FLORIDA SOLAR ENERGY CENTER®

# Solar Thermal Billing Program in Florida

**Authors**

Colon, Carlos
Curry, Jeffrey

**Original Publication**

Carlos Colon, Jeffrey Curry, "Solar Thermal Billing Program in Florida", June 2002.

**Publication Number**

FSEC-RR-98-06



A Research Institute of the University of Central Florida
1679 Clearlake Road, Cocoa, FL 32922-5703 • Phone: 321-638-1000 • Fax: 321-638-1010
www.fsec.ucf.edu

# SOLAR THERMAL BILLING PROGRAM IN FLORIDA

Carlos J. Colon
Florida Solar Energy Center
1679 Clearlake Road
Cocoa, FL 32922
carlos@fsec.ucf.edu

Jeffry D. Curry
Lakeland Electric
501 East Lemon Street
Lakeland, FL 33801
jeff.curry@lakelandgov.net

ABSTRACT

This paper presents the development, implementation, and results of Lakeland Electric's solar thermal billing program in Florida. The three-phase solar program was started in 1997 with funds from the Florida Energy Office (FEO) and the technical assistance of the Florida Solar Energy Center (FSEC). It was designed as a model to expand the concept of distributed energy generation, and to augment the use of solar domestic hot water (SDHW) systems. The solar thermal billing program relies on the proceeds generated from the sale of hot water energy. Twenty-nine SDHW systems, which are owned by Lakeland Electric (LE), gradually began operation during 1999. Lakeland Electric offered homeowners a direct active system comprised of a 40 $ft^2$ (3.7$m^2$) glazed collector and 80 gallons (302 liters) of hot water storage. The tank is assisted by a single 4500 Watt heating element during periods of heavy hot water demand or continuous cloudy weather. The solar system operates independent from the utility grid, utilizing a 5-Watt photovoltaic module and direct current pump to circulate hot water. Billing for the hot water energy relies on a thermal-electric metering approach. The metering requires a net combination of the total thermal energy delivered and the auxiliary heating energy consumption. Lakeland personnel (i.e. metering division) read the kilowatt-hour meters as part of their monthly routine activities. Net solar energy consumption is then determined and incorporated into the monthly electric bill statement of participating customers.

Results from data collected during the last 16 months indicate a varying degree of revenues which is dependent on weather but mainly on customer hot water use. During the 12-month period ending in August 2001, the average consumption for the 4.2 person household reached 66.2 gallons of hot water per day (252 liters/day). Revenues generated from the sale of hot water are determined based on Lakeland's average electricity rate of $0.075 per kilowatt-hour (kWh). As a result, monthly net solar energy charges per system averaged $12.50 for the year-long period ending in December 2001. Daily hot water energy consumption for the 29 homes participating in the program totaled 9.2 kilowatt-hours per day (kWh/day). Solar energy contributed at least 5.3 kWh/day or 61% of the total hot water energy used by the household. Electric energy consumption amounts to 3.4 kWh/day (39%). Incidentally, hot water energy used for the same period represents at least 15% of the total house electric bill, of which 8% is now supplied by renewable solar energy.

## 1. INTRODUCTION

### 1.1 BACKGROUND

In 1995, Lakeland Electric submitted a business proposal to the Florida Solar Energy Center (FSEC) detailing the structure of a distributed energy generation program utilizing solar-thermal collectors (1). During 1996, Lakeland Electric contracted a market research company (the Melior Group, PA) to conduct a solar water heating research study. Positive results were obtained from the telephone survey, which in most cases was analyzed by level of interest, household income and age group (2). The study demonstrated that 67% of the respondents in a total sample of 401 would have consider the use of solar energy. In 1997, the first pilot utility-metered solar system was installed. Lakeland Electric recruited those customers within its service territory by signing a non-binding contract agreement for the hot water service. Solar system installations were rapidly incremented to 29 by September of 1999. Billing for use of solar hot water energy commenced during December of 1999. Although billing was manually executed at first, Lakeland's solar billing system was fully implemented and automated into its billing system in July 2001. The electric billing system was updated to include a solar service meter category into its data base (i.e. FOCUS), for only those customers participating in the program. The process also involved the training of LE meter reading personnel to enter the additional data into their handheld computers when en-route reading at the field.

