Solar Heat Pump Seasonal and Peak Demand Energy Analysis

Executive Summary Section

FSEC-CR-1957-13

November 19, 2013

Submitted to:

Craig V. Muccio
General Office, GO
Florida Power & Light
9250 W. Flagler Street, DMO-GO
Miami, Florida 33174

Submitted by:

James B. Cummings
Charles R. Withers, Jr.
Houtan Moaveni
David Hoak

Florida Solar Energy Center®
University of Central Florida
1679 Clearlake Rd., Cocoa, FL 32922
Phone: 321-638-1000 • Fax: 321-638-1010
www.fsec.ucf.edu

List of Figures

List of Tables

ACKNOWLEDGEMENTS

The authors would like to acknowledge assistance and guidance provided by Dave Click, Principal Research Scientist at the Florida Solar Energy Center, support and encouragement from Craig Muccio – project monitor from Florida Power and Light, and for financial support for this research from Florida Power and Light.

EXECUTIVE SUMMARY

A research project was conducted to evaluate the potential annual and peak electrical energy reduction resulting from the addition of a solar powered mini-split heat pump system to an existing home with central heat and cooling in the Florida Power and Light service territory. Experiments were performed to characterize the performance of a solar powered mini-split heat pump over a 12-month period and to determine seasonal and peak demand savings for both heating and cooling periods. The 1.5-ton mini-split heat pump, along with 2 kW of photovoltaic (PV) panels, 8 deep discharge batteries, a charge controller, and an inverter were installed in a 2,000 ft^2 facility called the Building Science Lab building on the Florida Solar Energy Center (FSEC) campus. Instrumentation was installed to record solar and outdoor temperature, indoor temperature and relative humidity (RH), and electrical energy flows from PV, batteries, inverter, and utility grid to heat pump.

The mini-split heat pump was a 1.5-ton Fujitsu model with 19.2 SEER and 10.0 HSPF energy efficiency ratings. Cooling capacity of the system is variable and ranges from 7,000 to 23,000 Btu/h. Heating capacity is variable and ranges from 7,000 to 29,000 Btu/h. The mini-split has two modes of operation; 1) Standard and 2) Economy. In Standard cooling mode, the supply air temperature is about 46°F when the return air is about 75°F. This 29°F temperature drop is unusually large for an A/C system. The cold coil (and cold supply air) yields excellent indoor RH control, with typical RH levels being 39-42% in the lab building (it is an unoccupied building without mechanical ventilation but had water vapor added to the space at a rate of about 8 pounds/day). In Economy mode, the compressor cooling capacity is reduced much of the time and the supply air was delivered typically at a temperature of about 52°F. This supply air temperature is still sufficiently cold to provide good RH control, typically about 46% indoor RH on hot and humid summer days. It was found that Economy mode allows the system to operate considerably more efficiently and utilize the available solar energy considerably more effectively.

Experiments were operated variously with Standard and Economy modes, with 8 batteries and 4 batteries acting as storage, and with the mini-split operated from solar alone or from the utility grid. A 5-ton central ducted heat pump, with a SEER rating of approximately 11, operated as back-up to the mini-split heat pump when the space conditioning load could not be otherwise met.

Energy analysis. Electrical energy flows were monitored for the PV system, the charge controller, the batteries, the inverter to the mini-split heat pump, and the utility grid to either the mini-split or the central system.

Regression analysis was performed to characterize cooling and heating energy delivered to the Building Science Lab by the solar powered mini-split heat pump, by the mini-split heat pump when operating from the utility grid, and by the central ducted heat pump. While the experiments were carried out in the Building Science Lab, seasonal energy savings and peak demand reduction were determined for the MH Lab. The MH Lab is a highly instrumented 1600 ft^2 lab wood frame house, space conditioned by a split direct-expansion 3-ton SEER 13 heat

pump having central air distribution through essentially leak free ducts in the attic space. MH Lab cooling and heating loads and heat pump performance characteristics had been characterized in previous experiments. Seasonal and peak energy consumption and savings from operation of the solar mini-split heat pump (and also from operation of the mini-split from the grid when the solar resource was depleted) were characterized for the MH Lab based on regression analysis equations and Typical Meteorological Year (TMY3) data from four Florida cities (weighted to characterize the FPL service territory).

