FSEC Energy Research Center

UCF

UNIVERSITY OF CENTRAL FLORIDA

# Side-by-Side Testing of SolAire Solar AC

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***Final Report***
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## Submitted to:


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## Disclaimer

## Executive Summary

The Florida Solar Energy Center performed a series of side by side tests to compare a heat pump system with a Solaire thermal collector against one without. The tests were performed in three phases: 1) baseline operation, 2) heat pump system operating with Solaire collector using collector manufacturer's wiring specifications, and 3) heat pump system operating with Solaire collector using Daiken/OEM wiring specifications. Each phase represented 5 full days of continuous operation during August of 2018 in Cocoa, Florida. Phase 1 baseline testing demonstrated that the two Daiken heat pump systems and test houses performed similarly and there were no differences between the two installations. Phase 2 testing of the heat pump system with the Solaire collector using the collector manufacturer's field wiring scheme showed no improvement in performance when compared to a heat pump system without a collector. Phase 3 testing of the heat pump system with the Solaire collector using the Daiken/OEM field wiring scheme showed a 2% penalty (increase) in cooling energy when compared to a heat pump system without a collector. These results were consistent with laboratory tests performed at the Center in 2017 where no improvement in performance was demonstrated.

## Background

The FSEC Energy Research Center of the University of Central Florida (UCF), will provide services to measure the operational field performance of a modified standard heating, ventilation, and air conditioning (HVAC) system as proposed and requested by Sekhon Group, herein referred to as the Customer. Previously, laboratory tests were performed on the SolAire solar AC system at FSEC between August and December 2017 in accordance with ANSI/AHRI Standard 210/240-2008 for both cooling and heating mode. The Standard evaluates the performance of unitary equipment and then rates the equipment using capacity and energy related performance metrics. The results indicate both total cooling capacity and system EER are negatively impacted by the installation of the solar collector. In heating mode, measurements indicate that the system performance was no different from the manufacturer's published data without a solar collector.

The manufacturer of the SolAire solar AC collector currently has a number of systems installed in Texas. Anecdotal evidence and customer testimony have pointed to positive experiences as well as reductions in energy use that contradict laboratory test results. This could suggest that some mechanism through which the customer's savings are being achieved is not being effectively evaluated in standardized laboratory testing. Given this premise, alternative testing methods may need to be employed to further document the performance of the SolAire solar AC system.

The FSEC Energy Research Center proposed to evaluate the SolAire solar AC system at the Flexible Residential Test Facility (FRTF) located on the FSEC campus. This is a unique facility comprised of two exact, side by side residential structures constructed primarily for the purpose of providing a controlled environment to conduct research and evaluation of advanced energy-efficiency technologies. The test would consist of installing the laboratory tested unit (Daiken heat pump with SolAire collector) at one building (experiment) and the same model Daiken heat pump unit in the other unit (control). The test would be performed over a three week period with week one gathering baseline data on the two systems and structures, followed by two weeks of comparison testing with the solar collector in the loop.

## Flexible Residential Test Facility (FRTF)

The state of Florida provided funding for the design and construction of two reconfigurable, geometrically and materially identical, full-scale, side-by-side residential building energy research facilities at the Florida Solar Energy Center (FSEC), as shown in Figure 1. The buildings were built at the same time with exact same construction materials and practices. They contain identical sets of instrumentation and monitoring equipment to conduct research on advanced building energy efficiency technologies under controlled conditions.


**Figure 1. Completed flexible residential test structures on FSEC campus**

The purpose of the FRTF is to provide a controlled research environment that serves two main purposes. First, it is used to research and evaluate advanced energy-efficiency technologies and operational strategies. Second, it serves as a venue to help validate building simulation programs and algorithms. Details of the 1,536-ft$^2$ single-story buildings (volume = 13,050 ft$^3$) and their instrumentation are provided in the "Flexible Residential Test Facility Instrumentation Plan" (Vieira and Sherwin 2012). In preparation of testing, both house and duct tightness tests were performed on the buildings.