## 1.2 CUSTOMER, UTILITY AND BENEFITS TO THE SOLAR CONTRACTOR

During meetings held on the subject of solar thermal and distributed generation, many questions were brought up about benefits the program had to offer. The following list of benefits are considered the major assets of a utility pay-for-energy basis solar thermal program.

### BENEFITS TO THE CUSTOMER

- Opportunity to replace and improve existing or aging hot water system at a significantly less out-of-pocket cost.
- Increased hot water capacity and reservoir, (i.e. 80 gallons).
- Slight savings -- Solar preventing of auxiliary electric heating for the recovery of standby losses.
- Immunity to fuel adjustment charges which vary according to the volatility of fossil fuel market.
- Participation in a green environmental program at a fair monthly cost with benefits shown above.

### BENEFITS TO THE UTILITY

- Reduced impact on electricity peak demand hours.
- Tax exempt on the purchase of solar equipment.
- Pollutant reductions on power plant emissions.
- Opportunity to regain market share and increase revenue within utility service territory utilizing solar thermal as pre-heat to gas-fired hot water systems (residential and commercial).
- Improved relations to satisfy energy preferences of customers.
- Diversification of utility renewable energy portfolio using solar energy.
- Meet or expand generation capacity for green certification programs.
- On-site generation advantage which does not incur power plant inefficiencies and power line transmission losses.

### BENEFITS TO THE SOLAR CONTRACTOR

- Increased revenues from solar heating installations and service, with no “up-front” capital investment.
- Increased profits through the sale of other materials (BOS- balance of the system).
- Additional profits from installation and service contracts on metering equipment.
- Opportunity to establish permanent relationship and contracts with the utility.

## 2.0 SOLAR SYSTEM DESCRIPTION

The solar thermal system used for LE program consists of a 40ft$^2$ glazed collector, a 5-Watt photovoltaic (PV) module and a direct current pump. Hot water energy is stored in an 80-gallon (302 l) solar tank. The storage vessel is equipped with four connecting ports at the top. Because of its design (i.e. direct, open loop), the system is simple and reliable in operation. The 5-Watt photovoltaic panel provides enough current to begin pump rotation with as little as 0.09 milliamps. Typical hot water circulation flow rates have been previously reported in the range of 0.6 gallons per minute (gpm). These flow rates vary according to the sunlight intensity, but have been predicted with a PV supplying a current of 0.160 milliamps to the pump. The low head capacity pump circulates hot water in a 1/2" O.D. city water pressurized loop (3,4) The main components of the solar system are listed in Table 1.

TABLE 1: SOLAR-THERMAL SYSTEM

| System Component | Feature Description |
|---|---|
| 40 ft$^2$ (3.7 m$^2$) Flat plate collector | Selective Coat Absorber |
| 80 gallon (302 liter) Solar storage tank | Single auxiliary heat element (4500W) |
| Brush less DC pump | Static Impeller driver |
| 5 Watt Photovoltaic (PV) | Thin Film or CIS |
| Freeze Valve | Exterior mounted |
| Anti-Scald Valve | Set at 135 °F (54.4 °C) |

## 2.1 SYSTEM COST, INSTALLATION AND BILL OF MATERIALS

Being part of the energy generation business required careful attention to the design and purchase of the solar equipment. In order to reach cost-effective results, the systems were purchased in bulk quantities by the utility. However, the solar system and thermal metering was installed by a local solar subcontractor. Purchasing of the system was arranged in lots of 25 to keep the system cost below one thousand ($1,000) U.S. dollars. Ultimately, LE managed to reduce the total cost of an installed system, including metering to $1898 per system. The costs associated with the final solar installation are itemized in

Table 2. The percentages also indicate the main system components (i.e. collector, tank, pump and PV) represent a little over 50% of the final installed cost.