Seasonal cooling savings. Cooling savings were characterized for a variety of experimental configurations versus the 3-ton SEER 13 central heat pump which serves the MH Lab. Annual cooling energy consumption for the SEER 13 system with attic ductwork (in all cases weighted for the FPL service territory) was 6,204 kWh when operating by itself. When the solar-powered mini-split was operated, between 34% and 54% of the annual cooling load was satisfied by the solar heat pump depending upon the number of batteries used and whether Standard or Economy mode was employed (Table ES-1). Economy mode yielded about 24% greater annual cooling energy savings compared to Standard mode. The larger battery bank (8-batteries) yielded about 32% greater annual cooling energy savings compared to 4 batteries. The title of last row in Table ES-1 uses the term “100% mini-split” meant to indicate that this system is free to operate at all times even if solar generated power is not available. The central system was also still able to operate if the mini-split could not keep up with the load. Additional savings resulted when the mini-split operated on grid power after the solar resource was depleted. In total, when operated from solar and the grid, savings of 4,442 kWh/y or 72% of space cooling energy that would have otherwise been consumed in the MH Lab house by the central system, are achieved.

Table ES-1

Annual cooling energy required by the MH Lab SEER 13 central system and annual energy savings provided by the solar heat pump system using 5 different system configurations.

	Annual Cooling kWh	**Annual Savings %**
MHL SEER 13 Average Annual kWh	**6204**	**0%**
8 Battery Economy kWh Savings	**3322**	**53.5%**
8 Battery Standard kWh Savings	**2683**	**43.3%**
4 Battery Economy kWh Savings	**2516**	**40.6%**
4 Battery Standard kWh Savings	**2101**	**33.9%**
100% Mini-Split Economy kWh Savings[1]	**4442**	**71.6%**

[1] These savings assume that the mini-split also operates on the grid when the solar resources has been depleted, is limited, by assumption, to meeting no more than 80% of the space cooling load during hours when it operates on the utility grid, and the PV system uses 8 batteries.

Peak demand cooling savings. Cooling peak demand savings were characterized for a variety of experimental configurations versus the MH Lab central heat pump. Peak cooling demand for the hottest hours of the hottest TMY3 day for each of the four FPL cities was determined based on regression analysis. Generally, the solar heat pump is very effective at meeting cooling demand during the 3-5 PM peak period. Depending upon which of the solar heat pump configurations was active, peak demand savings ranged from 69% to 100% (Table ES-2). Peak demand savings were about 20% higher with Standard mode than with Economy mode. Likewise, peak demand savings were about 20% higher with 8 batteries than with 4 batteries. Maximum peak demand savings were 2.25 kW for the solar heat pump.

Table ES-2

Peak cooling energy required by the MH Lab SEER 13 central system and peak demand reduction provided by the solar heat pump system for 4 different system configurations.

	Cooling Peak kW	Peak Reduction %
MHL SEER13 Cooling Peak Demand	**2.25**	**0%**
8 Battery Standard Peak Reduction	**2.25**	**100.0%**
8 Battery Economy Peak Reduction	**1.91**	**85.1%**
4 Battery Standard Peak Reduction	**1.91**	**84.9%**
4 Battery Economy Peak Reduction	**1.55**	**69.1%**

Seasonal heating savings. Early in the heating evaluation period, it was determined that the solar heat pump system would not meet a substantial portion of the heating load with 4 batteries or under Standard control mode. Therefore, the heating experiments focused on operation with 8 batteries with Economy control mode. (Clarification: Economy mode yielded greater solar heating savings because the mini-split operated at about 34% higher efficiency in Economy mode versus Standard mode.) Heating savings were characterized for one experimental configuration (Economy with 8 batteries) versus the MH Lab central heat pump. Annual heating energy consumption for the SEER 13 system with attic ductwork (in all cases weighted for the FPL service territory) was 260 kWh when operating by itself, based on the regression equations and TMY3 data. When the solar-powered mini-split was operated, 213 kWh (or 82%) of the annual heating load was satisfied by the solar heat pump (Table ES-3). In total, when operated from solar and the grid, 232 kWh/y or 89% of space heating energy that would have occurred by the central system, are saved.

Table ES-3

Annual heating energy required by the MH Lab SEER 13 central system and annual energy savings provided by the solar heat pump system based on two operating modes.