The house and duct air tightness tests were completed in accordance with the **ANSI/RESNET/ICC 380 2016 Standard** in both Flexible Residential Test Facility (FRTF) lab homes. Both East and West lab homes were in their "tight" test configuration with no intentional air leakage pathways added.

**Comparison between East and West Flexible Residential Test Facility (FRTF) lab homes.**

| Test Lab | House Tightness ACH50 | Duct Total Tightness CFM25 per 100ft$^2$ | Duct Leakage to Outside Conditioned Space CFM25 per 100ft$^2$ |
|---|---|---|---|
| **East** | 2.6 +/- 2.0% | 2.86 | 2.44 |
| **West** | 2.7 +/- 1.3% | 2.28 | 1.88 |

The tightness test results show the houses and ducts were very tight and that there was no significant difference between the two lab homes. Not only were the central air ducts tight, they were installed exactly the same and had same total operational external static pressure on the central fan.

## HVAC SYSTEM TEST AND INSTALLATION METHODOLOGY

The project will consist of the following tasks

1. Install standard Daiken Heat Pump system into control home with no modifications
2. Install standard SolAire Solar AC system into experimental home with solar panel and associated refrigerant valves. Adjust refrigerant charge per manufacturer's instructions.
3. Collect baseline data: operate and monitor both systems in standard configuration (with solar collector off) for a period of 5 consecutive days. Verify that similar interior conditions (temperature and relative humidity) of both homes are maintained within 3% and that HVAC system power consumption is within 5%.
4. Open valves to solar collector. Operate experimental system for 5 days per Solaire wiring/control scheme in tandem with control system.
5. Operate experimental system for 5 days per standard OEM wiring/control scheme in tandem with control system.

### Solaire Solar Panel Collector Installation.

The solar panel was sited on the roof area directly adjacent the host Daiken heat pump as a vertical distance of 17 ft. A total of 48 ft of ½" refrigerant tubing was used to make the connection along with matching Armaflex insulation. The panel was placed near the peak of the roof structure using an adjustable tilt mount racking structure to meet the 5-degree mounting requirement (see Figure 2).

**Figure 2 Solaire Collector installation**

### Baseline Testing.

A critical component to the side by side testing is to establish that the two unmodified Daiken heat pump systems used in the study are operating in a similar manner and maintain similar conditions. As described above, the facility is comprised of two residential structures located adjacent to each other (i.e. RTF East and RTF West). The RTF East contained the control heat pump system and the RTF West contained the experiment heat pump system with the Solaire solar panel apparatus. The system containing the Solaire collector was configured in a manner so as to allow it to be bypassed and operated as a conventional heat pump the same as the control unit in the RTF East. An additional 12 ounces of R-410 refrigerant was added to each system to account for the 35.5 ft of installed line length. Subcooling was measured at 7.2 °F and 7.4 °F for the east and west units respectively (target subcooling is 7-9 °F). While the installation of all the equipment was performed by FSEC engineering staff, upon completion of the installation, the services of an authorized Daiken installer were retained to confirm and verify the startup and operation. Per the test plan, the systems were operated in a baseline test mode for a period of 5 days to ensure similar conditions were maintained and power consumption. Table 1 shows the period average hourly temperatures and RH, as well as the daily total condenser and air handler energy use. This shows that both systems maintained similar interior conditions with very little difference in cooling energy. While the west used about 1% less cooling energy (condenser + air handler), the difference in energy is within the error of measurement ( +/-1%).

| | East Baseline | West Solaire | % Diff |
|---|---|---|---|
| **Interior Temp °F** | 75.55 | 75.71 | 0.42 |
| **Interior RH %** | 49.37 | 49.75 | 0.77 |
| **Condenser (Wh)** | 928.17 | 914.0 | 1.5 |
| **Air Handler (Wh)** | 167.37 | 170.95 | -2.1 |

**Table 1. Average Hourly Baseline Interior Conditions and Power Consumption**

Regression analysis was employed to evaluate the baseline power consumption of the two heat pumps (no collector). A correlation coefficient of 1 would indicate the two systems operate exactly the same. In Figure 3 below, the coefficient of 0.97 indicates the (experiment) system consumes slightly less energy that the east (control) over the 5 day baseline period.