TABLE 2: SOLAR SYSTEM INSTALLATION COSTS

| | Cost (U.S. dollars) | Percentage of Total |
|---|---|---|
| System bundle | $990 | 52.2 % |
| System install | $300 | 15.8 % |
| Meters (2) | $258 | 13.6 % |
| Meter install | $130 | 6.8 % |
| Other Misc. | $220 | 11.6 % |
| Total | $1898 | 100% |

## 3.0 METHODOLOGY - SOLAR NET METERING

Metering was accomplished by the use of a thermal meter calculator and a dedicated rotary kWh meter (shown in Figure 1). The thermal meter consists of a rotary vane flow

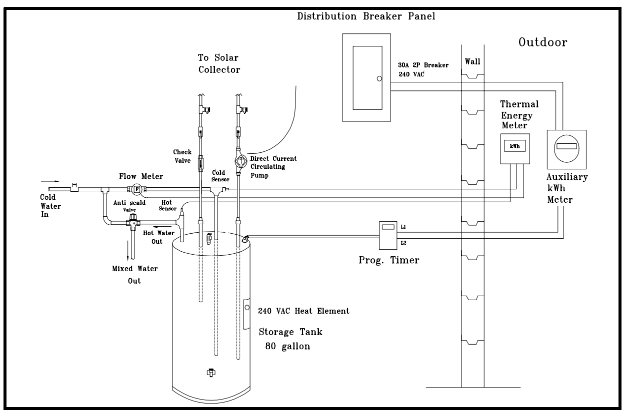


Figure 1: Net metering on solar thermal system

meter installed at the cold water inlet to the tank, and a pair of differential RTD temperature sensors. When in standby mode, the battery-operated calculator display, defaults to the total accumulated kWh. However, this total thermal energy includes both the solar energy and the auxiliary heating energy delivered to the customer. A second meter is used exclusively to record the energy consumption of the auxiliary heating element when in operation. In essence, the metering system consists of a dual meter system, where the electric energy portion is subtracted from the total energy.

The resulting energy is referred to as the "Net Solar Energy." The net solar energy relationship can be observed in the equation below.

$$Net\ Solar(kWh) = kWh_{Total} - kWh_{Electric}$$

Net solar energy charges become a two-step task for the meter readers in the field. This in turn requires two entries into the billing process. The net solar energy calculation is performed by LE's automated billing software program, which is itemized into the customers monthly billing statement.

## 4.0 PROGRAM RESULTS

Because of the combined research and business nature of this program, data was collected periodically to fulfill two different tasks. At first, data was collected to examine hot water consumption and evaluate the solar system performance. In addition to the total thermal and auxiliary electric data, the amount of hot water consumption in cubic meters ($m^3$) was read periodically from the thermal calculator (90 days on average). This data variable is not available in the LE customer billing records. On the business aspect, total thermal and electric auxiliary data was acquired for the customers billing records (monthly). This task was performed by the LE personnel, based on their meter reading routing schedule.

### 4.1 LESSONS FROM THE FIELD

Prior to the installation of systems, all potential customer sites underwent surveying inspection. Some of the customers requesting the solar service had to be rejected due to a partial or fully shaded roof. Placement of the solar thermal energy calculator required careful positioning, not only because it needed to be accessible to the readers, but also because of temperature sensor wiring limitations. At first, thermal energy meters (calculator) experienced a high rate of failure during the first year. Lakeland Electric quickly discovered the meters were not designed for long-term exposure to the outdoor weather elements. Consequently, the meters were enclosed inside a plastic protective box with a hinged door allowing easy access to the readers. For the next phase of 25 system installations (in progress during 2002), LE has devised a production of pre-installed meters in a vented box enclosure. Placement of the solar tank also required sufficient space indoors. In most cases the system installers arranged a tight plumbing within the vertical space above the 24-inch diameter tank. Piping to the solar collector was insulated and routed through the attic. Billing and administration software required updating which involved a considerable coordination and effort within LE divisions. A "Solar Service" category with a meter serial number was added to the customers' data base records. Within a two-year period, LE experienced two cases of customers selling their property. Accounts for the service were quickly transferred at the consent of the new homeowners. In one particular case, a customer's property underwent foreclosure, forcing LE to remove the system and find a new customer. Finally, other than initial PV module manufacturing defects, which were fully backed and replaced by the manufacturer, there has been little or no indication of component failures to date (4).