	Annual Heating kWh	Annual Savings %
MHL SEER 13Aveage Annual	**260**	**0%**
8 Battery Economy Savings	**213**	**81.9%**
100% Mini-Split Economy Savings[2]	**232**	**89.2%**

[2] These savings are based on the assumption that the mini-split operating on the grid meets no more than 80% of the space heating load that would otherwise be met by the SEER 13 central system.

Peak demand heating savings. There was insufficient peak heating data to perform regression analysis. The research team examined a representative sample experimental peak demand periods on cold winter mornings and found that in no case did the solar heat pump operate at all during the 6-8 AM (EST) period. It is concluded, therefore, that the solar heat pump system was unable to achieve any peak demand savings on winter mornings, because the batteries could not carry sufficient electrical energy forward through a cold night to keep the system operating.

Lessons learned.

1. The tested solar heat pump system can meet over 70% of the annual space conditioning energy usage, but does not yield attractive economic returns, with typical payback on the order of 20 years when taking into account maintenance and periodic equipment replacement (for batteries, inverters, and mini-split) .
    a. On the other hand, the solar heat pump system does produce substantial cooling peak demand reduction which can be attractive to the utility.
    b. It also provides some space conditioning and potentially 120V alternating current service to the customer during periods when the grid goes down
2. Batteries are the weak link in the solar heat pump system. When subjected to nearly daily cycling from 45% to 90% state-of-charge (SOC), the batteries exhibited evidence of significantly diminished storage capacity by the end of 12 months.
    a. It is noteworthy that the battery manufacturer recommends that only about 50% of total battery storage capacity be used on a regular basis. However, even limiting battery discharge to about 50% of full capacity, the 8 AGM batteries used in this work had essentially failed by the end of 12 months of service.
3. The inverter proved to be more inefficient than originally anticipated (84% monitored efficiency). It will be important, for future stand-alone applications, to find higher efficiency inverters.
4. A bimodal inverter (able to both receive from and deliver to the central grid) is needed in order to use excess solar energy that is available on sunny days with limited space conditioning loads.
    a. Based on the findings of this research effort, it is recommended that an inverter for this type of stand-alone system be bimodal, that is having the capability to also send power to the electric utility grid. Converting this system to bimodal would make the overall yearly solar heat pump system operation more energy efficient because excess PV power that is not needed by the mini-split heat pump on mild autumn, winter, and spring days could then be put to good use (that is, the excess power could be sent back to the grid). As it was, there were a significant number of days when a significant portion of the available solar could not be used, because of limited cooling or heating load on the building.
5. An optimized stand-alone bimodal system design is proposed in this report that will make the system more cost-effective by delivering all of the available solar energy either to the mini-split or to the utility grid and by greatly extending the life of the batteries.
    a. This bimodal system can operate in grid-integrated mode or as a stand-alone system. Compared to the “as-tested” system, there are two main differences.

b. The first difference is that the inverter can also deliver excess solar to the utility grid, allowing essentially all potential solar power to be put to effective use, either going to the solar heat pump or directed to the grid.
c. The second difference is that in normal everyday operation this bimodal system will limit the battery SOC range to only about 5% of full capacity. With this small cycling range, it is expected that battery life will increase by an order of magnitude. However, the system can still be effective as a stand-alone back-up system because when the utility grid goes down the batteries can be exercised across a larger range of SOC (to 50% or more of full capacity) in order to allow the system to deliver significant back-up solar power to the home.

Economic analysis summary and conclusions. Economic analysis was performed for a total of four solar heat pump configurations. Additionally, three other variations of the “as-tested” solar heat pump system were examined.

All seven of the designs had battery back-up with the exception of 1) a grid-tied solar system with a separate mini-split heat pump system (operating in parallel but not integrated); this was the baseline against which the other system designs were compared. Other examined designs included 2) the “as-tested” solar heat pump system, 3) the dc-powered solar heat pump system which was originally proposed but was unavailable for testing, and 4) an optimized bimodal ac-powered solar heat pump system. Three additional variations of the “as-tested” system also examined were; 5) operation of the system with 4 batteries versus 8 batteries, 6) operation of the system with a lower or a higher efficiency mini-split heat pump, and 7) operation of the system with expanded PV/battery capacity.