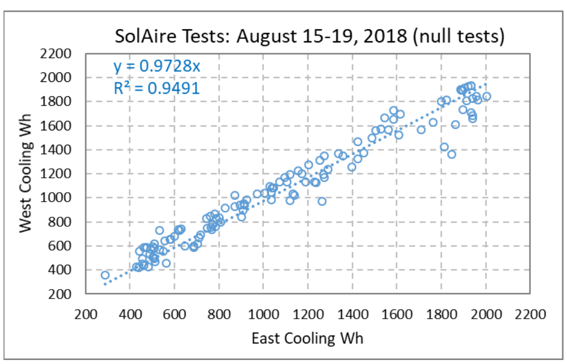


**Figure 3 East vs West Cooling - Baseline**

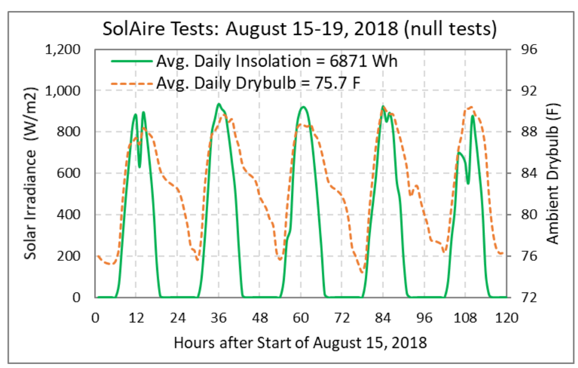


**Figure 4 Ambient Conditions - Baseline**

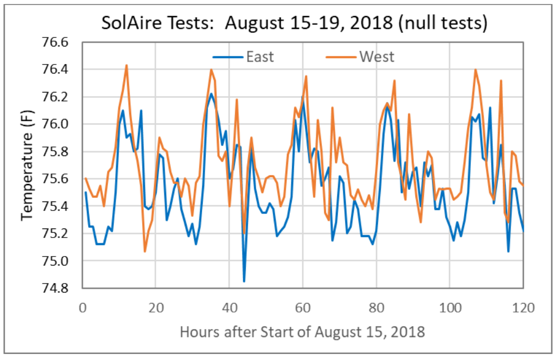


**Figure 5 Interior Temperature Profile**

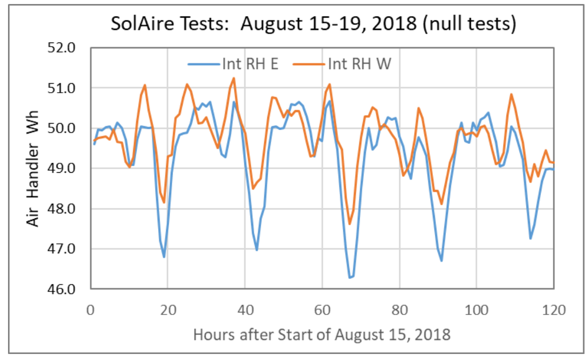


**Figure 6 Interior Relative Humidity Profile**

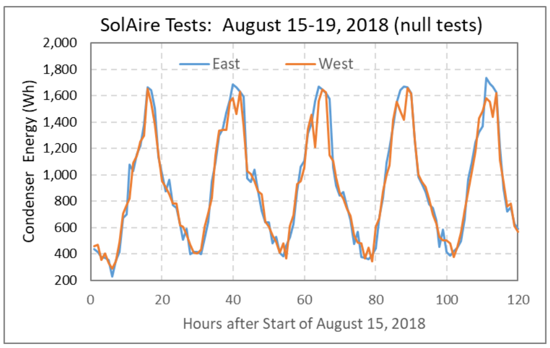


**Figure 7 Condenser Energy Profile**

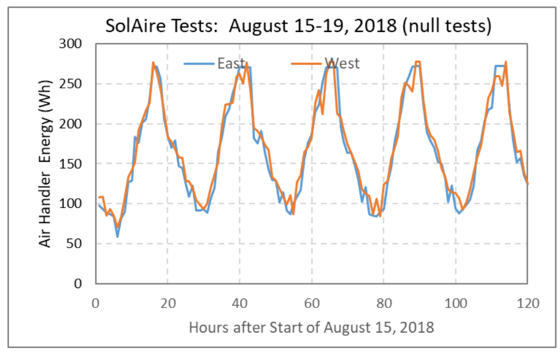


**Figure 8 Air Handler Energy Profile**

Figures 5 through 8 above represent hourly averages of the time series data collected over the 5 day baseline period (120 hours). These data confirm the two heat pump systems were installed and were operating same.

## Collector Testing – Solaire configuration.

The collector was sited and installed per the manufacturer's specifications. Evacuation and charging procedures were strictly followed. The addition of the collector required 14oz of R-410 to be added to the experimental system. This resulted in 9 °F of subcooling which was within the target range. The goal of this phase of testing was to evaluate impact of the collector using the manufacturer's (Solaire) field wiring scheme which places the air handler air flow rate to high and the compressor in 1$^{st}$ stage cooling mode. The control heat pump system in the east house was set up similarly.

Table 2 shows the period average temperatures and RH, as well as the daily total condenser and air handler energy use. Both systems maintained similar interior conditions with an insignificant difference in cooling energy. The West Solaire cooling energy was only 0.6% less than the East baseline. Given the west system used slightly less energy in the baseline configuration, the difference is within the error of measurement.

| | East Baseline | West Solaire | % Diff |
|---|---|---|---|
| **Interior Temp °F** | 75.52 | 75.90 | -0.5 |
| **Interior RH %** | 47.53 | 47.80 | -0.6 |
| **Condenser (Wh)** | 709.96 | 704.15 | 0.8 |
| **Air Handler (Wh)** | 136.57 | 137.17 | -0.4 |

**Table 2 Average Hourly East vs West Cooling Comparison - Solaire Configuration**

The same regression analysis was employed to evaluate the power consumption of the two heat pumps. A correlation coefficient of 1 would indicate the two systems operate exactly the same. In Figure 9 below, the coefficient of 0.97 was the same as found in the baseline. This is an indication that the experiment system with the collector in use, consumed roughly the same amount of energy as the control.