4.2 HOT WATER CONSUMPTION AND SYSTEM PERFORMANCE

During the period of September 1999 to July 2000, hot water consumption for a sample of 27 customers averaged 67.5 gallons (255.5l). This average correlates to 4.2 persons per household, and it is slightly over the national average of 64.3 gallons per day (5). Figure 2 presents a frequency distribution chart corresponding to the amount of homes, and range of average daily hot water consumed. The chart indicates that 26% of these homes utilize between 60 and 70 gallons (227-265l) of hot water per day. Fifty-nine percent of the homes utilized at least 60 gallons of hot water per day. Three customers with five and six persons living at the premises utilized in excess of 100 gallons (378.5 l) of hot water per day.

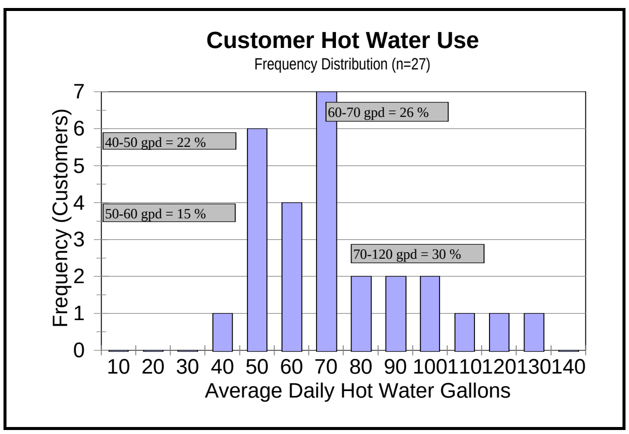


Figure 2: Customer hot water use distribution

During these periods, daily average hot water energy delivered to the customer amounted to 8.8 kWh. Solar net contribution averaged 4.8 kWh or 55% of the total energy delivered. The solar system contributes more than 4.8 kWh per day, since the energy lost during standby is not being metered. Similarly, average hot water consumption and solar net contribution amounted to 5.3 kWh/day or 60% of the total energy delivered for the period ending in August 2001. The average daily hot water consumption, net solar and auxiliary energies, and electrical system efficiency (COP), are shown in Table 3.

TABLE 3: TYPICAL SYSTEM PERFORMANCE

| Period | Gals. (liters) Avg. /day | kWh / day | | COP |
|---|---|---|---|---|
| | | Solar | Aux | |
| 9/99 - 7/00 | 67.5 (255) | 4.8 | 4.0 | 2.2 |
| 7/00 - 8/01 | 66.2 (251) | 5.3 | 3.4 | 2.6 |

4.3 SOLAR THERMAL BILLING

Once the solar thermal billing system was implemented, billing for the hot water energy service became a routine process. The "Net Solar" column in Table 4, displays the typical average daily energies for the respective month of the year (combined 2000-2001). The monthly average total hot water energy consumption can be determined by adding the net solar and auxiliary kilowatt-hours. Net solar energy reached the highest levels during June 2000 and 2001. In turn, LE's solar thermal billing for 29 systems amounted to $479 and $438 based on Lakeland's kilowatt-hour rate of $0.075/kWh. The net solar fraction column represents the percentage of total energy contributed by the solar system.

TABLE 4: NET SOLAR AND AUXILIARY ENERGIES AVERAGED BY MONTH

| Month (2000-01) | Ne t Solar kWh/Day | Auxiliary kWh/Day | Net Solar Fraction |
|---|---|---|---|
| January | 3.74 | 6.68 | 35.9% |
| February | 4.13 | 7.33 | 36.0% |
| March | 4.80 | 4.59 | 51.1% |
| April | 5.33 | 3.77 | 58.6% |
| May | 6.00 | 2.58 | 69.9% |
| June | 6.95 | 2.17 | 76.2% |
| July | 5.26 | 2.24 | 70.1% |
| August | 4.79 | 2.31 | 67.4% |
| September | 6.12 | 2.54 | 70.6% |
| October | 4.56 | 3.04 | 60.0% |
| November | 4.46 | 3.80 | 54.0% |
| December | 4.26 | 5.30 | 44.6% |

5.0 ANALYSIS

Field data collected during a period of 18 months, clearly demonstrate that revenues generated from the sale of hot water are mainly dependent on customer hot water use. The relationship between average daily net solar, auxiliary energy and hot water consumption can be observed in Figure 3. The data plot presented here corresponds to a one-year period ending in August 2001.