- Table ES-4 presents a summary of economic analysis results for the four primary solar heat pump system design variations (economic analysis of the three additional variations on the “as-tested” system are presented later in the report). While energy savings analysis derived from the year-long monitoring and regression analysis is available for the “as-tested” system, that analysis is not available for the other configurations. Therefore, the economic performance of the other configurations has been examined using a solar simulation tool called PV-DesignPro-S. In order to provide internally consistent results, the analysis has also been performed for the “as-tested” system using the same PV-DesignPro-S software. Therefore, analysis results from PV-DesignPro-S for all four of the primary system configurations are presented in the table. The following information is presented in Table ES-4:Solar generated electricity
- Electrical energy savings that result from the operation of the mini-split using solar generated electricity as a result of avoided electrical energy use that the central ducted SEER 13 system would have used
- Electrical energy savings that result when the mini-split heat pump operates on the grid when the solar resource has been depleted. The savings occur because the mini-split is essentially two times as efficient as the central ducted system
- Gross and net system cost

- Payback period taking into account maintenance and replacement costs for batteries, inverters, and mini-split.

Table ES-4

Seasonal Savings and Payback Period for Four Solar Heat Pump System Designs Taking into Account Maintenance and Component Replacement Costs over a 20-year Period

	PV produced kWh/y	PV+M-S avoided kWh/y	Mini-split on grid savings kWh/y	Seasonal savings kWh/y	Gross system cost	Net system cost [1]	Payback period years
Grid-integrated	2968	3877	1274	6151	$11,200	$7840	12
"As-tested" [2]	2734	5386	539	5925	$15,200	$10,640	20
DC	2441	4247	-	4247	$12,860	$9002	22
Bimodal	2968	3877	1274	6151	$13,600	$9520	17

[1] after 30% Federal tax credits

[2] Economy mode with 8 batteries

All of the systems employed a mini-split heat pump. In all cases a substantial portion of the seasonal energy savings occurred as a result of the high efficiency of the mini-split heat pump. The ac-powered mini-split had a net efficiency that was 1.97 times that of the central SEER 13 ducted heat pump (which has an effective SEER of 9.75 after including 25% attic duct system losses). The dc-powered mini-split's net efficiency was 1.74 times that of the central system. The fact that in most cases all of the solar power was being delivered through the mini-split means that the mini-split can be thought of as an amplifier, in effect doubling (or nearly doubling) the delivered savings that the solar system would otherwise have provided. In the case of the baseline system (grid-tied system with the mini-split heat pump operating in parallel), the solar power is not actually delivered through the mini-split but can in effect be thought to be substantially delivered through the mini-split.

There is another source of seasonal energy savings apart from solar powering of the mini-split, and that is operation of the mini-split from the grid when the solar resource has been depleted. While the solar heat pump system meets about 54% of the heating and cooling load of the house (MH Lab, in this case; see Table ES-1), the remaining space conditioning load can be substantially met by operation of the high efficiency mini-split operating from the utility grid. The "as-tested" solar heat pump system in our lab building had a relay installed that allowed the mini-split to switch seamlessly from solar to grid power when the solar resource was depleted. For this analysis, the research team assumed that 80% of the remaining heating and cooling load that had not been met by the solar heat pump would, in fact, be met by the mini-split operating off of the grid. The fact that the mini-split could provide the required space conditioning at approximately twice the efficiency of the central ducted heat pump meant that the energy represented by the remaining 46% of the yearly load not met by solar would then be effectively cut in half. As a result, about 72% of the energy use that would have occurred with the central ducted system was saved by the mini-split heat pump system when operating from solar and the grid.

This is a key point. While the 2 kW of solar panels can typically deliver about 2400 to 3000 kWh annually to end uses in a typical year (depending upon which system is being examined), the delivered energy savings (from avoided space conditioning energy consumption by the SEER 13 central, ducted system) increases to the 4,200 to 6,200 kWh per year range when tied in with a high efficiency mini-split.

In spite of the energy savings enhancement provided by the mini-split, the economic benefits are not particularly attractive strictly from yearly energy savings. For most of the examined systems, the payback period is on the order of 17-22 years. The grid-tied (baseline) system (2 kW of PV with a SEER 19.2 mini-split heat pump, but no batteries) has a payback of about 12 years.