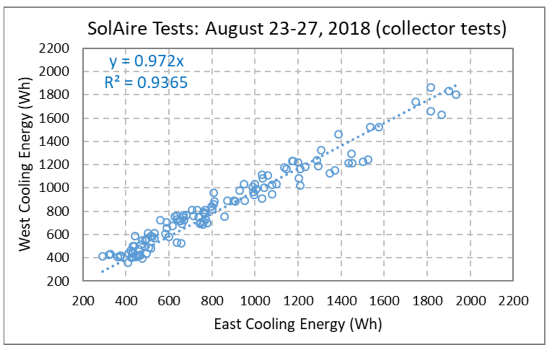


**Figure 9 East vs West Cooling – Solaire wiring**

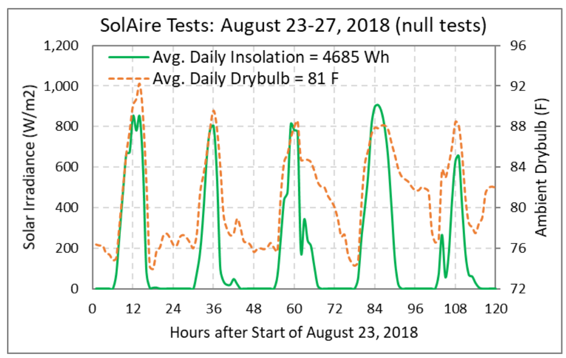


**Figure 10 Ambient Conditions - Solaire wiring**

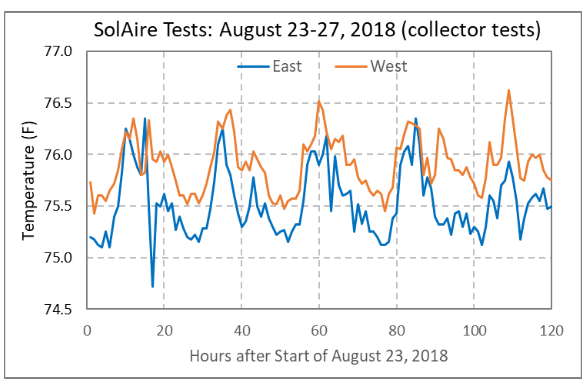


**Figure 11 Interior Temp Profile - Solaire wiring**

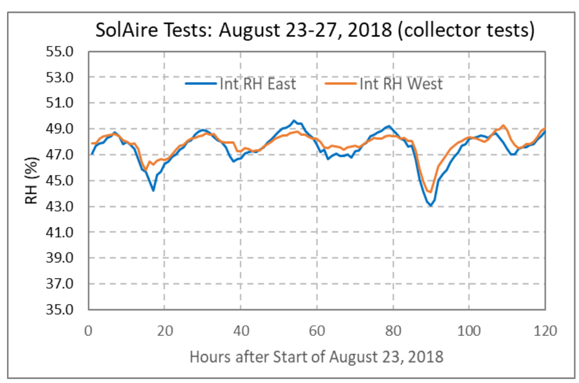


**Figure 12 Interior RH Profile - Solaire Wiring**

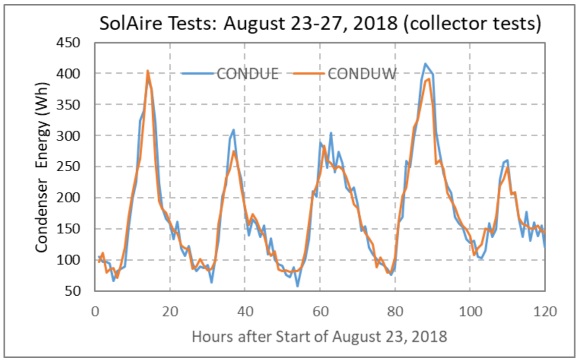


**Figure 13 Condenser Energy Use – Solaire wiring**

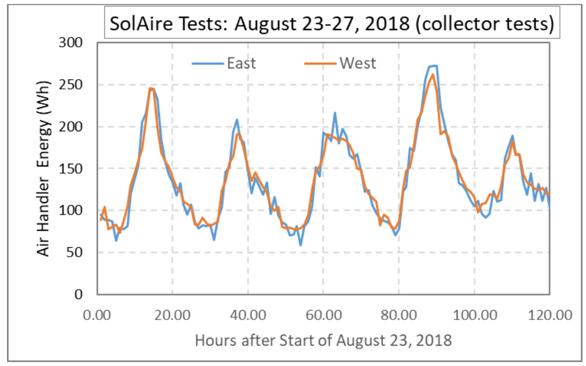


**Figure 14 Air Handler Energy Use – Solaire Wiring**

Figures 11 through 14 above represent hourly averages of the time series data collected over the 5 day testing of the experiment heat pump using the collector. The figures reveal little no discernable difference between the two systems. The control house averaged 0.5 °F cooler that than the experiment which leads to a corresponding increase in system energy consumption. These data indicate the two systems were operating the same.

## Collector Testing – OEM configuration.

This phase of testing was to evaluate impact of the Solaire collector using the Daiken field wiring per their OEM instructions (i.e. a standard field wiring scheme). This configuration allows both the air handler and condenser to be controlled by the thermostat settings in a conventional manner. This is where the 1st stage airflow and condenser operation are activated first and then after some time if 1st stage is not enough to meet load, 2nd stage (full capacity) gets activated. The system cycled on and off according to cooling load.

| | East Baseline | West Solaire | % Diff |
|---|---|---|---|
| **Interior Temp °F** | 75.59 | 76.31 | -0.95 |
| **Interior RH %** | 40.74 | 43.92 | -3.77 |
| **Condenser (Wh)** | 758.66 | 725.23 | 4.51 |
| **Air Handler (Wh)** | 58.28 | 62.94 | -7.69 |

**Table 3 Average Hourly East vs West Cooling Comparison – Solaire with OEM wiring**

As shown in Figure 15 below, the correlation coefficient for the experiment system with the collector employed using the OEM wiring configuration was 0.94. Since physical systems (in this case the house) have unique external factors (noise) that will affect the time response of the thermostat, the increased variability between this value and those previous is expected.