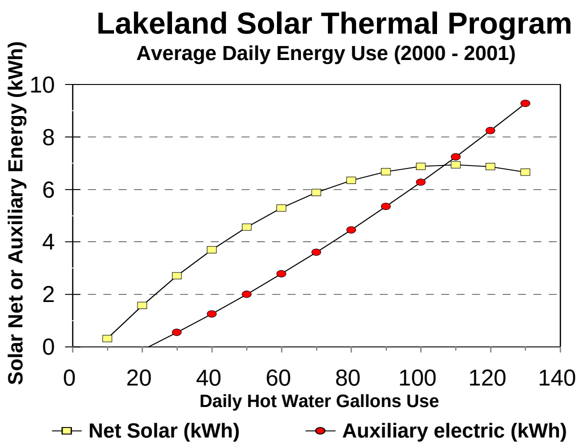


Figure 3: Net Solar and auxiliary energy used based on hot water consumption.

Data gathered from LE solar customer records also indicate that during a one-year period ending in May 2001, total house consumption amounts to 57 kWh/day. Hot water energy represents 14.5% of the total house electric consumption. This percentage falls conservatively within the national end use energy percentage for water heating (6) The program demonstrated, that on average, solar net electric charges contributed as much as 8.3% of the total house energy consumption.

6.0 CONCLUSIONS

Results obtained from the solar thermal billing program proved to be an extraordinary success. Lessons learned during the two years in operation forced the teams involved in its development to devise new strategies. These included the design and use of a simple, grid-independent solar system, a solar thermal net metering mechanism, and bulk purchasing to reduce equipment cost. Site selection plays an important role in the success of the customer-utility business relationship. Financially, business results can be examined from two different viewpoints. The program has demonstrated a simple payback of about 7% annual return on investment, based on the total cost of an installed system. System payback is considered to be about 12.6 years on average, for those customers using around 65 gallons of hot water per day. Similarly, based on LE electric rate, system payback can be attained in 10 years for customers using 100 gallons per day. Considering the fairly low cost of residential energy rates in Florida, system payback fares extremely well when compared to other green generation technologies (e.g., wind and photovoltaic systems). The program proved to be a well-balanced business opportunity for the electric customers, utility and solar installer. However, the biggest winner of all is the environment.

7.0 ACKNOWLEDGMENTS

The authors gratefully acknowledge the financial assistance of the Department of Community Affairs - Florida Energy Office (DCA-FEO). Special recognition to the administrative personnel of UCF-FSEC, the Lakeland Electric administration, Lakeland City Council Commission and office of public relations. Finally, a well deserved recognition to the solar subcontractor performing installations (Solar Source, Tampa, Florida).

8.0 REFERENCES

(1) Cost Effective Solar Water Heating Program for Utilities, Proposal Report, Lakeland Utilities,, FL, 1995

(2) Solar Water Heating Market Research Study, Final Report, The Melior Group, Philadelphia, PA, 1996

(3) Colon, C., and S. Long, A Non-Invasive Experimental Method for the Determination of Flow Rate in a Photovoltaic Pumped Solar Domestic Hot Water System, Proceedings of the 1998 Annual Conference - American Solar Energy Society, 1998

(4) Colon, C., Cost Effective Solar Programs for Utilities/Energy Service Companies, Florida Solar energy Center, Cocoa, Florida, February 2000

(5) Department of energy, 1990 " Final rule regarding Test Procedures and energy Conservation Standards for Water Heaters," Federal Register, Vol. 55, No. 201, Washington, D.C., 1990

(6) Changes in Energy Uses in Residential Housing Units http://www.eia.doe.gov/emeu/recs/recs97/