The reader may have noticed that the predicted annual kWh savings of the "as-tested" system based on monitored data, regression analysis, and TMY3 data is about 25% lower than that predicted by the simulation tool PV-DesignPro-S. Inevitably, measured data (with simplified modeling based on regression analysis) and complex modeling using PV-DesignPro-S do not provide the same answers. There are too many variables to account correctly for all effects. Furthermore, models are only as good as the software developer and the data upon which the model was constructed and verified. The PV-DesignPro-S modeled results tend to yield greater annual savings.

It would be difficult for the research team to point to any one item or group of items that explains the difference between these modeling approaches. However, based on the research team's observations, it is likely that battery charging issues and load scheduling may contribute significantly to the modeled differences.

- In our 12-month experiments, the research team observed that the batteries go through three stages – BULK, ABSORB, and FLOAT. In BULK, the batteries are able to accept energy at a high rate and can accept all of the solar available from the PV panels. As State of Charge (SOC) approaches 90%, charging goes into ABSORB mode, and the rate of energy acceptance by the batteries is cut substantially, so that about 50% of the available solar may be thrown away while in this charging mode. When charging goes into FLOAT, perhaps 90-95% of the available solar is thrown away. It is uncertain whether the PV-DesignPro-S model can fully account for the energy acceptance rate of the batteries that occurs in actual system operation, since these charging rates change from minute to minute as solar input and load output fluctuate in real time.
- Regarding load, the PV-DesignPro-S model assumes a single, typical daily load profile for each day of a given month. This simplification may well miss important outcomes from the variability which occurs in real weather patterns. For example, in the month of March, real weather may include 6 days of cold weather, followed by other days when neither heating nor cooling is required, and then mixed with days of significant space cooling. While the solar heat pump system will provide certain savings results when exposed to the variability of real weather and building loads, the predicted system performance based on average daily load may yield different annual savings. It is

difficult to predict how load profile simplifications like this can affect the annual predicted space conditioning savings.

- Nevertheless, the authors feel that the modeling results across the four primary system configurations, and three variations on the “as-tested” system, are sufficiently representative of actual seasonal performance that the relative economic performance of the systems can be meaningfully compared.

In order to observe differences in annual energy savings, the PV-DesignPro-S model was run for the various configurations based on a single TMY3 weather station (Melbourne). Melbourne was chosen to make comparison to the 12-months of our measured lab results (in Cocoa) most comparable. The objective of this exercise was not to provide service territory-weighted annual savings for the FPL service territory but rather to allow internally consistent comparison of each system to all of the others and to identify the relative economic performance of the systems. Following is a partial list of economic results and conclusions.

- All of the solar heat pump systems with battery back-up have a payback period on the order of 17-22 years. On the other hand, the grid-tied system with mini-split heat pump operating in parallel (but no battery storage) showed a payback period of about 12 years.
- A direct current-powered solar heat pump system is projected to have a similar level of cost-effectiveness compared to the “as-tested” system. On one hand, it would deliver slightly more solar space conditioning (because there are no inverter losses) and is estimated to be less costly. On the other hand, the ac-powered mini-split can provide additional annual cooling and heating energy savings by operating on grid power during periods when the solar resource has been depleted.
- A bimodal, optimized stand-alone solar heat pump system (as described earlier) would provide greatly expanded battery life and therefore greatly expanded functionality. On the other hand, as the system was modeled, it yields a longer payback period because the system expends more of its solar energy providing uninterruptable power to other end uses (i.e., computers, communications, refrigeration, and lighting) besides the mini-split, which unlike the high-efficiency mini-split, do not have the capability of amplifying the energy output of the solar system.

While cooling and heating savings do not make a compelling economic case for the solar heat pump systems (though the grid-tied solar heat pump system without batteries has a much shorter payback), cooling season peak demand savings is an attractive feature from an electric utility perspective, with fairly reliable 2.2 kW peak savings. If incentives are made available to the customer, the payback periods would be even more attractive. On the other hand, the systems with battery backup provide additional functionality which can offer significant value to the customer. The ability of the systems operating on alternating current to provide uninterruptable power to the house and power for both short-term and more extended grid power disruption can be seen as a major bonus. The ability of the optimized bimodal system to provide those functions and optimize battery life (which has been identified as major issue in this research project) will make it an attractive option for many consumers.