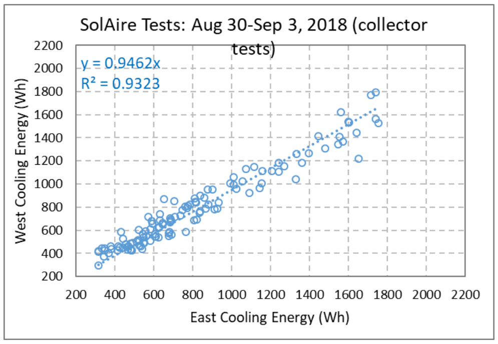


**Figure 15 East vs West Cooling – OEM wiring**

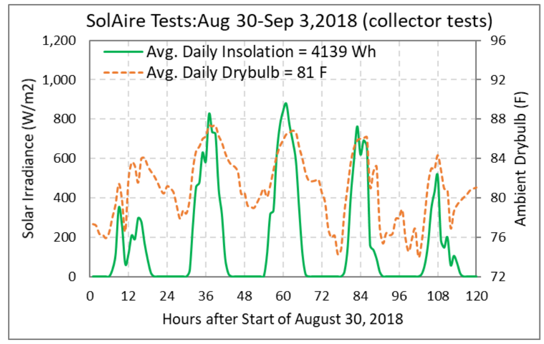


**Figure 16 Ambient Conditions – OEM wiring**

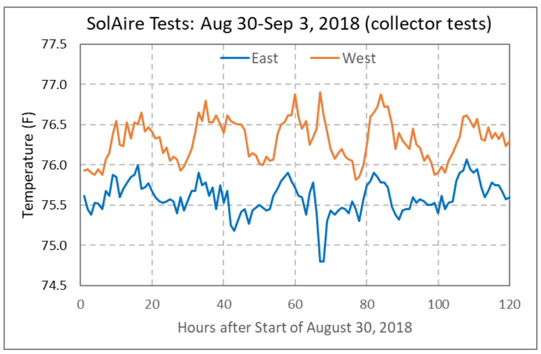


**Figure 17 Interior Temperature Profile**

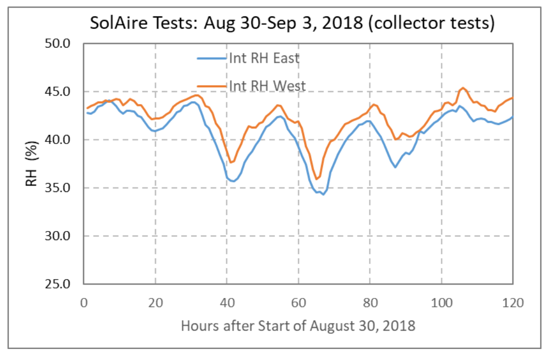


**Figure 18 Interior Relative Humidity Profile**

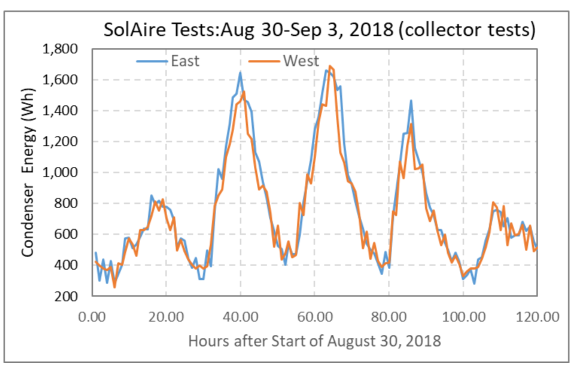


**Figure 19 Condenser Energy Use**

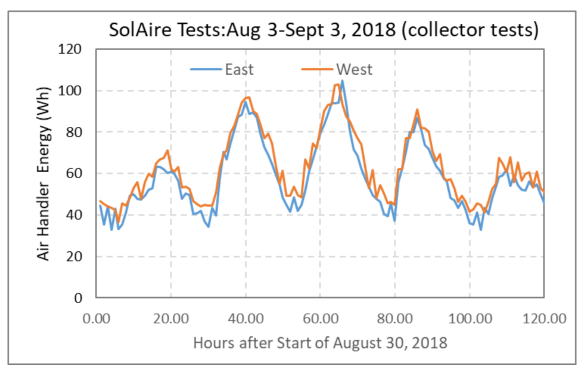


**Figure 20 Air Handler Energy Use**

Figures 17 through 20 above represent hourly averages of the time series data collected over the 5 day testing of the experiment heat pump using the collector under control of thermostat using the standard, Daiken OEM field wiring scheme. The control house consumed 3% more energy that the experiment house during this phase of testing. However, the control house also ran nearly 1 °F cooler and 3% RH dryer than the experiment house with the collector which explains the increased use (see discussion below).

## Results / Discussion

The experimental design and test method for the side-by-side evaluation of the Solaire thermal collector was divided into three parts: 1) establish baseline operation of two hvac systems without interaction of the collector and verify similar cooling loads, cooling energy consumption and interior conditions in both facilities, 2) compare energy consumption and space conditions of the two systems with the interaction of the Solaire thermal collector utilizing the Solaire specified field wiring and operational procedure, and 3) compare energy consumption and space conditions of the two systems with the interaction of the Solaire thermal collector utilizing a standard, OEM (Daiken) wiring scheme. The scope of the study was to measure and document comparisons of cooling energy use and resulting indoor conditions between the energy consumption of the Solaire thermal collector against a system installed in the exact same way and operating under the exact same environmental conditions. The testing was limited to typical hot and humid summer weather conditions in Florida and did not include evaluations at other environmental conditions or over long-term seasonal conditions. Impacts upon capacity or operational parameters of the systems and their components were not within the work scope.

