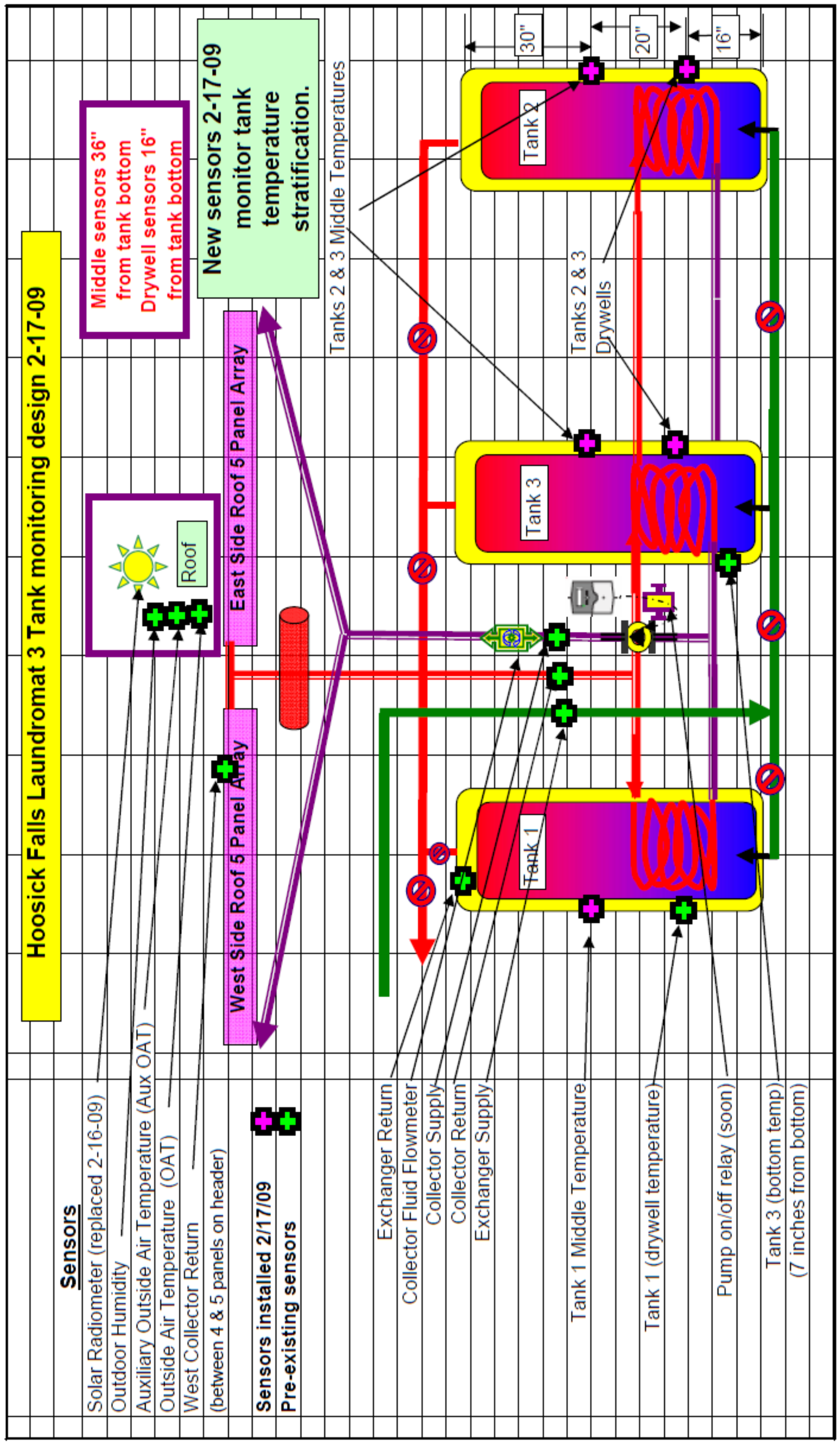
Appendix B: SolarWave Monitoring Unit



Appendix C: Solar Thermal System Diagram



Appendix D: Monitoring Diagram



Appendix E: SRCC Ratings for Alternate Energy Technologies Flat Plates

SOLAR COLLECTOR CERTIFICATION AND RATING

SRCC OG-100

CERTIFIED SOLAR COLLECTOR

SUPPLIER: **Alternate Energy Technologies**
1057 N. Ellis Road Jacksonville, FL 32254
USA

MODEL: AE-40

COLLECTOR TYPE: Glazed Flat-Plate

CERTIFICATION#: 2002001F

COLLECTOR THERMAL PERFORMANCE RATING

Megajoules Per Panel Per Day				Thousands of BTU Per Panel Per Day			
CATEGORY	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY	CATEGORY	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY
A (-5 °C)	54.8	41.4	28.1	A (-9 °F)	51.9	39.2	26.6
B (5 °C)	49.8	36.4	23.1	B (9 °F)	47.2	34.5	21.9
C (20 °C)	41.7	28.6	15.6	C (36 °F)	39.6	27.1	14.8
D (50 °C)	25.1	13.3	2.9	D (90 °F)	23.7	12.6	2.8
E (80 °C)	9.7	1.4	0.0	E (144 °F)	9.2	1.4	0.0

Original Certification Date: 22-NOV-02

COLLECTOR SPECIFICATIONS

Gross Area:	3.696 m^2	39.79 ft^2
Dry Weight:	69.4 kg	153. lb
Test Pressure:	1103. KPa	160. psig

Net Aperature Area: 3.48 m^2 37.47 ft^2

Fluid Capacity: 6.1 liter 1.6 gal

COLLECTOR MATERIALS

Frame:	Anodized Aluminum
Cover (Outer):	Low Iron Tempered Glass
Cover (Inner):	None
Absorber Material:	Tube - Copper / Plate - Copper Fin
Absorber Coating:	Selective Coating
Insulation Side:	Polyisocyanurate
Insulation back:	Polyisocyanurate

Pressure Drop

Flow		ΔP	
ml/s	gpm	gpm	in H_2O

TECHNICAL INFORMATION

Efficiency Equation [NOTE: Based on gross area and (P)=Ti-Ta]

				Y INTERCEPT	SLOPE
S I UNITS:	η= 0.6910	-3.39600 (P)/I	-0.01968 $(P)^2/I$	0.7	-4.9 W/m^2.°C
I P UNITS:	η= 0.6910	-0.5982 (P)/I	-0.0019 $(P)^2/I$	0.7	-0.9 Btu/hr.ft^2.°F

Incident Angle Modifier [(S)=1/cosθ - 1, 0°<θ<=60°]

Kα = 1	-0.194 (S)	-0.006 $(S)^2$
Kα = 1	-0.20 (S)	Linear Fit

Model Tested: AE-21

Test Fluid: Water

Test Flow Rate: 38.8 ml/s 0.61 gpm

REMARKS:

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

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