Strategies for Achieving Maximum Seasonal Energy Savings

During the 12-months of experiments, the research team made observations regarding how the solar heat pump system can be operated for maximum savings. Most of these observations relate to how operation in Economy mode yields substantial energy efficiency benefit.

Greater cooling energy savings can be achieved by operating the solar heat pump in Economy mode versus Standard mode, for three reasons.

1. In Economy mode, the supply air is significantly warmer, about 54°F compared to 46°F. Heat pumps operate more efficiently when they are pushing energy flows against a smaller temperature differential. In Economy mode, monitored cooling EER (Energy Efficiency Ratio) is 34% higher compared to Standard control mode when outdoor temperature is 82°F (Figure ES-1). From the regression analysis equations, it can be calculated that the mini-split operates with 17.6 EER in Economy mode compared to 13.1 EER in Standard mode.
2. The fact that the supply air is about 8°F warmer means that the heat pump in Economy mode is providing proportionately less latent cooling (less water vapor removal from the room air) and is expending more of its space cooling energy on lowering room air temperature (sensible cooling). It therefore meets the thermostat setpoint sooner.
    a. Instead of producing typical 40% indoor RH (which it does while operating in Standard control mode), it produces about 46% indoor RH while operating in Economy control mode.
        i. 40% indoor RH is significantly lower than is necessary for most applications (46% RH is sufficiently low for essentially all circumstances), and the energy used to draw the humidity down to the lower level is largely wasted. Humidity in the 38 - 40% range can lead to drying of skin and eyes, and can contribute to static electricity discharges.
        ii. One could however argue that a lower indoor RH can produce similar occupant comfort at a higher temperature, which means that the thermostat could be raised by say 1°F with the lower RH. This would, however, require some thermostat adjustment on the part of the occupants, and it is uncertain that this sort of adjustment actually occurs in real homes.
        iii. Another way to say this is that in Economy mode the system is spending less of its energy on latent cooling (moisture removal) and more of its energy on lowering the space (drybulb) temperature. Since thermostats control based on room air temperature, higher equipment operating SHR leads to reduced space cooling energy use.
3. When the mini-split is in Economy mode, it draws about 600 W compared to about 1,000W in Standard mode. The relevance of the lower power draw in Economy mode to system efficiency relates to how this power draw interacts with the batteries. The smaller power draw of Economy mode tends to keep the system operating for an extended period. By contrast, the larger power draw of Standard mode tends to trigger premature cut-out of the inverter. As a result, more of its operation time (when in Economy mode) occurs at night when outdoor temperatures are cooler and the system operates more efficiently.

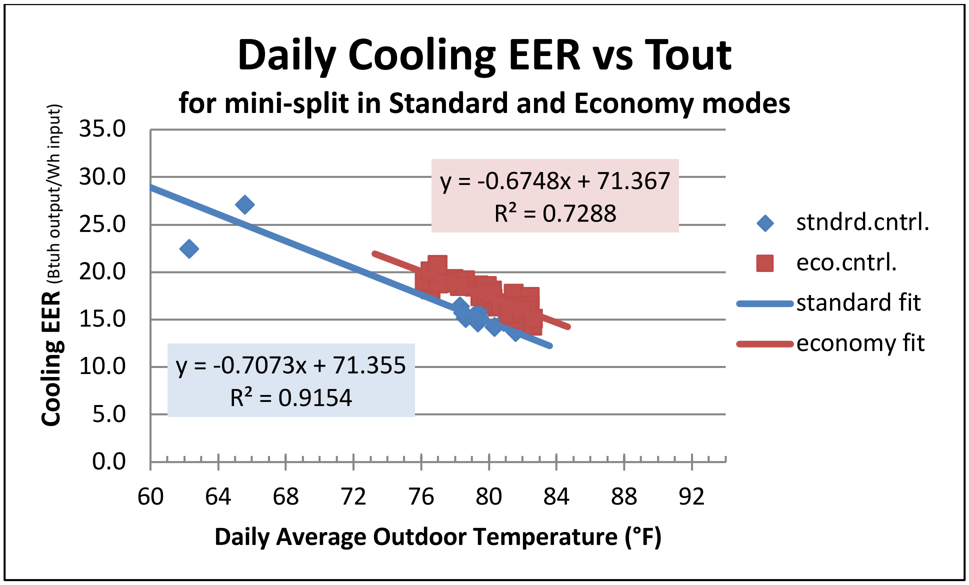

Figure ES-1. Monitored mini-split heat pump EER for Standard and Economy modes as a function of daily outdoor temperature with indoor temperature held constant at about 76^{o}F.