### Baseline Testing

Using regression analysis, the comparitive energy use of the east house (control) to the west (experiment) shows a linear fit with a high degree of correlation. The coefficient of the indepenent variable was calculated to be 0.97 which is indicative of a near perfect similarity (m=1) of cooling energy use between the two heat pump systems (Figure 3). The coefficient indicated that on average, the West lab system used about 97% of the cooling energy as the East lab. Along with the similar resulting interior conditions (Table 1), it was evident that the installation and operation of the systems was very close to the same and that evaluation of the collector could progress.

### Collector Testing – Solaire configuration

Testing of the Solaire system consisted of adding the thermal collector into the refrigerant loop with the air handler in “high” speed mode. Additionaly, the condenser was configured to only be allowed to run in 1$^{st}$ stage cooling (65% BTU capacity). The control heat pump system in the east house was configured in the same manner. This configuration tests the manufacter’s claim that the addition of the thermal collector would result and an increase in the performance of the system equal to 2$^{nd}$ stage operation (100% BTU capacity) along with lower compressor amp draw. Using the same analysis technique from the baseline testing that compared the east and west energy consumption, the linear correlation produced a multiplier of 0.97 (Figure 9). This indicates that there was effectively no difference between the system with collector and the one without. The results are consistent with the laboratory tests performed in 2017 where no improvement was found. The two regressions are compared in Figure 21 below.