Top Findings

This research project was primarily designed to measure the performance of a solar-powered mini-split heat pump with battery backup. Analysis was also performed for three additional system variations that were not tested in the lab based on simulations using the PV-DesignPro-S software. The simulations evaluated the economic merit of other system variations, including grid tied, dc-powered mini-split, and bimodal inverter options. Based on the economic analysis, the top two options with the best return on investment were:

1. Grid integrated PV no battery backup (12 years)

This is the only option evaluated that did not have battery backup. Because there are no expensive batteries, this system requires much less investment, but provides no benefit during storm events where grid power may not be available.

2. Bimodal inverter with 4 battery (17 years)

This system utilizes a bimodal inverter, permitting PV power to go to the mini-split, to the batteries, or to the grid when excess PV power is available. This system also employs electrical energy exchange between the grid and batteries to keep batteries within a narrow range of higher SOC which would extend battery life. While this system has a considerably longer payback period compared to the grid-tied system with no batteries, it has the significant advantage of providing uninterruptable power supply during periods of short power outages and providing power back-up during more extended periods of power outage.

Other major findings were:

- Money spent on upgrading the efficiency of the mini-split is more cost-effective than adding additional PV capacity, with payback periods of 8 years and 20 years, respectively.
- Operating with 4 batteries instead of 8 is more cost effective, but yields less effective back-up power during grid outages, reduced summer peak reduction, and about 4 hours less solar cooling on an average summer day.
- Better charge controllers are needed to more effectively manage battery SOC for optimum battery life. Drawing charges down to about half capacity requires careful monitoring on the part of the customer.
- Repeated cycling of the batteries (of about 45% typically on a daily basis) brings about shortened battery life and reveals significant performance and economic weakness of the batteries in this type of solar heat pump system. A bimodal system which reduces the daily range of SOC cycling from a 45% limit to about a 95% limit is projected to greatly extend battery life.
- Table ES-5 presents peak demand and annual energy savings developed from monitored data and modeling based on regression analysis and TMY3 weather input. Summer peak demand savings from solar ranged from 69% to 100%. Winter peak demand savings from solar was 0% in all cases. On the other hand, when the mini-split was also enabled to operate off of the grid, peak demand reduction was 45%. Seasonal space conditioning savings ranged from 33% to 72%.

Table ES-5

TMY3 Projected Demand and Annual Energy Savings for the FPL Territory.

	Summer Peak Demand (kW)	Summer Peak Demand Reduction	Winter Peak Demand (kW)	Winter Peak Demand Reduction	Annual Cool+Heat kWh	Annual Savings
MHL SEER 13	2.25	-	2.16	-	6464	-
8 Battery Economy Savings	1.91	85.1%	2.16	0%	3535	55%
8 Battery Standard Savings	2.25	100.0%	2.16	0%	2768 [2]	43%
4 Battery Economy Savings	1.55	69.1%	2.16	0%	2569 [2]	40%
4 Battery Standard Savings	1.91	84.9%	2.16	0%	2133 [2]	33%
100% Mini-Split Economy Savings	1.91	85.1%	0.98 [1]	45.4%	4674	72%
Grid Tied No Batteries Savings	2.25	100.0%	0.98 [1]	45.4%	5674[3]	88%

[1] Due to limited heating season data, winter peak demand and demand savings are estimated based on the assumption that during the peak hour (34°F ambient temperature) the mini-split meets 70% of the heating requirement while the SEER 13 central ducted system meets 30% of the heating requirement.

[2] Due to limited heating season data, annual heating energy savings have been estimated for three of the tested configurations. Because space heating represents such a small portion of the total space conditioning energy in the heavily south-Florida weighted region (about 4%), even significant errors in these heating estimates would yield very small errors in annual space conditioning.

[3] Based on 4674 kWh/y saved through PV and MS economy + 1000 kWh/y from PV power to other household use or utility grid per PV-DesignPro-S simulation.