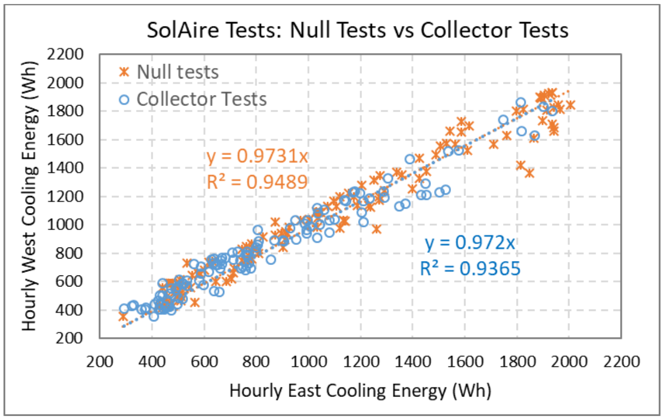


**Figure 21 East vs West Cooling Comparison with Solaire Collector & Null Test**

**Collector Testing – OEM Configuration**

The final test configuration was to run the two systems against each other when configured per the OEM (Daiken) installation manual. This test would allow the system (air handler and compressor) to be controlled by the thermostat. The analysis shows a lower slope of the regression curve, indicating slightly reduced energy consumption of the experiment house over the control (Figure 15). However, considering the initial baseline tests where the experiment house was consuming slightly less energy than the experiment (no thermal collector in use) along with the different space conditions of the two houses, the energy discrepencies could most likely be attributed to system runtimes influenced by the dynamic nature of the thermostat control aglorithm.

**Space Temperature Impacts**

The impact of space temperature control can be significant with 7-10% increase in air conditioning energy use for each degree Fahrenheit reduction. The difference between the thermostat control for the Null tests, where the average space temperature was 0.16 °F greater in RTF West (see Table 1) and the OEM Configuration tests, where the average space temperature was 0.72 °F smaller in RTF West (see Table 3) is significant at 0.88 °F. With this difference, it might be reasonable to correct the results for this range in interior temperature control between the Null tests and the OEM Configuration tests. Such a correction was made using statistical analysis with the following results.

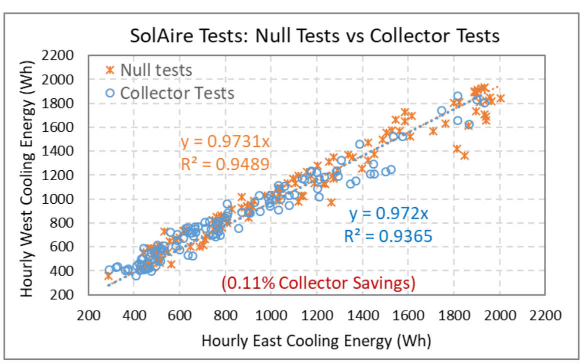


**Figure 22. Uncorrected test results**

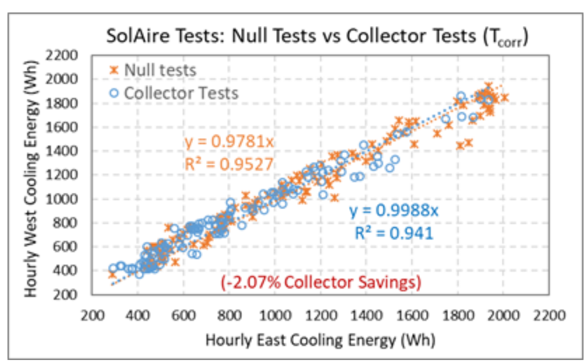


**Figure 23. Corrected test results**

From the uncorrected test results shown in Figure 22, one could surmise that a very small collector savings of 0.11% may have been achieved. However, if those results are corrected for space temperature difference between the two sets of results, the y-coefficient for both the Null tests and the OEM Configuration tests are moved in different directions, showing a collector loss of 2.07%.

## Conclusions

The side by side testing of the Solair thermal collector incorporated into a high effieciency heat pump system compared to the same system without a collector failed to produce any performance benefit. The collector was tested under continuous operation in two configurations over a 10 day period (5 continuous days in each configuration). The systems were installed with meticulous attention to detail in identical houses and operated under the “real world” conditions of a typical central Florida summer. Furthermore, the results of these field tests were consistent with laboratory tests performed at the Center wherein no benefit was found either. Per the discussion and results presented above, the technology was not shown to be viable or of any benefit.